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Plant Biology

Enhancing cassava for better nutrition in every bite

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ABSTRACT

Cassava is an important food crop in sub-Saharan Africa, but contains relatively small amounts of essential vitamins and minerals. The addition of just two genes from another plant into cassava enables it to produce and store significantly more iron and zinc, which is retained through common cooking processes. This new crop can contribute to a more balanced diet and prevent cases of 'hidden hunger'.

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Cassava is a staple food crop in sub-Saharan Africa, where millions of people eat it every day.

It's an especially important source of food during times of drought, because cassava is a hardy plant that continues to produce its starchy storage roots when water is scarce and other crops fail.

Cassava is an excellent source of carbohydrates, but provides very little iron and zinc. Reliance on a diet that lacks important vitamins and minerals can leave people susceptible to so-called 'hidden hunger'. Iron anemia and other nutritional deficiencies affect the immune system, stunt growth and impair intellectual development in children. Women who are pregnant or nursing are also at risk of severe health impacts if their diet provides insufficient amounts of essential vitamins and minerals.

Plant breeders have successfully developed 'biofortified' crops that contain increased levels of nutrients when harvested. Breeding tools such as marker-assisted selection have been successfully used to screen large populations of plants for their vitamin-producing power and cross-breed them with varieties with qualities important to farmers. This has produced new cassava varieties with increased vitamin A content, but raising levels of important minerals such as iron and zinc has proven difficult.

A second challenge to biofortification emerges in the kitchen. Processing and cooking all kinds of food, including those made from biofortified crops, often reduces nutrient levels.

In collaboration with an international group of plant breeders, molecular biologists and experts in nutrition, we have succeeded in developing cassava plants that can produce and store increased levels of iron and zinc. Importantly, these are retained after processing and cooking, and can contribute up to half of the estimated average requirement for iron and zinc in women and young children.

Our research took place over a ten-year period and involved more than a dozen scientists working in the laboratory, greenhouse, and field locations.

Given the lack of success in using breeding methods to develop cassava with higher mineral levels, we employed modern biotechnology tools for genetic modification. These had been used previously to raise iron levels in crops including rice, but non-cereal plants such as cassava take up minerals from the soil in a different way. It was therefore a challenge to find the right combination of genes that would raise both iron and zinc levels in cassava roots under field growing conditions.

Ultimately, success came from a combination of two genes called IRT1 and FER1. These were obtained from a plant of the cabbage family called ‘thale cress’ (*Arabidopsis thaliana*). The IRT1 and FER1 gene sequences were taken from the DNA of the thale cress and integrated into the genome of cassava. IRT acts at the root surface to pump iron and zinc from the soil into the plant, while FER causes the iron to be stored within the root cells. Over a 12 month growing cycle in the field, cassava plants modified with IRT1 and FER1 developed to accumulate iron concentrations 6-12 times higher than conventional cassava, and zinc concentrations that were 3-10 times higher.

Once that was accomplished, it was on to the next hurdle: the cooking pot.

To identify the impact of food processing on mineral levels in the biofortified cassava, we prepared foods called gari and fufu by chopping, soaking, fermenting, pressing and roasting cassava roots, following processes common in West African households.

We found that high levels of iron and zinc were retained through these cooking processes. Subsequent analysis in the lab confirmed that the nutrients remained available for absorption in the gut following digestion. Ultimately the biofortified cassava could provide 40-50 percent of Estimated Average Requirements (EAR) for iron and 60-70 percent of EAR for zinc for children and women in West Africa.

Our biofortified cassava has the potential to enhance nutrition and health of people who eat cassava as part of their staple diet, with the biggest benefits for mothers and small children for whom a balanced diet is most important.

We have more work ahead to bring this trait into cassava varieties that are commonly grown by farmers across West Africa and beyond. At every step we will reconfirm that iron and zinc biofortified cassava plants maintain yield and their ability to resist disease or drought. We continue our international collaboration with plant breeders, molecular biologists and experts in nutrition, in our quest to deliver more nutritious bites of this important staple food to those who need it most.