



High-Carotenoid Orange Corn Promises Nutritional Enhancement

As agricultural practices have evolved to meet the world's growing nutritional needs, innovations in plant breeding, genetics, and crop production have led to remarkable advances in productivity. But as yields have increased, the nutritional density of crops has often declined. Furthermore, recent studies indicate that the nutrient composition of many foods is being compromised by the rise in atmospheric CO₂ levels. These shifts are associated with reductions in essential micronutrients and protein across a range of staple crops.

NutraMaize, a West Lafayette, IN-based small business, is transforming the world's most-produced staple crop — corn — into an enhanced platform for delivering better nutrition. NutraMaize's innovation is nutritionally enhanced orange corn, which derives its vibrant color from significantly higher levels of carotenoids, the same type of natural antioxidant pigments that give carrots their orange color. NutraMaize's unique kernels also possess approximately 20% higher protein. Moreover, orange corn was developed using traditional plant breeding techniques (non-GMO), mak-



▲ An ear (left) of NutraMaize's first commercial high-yielding, high-carotenoid orange corn F1 hybrid (3–4 mg carotenoids/100 g corn kernels) and an ear (right) of the company's inbred parent with extremely high carotenoid levels (5–6 mg/100 g). Both have significantly higher carotenoid levels than #2 yellow dent corn hybrids typically grown in the U.S. (1–2 mg/100 g).

ing it suitable for adoption worldwide and within organic cropping systems.

With funding from the U.S. Agency for International Development, HarvestPlus, and the U.S. National Science Foundation (NSF) Plant Genome Research Program, Torbert Rocheford (NutraMaize cofounder and Professor of Agronomy at Purdue Univ.) and collaborators made discoveries in the carotenoid biosynthetic pathway that enabled the creation of corn lines with unprecedented levels of provitamin A carotenoids. Through HarvestPlus, beta-carotene-rich orange corn has subsequently been introduced in 12 African countries where vitamin A deficiencies are prevalent.

Even in high-income countries, research suggests a link between deficiencies of specific non-provitamin A xanthophyll carotenoids and degenerative conditions such as age-related macular degeneration and cognitive decline. Thus, there is a need to get Americans to consume more health-benefiting xanthophylls. However, it is extremely difficult to change dietary patterns, which makes the nutritional enhancement of already popular foods an attractive solution. Since corn is the dominant staple crop in the U.S., NutraMaize's xanthophyll-rich orange corn could make a significant contribution toward meeting this goal. However, this approach requires converting low-yielding varieties originally developed for Africa into yield-competitive hybrids adapted to the U.S.

There is considerable genetic variation in genes associated with carotenoid biosynthesis and stability. However, the most favorable expression is typically not found in lines that are commercially relevant to U.S. corn production. With support from the NSF, NutraMaize has used genotypic and phenotypic selection to convert

lower-yielding germplasm into elite inbreds capable of producing high-yielding, high-carotenoid F1 hybrids suitable for large-scale commercial applications. Using multilocation yield trials and high-performance liquid chromatography to measure carotenoids, NutraMaize has been able to identify an initial commercial hybrid with both competitive yields (~90% of non-GMO yellow hybrids) and high carotenoid levels (3–4 mg per 100 g harvested mature dry kernels vs. 1–2 mg/100 g for yellow corn).

The commercial potential of NutraMaize's innovation has attracted significant attention from specialty egg producers, who currently rely on expensive carotenoid supplements imported from overseas to achieve darkly colored yolks. Using NutraMaize Orange Corn, producers can significantly reduce or eliminate the need for these supplements while also enhancing the amount of health-benefiting xanthophyll carotenoids delivered to consumers through the yolk. Orange corn's higher protein levels also allow for the displacement of costly soybean meal, which is of particular interest for organic poultry production, which relies heavily on organic soybean meal imports. The use of orange corn presents the opportunity to reduce both the cost and carbon footprint of poultry feed.

Vital Farms, a leader in the specialty egg industry, is currently evaluating orange corn for incorporation in its laying hen feed. "We are excited to collaborate with NutraMaize to explore the potentially transformative benefits of orange corn for the specialty egg industry," says Mike Spangler, Vital Farms' Farm and Feed Commodities Sourcing Manager.

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