AGRI MAGAZINE
(International E-Magazine for Agricultural Articles)
Volume: 03, Issue: 08 (August, 2026)
Available online at http://www.agrimagazine.in

Biofortification: A Sustainable Approach to Achieve Nutritional Security in Vegetables

*Lalita Bochalya, R. K. Narolia, O. P. Garhwal, R. K. Bochalya, Rakesh Verma and Vinod Prajapat
Department of Horticulture, SKN College of Agriculture, Sri Karan Narendra Agriculture University, Jobner-Rajasthan, India
*Corresponding Author's email: lalitabochal89@gmail.com

Nearly 800 million people worldwide suffer from hunger, while an even larger proportion faces micronutrient malnutrition, commonly referred to as "hidden hunger". Deficiencies of iodine, vitamin A, iron and zinc are among the most serious nutritional problems, particularly in developing countries where cereal-based diets dominate and consumption of fruits and vegetables is limited. In countries such as India, deficiencies of iron (Fe), zinc (Zn) and vitamin A remain major public health challenges. Biofortification defined as the process of increasing the nutrient content of food crops through breeding, agronomic practices and biotechnology has emerged as a cost effective, sustainable and long-term strategy to improve human nutrition. By enriching commonly consumed staple and vegetable crops with essential micronutrients, biofortification offers a practical solution for addressing widespread nutritional disorders and ensuring long-term nutritional security.

Keywords: Biofortification, hidden hunger, vegetable crops and nutrition security

Introduction

The term biofortification originates from two words: *bio*, meaning life and *fortification*, meaning strengthening. It refers to the enhancement of nutritional quality of food crops by increasing the concentration and bioavailability of essential vitamins and minerals. Unlike conventional food fortification, which adds nutrients during food processing, biofortification improves the nutrient composition of crops during plant growth itself through plant breeding, agronomic management, or genetic engineering. Micronutrient deficiencies affect billions of people globally and are particularly prevalent among populations that rely heavily on cereal-based diets with limited dietary diversity. Iron deficiency leads to anemia and reduced work productivity, vitamin A deficiency causes impaired vision and weakened immunity, while zinc deficiency affects growth and disease resistance. Biofortification aims to address these issues by improving the nutrient content of crops such as vegetables, cereals and legumes, thereby delivering essential nutrients directly through daily diets. Vegetable crops play a significant role in improving human nutrition because they are naturally rich in vitamins, minerals, antioxidants and health-promoting compounds. Therefore, enhancing micronutrient concentration in vegetables such as potato, cauliflower, cabbage and okra can substantially improve dietary quality, particularly among low-income populations.

Criteria for Successful Biofortification

For biofortification programs to be effective and sustainable, several important criteria must be satisfied:

1. **High bioavailability:** Nutrients present in biofortified crops must be easily absorbed and utilized by the human body.

2. **Consumer acceptance:** Biofortified varieties should maintain acceptable taste, color, texture and cooking quality to ensure adoption.
3. **High productivity:** Biofortified crops must possess yield potential comparable to or higher than conventional varieties.
4. **Stable nutrient expression:** Nutrient enrichment should remain stable across environments and storage conditions.
5. **Economic feasibility:** Seeds and production technologies should be affordable for farmers.

Techniques of Biofortification in Vegetable Crops

1. Agronomic Biofortification

Agronomic biofortification involves the application of micronutrient-rich fertilizers, soil amendments and beneficial microorganisms to enhance nutrient uptake and accumulation in crops. For example, foliar application of zinc, iron, or selenium fertilizers can significantly increase micronutrient concentration in vegetables. Adjusting soil pH, improving organic matter content and using biofertilizers such as plant growth-promoting rhizobacteria also enhance nutrient availability. Agronomic biofortification is relatively quick to implement and can produce immediate results, making it an effective short-term strategy.

2. Conventional Plant Breeding

Conventional breeding involves selecting parent plants with naturally high nutrient content and crossing them with high-yielding varieties. Through repeated selection over generations, improved cultivars with enhanced micronutrient levels and desirable agronomic traits are developed. This approach is widely accepted because it does not involve genetic modification and is cost-effective once improved varieties are released. Many biofortified vegetable varieties with higher levels of provitamin A, iron and antioxidants have been developed through conventional breeding.

3. Genetic Engineering

Genetic engineering enables the direct modification of plant metabolic pathways to enhance nutrient synthesis or accumulation. A well-known example is Golden Rice, engineered to produce beta-carotene (provitamin A). Similar approaches are being explored in vegetables to enhance vitamin, mineral and antioxidant content. Although transgenic approaches offer precise and rapid improvements, regulatory approvals and public acceptance remain important considerations.

Advantages of Biofortification Combating Hidden Hunger

Biofortification directly addresses micronutrient deficiencies by increasing the nutrient content of staple and vegetable crops consumed daily. Regular consumption of biofortified foods improves nutritional status and reduces the prevalence of diseases such as anemia, impaired immunity and vision disorders.

Cost-Effectiveness

Biofortified crop varieties are developed and adopted by farmers, the nutritional benefits continue for many years without the need for continuous financial investment. This makes biofortification more economical compared to supplementation or industrial fortification programs.

Wide Reach and Accessibility

Biofortified crops are particularly beneficial for rural populations who have limited access to fortified foods or dietary supplements. Because seeds can be distributed widely, the technology can reach remote and economically disadvantaged communities.

Sustainability

Biofortification utilizes existing agricultural systems without requiring significant changes in infrastructure. By improving nutritional quality per unit of crop production, it contributes to sustainable agriculture and food systems.

Farmer Empowerment

Farmers cultivating biofortified crops not only improve their own household nutrition but also contribute to community health. Increased demand for nutrient-rich produce may also enhance farm income.

Long-Term Health Benefits

Regular consumption of nutrient-dense vegetables leads to improved immune function, better cognitive development in children, reduced maternal health complications and overall enhancement of public health outcomes.

Consumer Acceptance

Biofortified varieties are generally similar in taste, appearance and cooking quality to traditional varieties, ensuring easier adoption by consumers without major dietary changes.

Biodiversity Support

Many biofortification programs encourage the cultivation of diverse crop varieties with enhanced nutritional traits, thereby contributing to agricultural biodiversity conservation.

Examples of Biofortified Vegetable Crops

Cauliflower

- **Pusa Betakesari:** The first provitamin-A rich cauliflower variety developed in India, containing significantly higher beta-carotene levels compared to conventional varieties, with yields of 40–50 t/ha.
- **Purple Sicily:** A colorful cauliflower rich in anthocyanins, which provide antioxidant benefits.

Potato and sweet potato

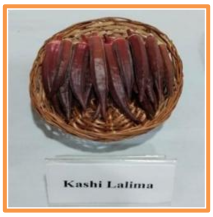
(a) **Kufri Neelkanth:** Anthocyanin-rich potato variety with high antioxidant capacity and good yield performance.

(b) **Kufri Jamuni:** unique purple flesh, biofortified nutritional benefits, high yield and good storability make it an excellent choice for farmers and consumers.

(c) **Bhu Sona:** Rich in provitamin-A content (approximately 14 mg/100 g), improving its nutritional value.

		
a	b	c

Okra



(a) **Kashi Lalima:** Produces reddish-purple fruits rich in anthocyanins and phenolic compounds, suitable for both summer and Kharif seasons.

Cabbage

(a) **Kinner Red:** A red-headed cabbage rich in anthocyanins and tolerant to certain pests, producing heads of 1–2 kg within about 90 days after transplanting.

These examples demonstrate the significant potential of biofortified vegetable varieties to enhance nutritional intake without altering dietary patterns.

Challenges and Future Prospects

Biofortification faces certain challenges such as limited awareness among farmers and consumers, the need for strong seed distribution systems and the requirement for continued research to ensure nutrient stability across different environments. Public acceptance of genetically engineered biofortified crops also remains a concern in some regions. However, increasing government support, international research collaborations and advances in molecular breeding technologies are expected to accelerate the development and adoption of biofortified vegetable crops. Future strategies should focus on integrating breeding, agronomic and biotechnological approaches to maximize nutrient enrichment while maintaining crop productivity and resilience. Public awareness campaigns, farmer training programs and policy support are essential for scaling up biofortification initiatives and ensuring their long-term success.

Conclusion

Malnutrition and micronutrient deficiencies continue to pose serious challenges to global health, particularly in developing countries. Biofortification provides a practical, sustainable and economically viable approach to enhance the nutritional quality of vegetable crops and staple foods. By combining agronomic practices, conventional breeding and modern biotechnology, it is possible to develop nutrient-rich crop varieties that can significantly improve dietary quality and public health. Promoting the cultivation and consumption of biofortified vegetables will play a crucial role in combating hidden hunger, strengthening food security and improving the nutritional well-being of present and future generations.

References

1. Athar, T., Khan, M. K., Pandey, A., Yilmaz, F. G., and Gezgin, S. (2020). Biofortification and the involved modern approaches. *Journal of Elementology*, **25**(2), 717–731.
2. Bouis, H. E., and Saltzman, A. (2017). Improving nutrition through biofortification: A review. *Global Food Security*, **12**, 49–58.
3. Gomathi, M., Vethamoni, P. I., and Gopinath, P. (2017). Biofortification in vegetable crops: A review. *Chemical Science Review and Letters*, **6**, 1227–1237.
4. Sharma, P., Aggarwal, P., and Kaur, A. (2017). Biofortification: A new approach to eradicate hidden hunger. *Food Reviews International*, **33**(1), 1–21.
5. Vandana, T., Akhilesh, S., Parveen, S., and Prabhat, K. (2022). Biofortification of vegetable crops for vitamins, minerals, and other quality traits. *Journal of Horticultural Science and Biotechnology*, **28**(10), 1–13.