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Biofortified Vegetables: Fighting Hidden Hunger

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Millions of people around the world consume enough food to satisfy their hunger, yet many suffer from a silent form of malnutrition known as **hidden hunger**. Hidden hunger occurs when the body lacks essential vitamins and minerals despite adequate calorie intake. Deficiencies of vitamin A, iron, zinc, iodine, and folate can lead to weakened immunity, poor growth, impaired cognitive development, anemia, and increased susceptibility to diseases. Biofortification has emerged as one of the most sustainable and cost-effective solutions to combat hidden hunger. Unlike conventional fortification, where nutrients are added during food processing, biofortification enhances the nutritional quality of crops during their development through plant breeding, biotechnology, or improved agronomic practices. Vegetables, being naturally rich in vitamins, minerals, and antioxidants, are ideal candidates for biofortification.

What Are Biofortified Vegetables?

Biofortified vegetables are varieties that have been developed to contain higher concentrations of essential nutrients without compromising yield, quality, or consumer acceptance. Plant breeders identify nutrient-rich parent lines and develop improved varieties through conventional breeding or modern biotechnological approaches. The objective is simple: **to provide better nutrition through everyday diets**, especially for populations with limited access to dietary supplements or fortified foods.

Why Is Biofortification Important?

Micronutrient deficiencies remain a major public health concern in many developing countries. Poor dietary diversity, poverty, and limited access to nutritious foods contribute to hidden hunger. Biofortified vegetables offer several advantages:

- Improve nutritional status naturally.
- Reduce micronutrient deficiencies.
- Strengthen immunity and overall health.
- Enhance child growth and cognitive development.
- Support pregnant and lactating women.
- Provide a sustainable and affordable nutrition intervention.

Because vegetables are consumed regularly, increasing their nutrient content can have a significant impact on public health.

Vitamin A (β -Carotene): Vitamin A is an essential micronutrient required for healthy vision, immune function, reproduction, and normal growth and development. In biofortified vegetables, vitamin A is mainly present as **β -carotene**, a provitamin that is converted into active vitamin A in the human body. Adequate intake of vitamin A helps prevent night blindness, xerophthalmia (dry eyes), and other vision-related disorders while strengthening the immune system and protecting against infections. It also supports healthy skin, cell differentiation, and antioxidant activity by neutralizing harmful free radicals. Biofortification aims to increase β -carotene levels in vegetables to combat vitamin A deficiency, which is a

major public health concern in many developing countries. **Orange carrot, orange-fleshed sweet potato, pumpkin, and orange-fleshed squash** are important biofortified vegetable sources rich in β -carotene.

Iron (Fe): Iron is an essential mineral that plays a crucial role in the formation of hemoglobin, the oxygen-carrying protein in red blood cells, and myoglobin, which stores oxygen in muscles. It is also involved in energy metabolism, enzyme activity, cognitive development, and immune function. Iron deficiency is the leading cause of nutritional anemia worldwide, especially among women, children, and pregnant mothers, resulting in fatigue, weakness, reduced work capacity, and impaired learning ability. Biofortification increases the iron content of vegetables to improve dietary iron intake and reduce the prevalence of anemia and hidden hunger. Iron-rich biofortified vegetables such as **spinach, amaranthus, iron-enriched beans, and other leafy vegetables** contribute significantly to improving nutritional status and overall health.

Zinc (Zn): Zinc is an essential trace mineral required for the proper functioning of more than 300 enzymes involved in metabolism, protein synthesis, DNA synthesis, cell division, and growth. It plays a vital role in maintaining a healthy immune system, promoting wound healing, supporting reproductive health, and ensuring normal physical and mental development. Zinc deficiency can lead to stunted growth, impaired immunity, delayed wound healing, hair loss, skin disorders, and loss of appetite, particularly among children. Biofortification enhances the zinc concentration in vegetables, providing an effective and sustainable approach to improving zinc intake in populations dependent on plant-based diets. **Zinc-enriched beans, spinach, peas, and green leafy vegetables** are important dietary sources of this micronutrient.

Vitamin C (Ascorbic Acid): Vitamin C, also known as ascorbic acid, is a water-soluble vitamin and a powerful natural antioxidant that protects body cells from oxidative damage caused by free radicals. It plays an important role in collagen synthesis, wound healing, healthy skin, blood vessel integrity, and immune function. One of its most significant nutritional benefits is enhancing the absorption of non-heme iron from plant foods, thereby reducing the risk of iron deficiency anemia. Vitamin C deficiency results in scurvy, characterized by bleeding gums, delayed wound healing, and weakened immunity. Biofortified vegetables with increased vitamin C content improve overall nutritional quality and provide better health benefits. **Tomato, bell pepper (capsicum), broccoli, cabbage, and leafy vegetables** are excellent sources of vitamin C.

Folate (Vitamin B9): Folate, also known as vitamin B9, is an essential water-soluble vitamin required for DNA and RNA synthesis, cell division, protein metabolism, and the formation of healthy red blood cells. It is particularly important during pregnancy because it supports fetal growth and helps prevent neural tube defects such as spina bifida. Folate also contributes to brain development, cognitive function, and overall growth. Deficiency of folate can cause megaloblastic anemia, fatigue, poor growth, and congenital abnormalities in newborns. Biofortification of vegetables with folate is an effective strategy to improve maternal and child nutrition and reduce micronutrient deficiencies. **Spinach, broccoli, asparagus, amaranthus, and other green leafy vegetables** are important biofortified sources of folate.

Examples of Nutrient-Rich Vegetables

- **Carrot** – Rich in β -carotene (pro-vitamin A)
- **Sweet potato** – Excellent source of vitamin A
- **Tomato** – High in lycopene and vitamin C
- **Spinach** – Rich in iron, folate, calcium, and antioxidants
- **Broccoli** – High in vitamins C and K and folate
- **Red and yellow capsicum** – Rich in vitamin C and carotenoids
- **Purple cabbage and purple carrot** – Rich in anthocyanins
- **Beetroot** – Contains folate and natural antioxidants

Role of Plant Breeding

Plant breeders play a crucial role in developing biofortified vegetables by:

- Identifying nutrient-rich germplasm.
- Crossing superior parents.
- Selecting nutrient-dense offspring.
- Combining high nutritional quality with superior yield and disease resistance.
- Evaluating varieties under different environmental conditions.

Modern breeding techniques such as **marker-assisted selection, genomic selection, and genome editing (CRISPR/Cas9)** are accelerating the development of nutrient-rich vegetable varieties.

Benefits to Farmers

Biofortified vegetables benefit farmers by:

- Producing premium-quality crops.
- Increasing market demand.
- Improving consumer confidence.
- Enhancing farm income.
- Supporting climate-resilient agriculture.

Many biofortified varieties are also bred for higher productivity and improved resistance to pests and diseases.

Benefits to Consumers

Consumers gain multiple health advantages:

- Better nutritional intake through regular meals.
- Improved immunity and overall well-being.
- Reduced risk of micronutrient deficiencies.
- Better growth and development in children.
- Healthier pregnancies through adequate vitamin and mineral intake.

Unlike dietary supplements, biofortified vegetables provide nutrients through fresh, natural foods that are already part of daily diets.

Challenges

Despite their potential, biofortified vegetables face several challenges:

- Limited public awareness.
- Slow adoption among farmers.
- Need for stronger seed distribution systems.
- Consumer preference for appearance over nutritional value.
- Requirement for nutrition education and awareness campaigns.

Addressing these challenges requires collaboration among researchers, governments, extension agencies, seed companies, and consumers.

Future Prospects

The future of biofortified vegetables is promising. Advances in genomics, precision breeding, artificial intelligence, and biotechnology are enabling the rapid development of nutrient-rich varieties. As concerns about malnutrition, food security, and climate change continue to grow, biofortified vegetables will become increasingly important in creating healthier and more sustainable food systems.

Conclusion

Biofortified vegetables represent a powerful strategy to combat hidden hunger by delivering essential vitamins and minerals through everyday diets. They bridge the gap between agriculture and nutrition, offering benefits to farmers, consumers, and society alike. By integrating advanced plant breeding with sustainable agricultural practices, biofortification has the potential to improve public health, strengthen food security, and build a healthier future for generations to come.

"Every nutrient-rich vegetable grown today is an investment in a healthier tomorrow."