Bio-Fortified Crops- Future of Sustainable Food Processing

Prerana Shere[1] and Vaibhavi Uttarwar[2]

[1]Professor, Dept. Food Product and Process technology, MIT School of Food Technology, MIT Art, Design and Technology University, Pune, Maharashtra

[2]PhD Scholar, MIT School of Food Technology, MIT ADT University, Pune, Maharashtra

Corresponding Author: prerana.shere@mituniversity.edu.in

Introduction

Deficits in essential vitamins and minerals hinder both human health and economic development. Malnutrition has become a national and state priority in India, shifting the focus from food security to nutrition security. To meet the population's nutritional needs, the agriculture industry is focusing on producing enough nutrient-rich food crops. The national and state governments are implementing efforts to enhance nutrition outcomes. Significant progress has been made with regard to production enhancement and diversification, and including steps being taken to promote nutritious cereals. Bio-fortification is an approach for improving human nutrition without altering current food patterns.

Bio-fortification is a promising technique for improving vitamin and mineral availability in diets that include micronutrient-poor staple crops. It involves identifying crop cultivars with naturally occurring certain micronutrients are highly concentrated. Plant breeders use these variety to produce new, productive and 'biofortified' crop lines for farmers to cultivate, market, and consume. The World Health Organization defines bio-fortification as improving the nutritional quality of food crops through agronomic methods, plant breeding, or biotechnology. Bio-fortification tries to boost nutrient levels in crops during growing, rather than during processing. Bio-fortification involves growing nutrient-rich crops that have higher levels of micronutrients such as zinc, iron, and vitamins than conventional food crops. Bio-fortification enhances the nutritional value of food by increasing protein, zinc, iron, vitamin A, vitamin C, calcium, anthocyanin, lysine, and tryptophan levels in crops. These nutritional components are necessary for the human body to function properly.

The Bio-fortification Process

Various technologies, particularly genetic engineering and plant breeding have been employed to achieve sustainable micronutrient levels in the product. Let us explore some of these approaches in depth. This method is commonly employed in the creation of nutrients filled crops.

Conventional plant breeding: To create nutrient-rich crop varieties, this process involves transferring appealing characteristics from the donor to the recipient parental line. Conventional plant breeding approaches rely on crop genetic diversity to attain this goal. Breeders effectively use germplasms throughout primary, secondary, and tertiary gene pools for identification. The production of biofortified cultivars requires the presence of critical genes.

Transgenic breeding: It involves overexpressing desired features from a different plant species in a staple crop. The donor organism or species may not be related to the staple crop's taxonomy or evolution. Genetic engineering remains the favoured option when there is no, or minimal genetic diversity related to vital nutrients in the current germplasm. However, a successful genetic engineering approach necessitates a number of key factors, including dependable tissue culture and regeneration methods, the development of gene constructs with appropriate promoters, Efficient transformation methods, and the multiplication and characterization of transformed plants for traits introduced by conventional breeding methods.

Developing a transgenic crop requires significant time, effort, and financial investment during the research and development stage. However, if successful, it can be cost-effective and long-lasting. Furthermore, the transgenic approach has no taxonomic limits, and intentionally created genes can be used.

Agronomic management: Agronomic bio-fortification involves applying mineral fertilizers, such as iron and zinc, to soil or foliage to increase their solubility and micronutrient content. This approach aims to increase the concentration of essential nutrients in the plant's edible parts. Using micronutrients as fertilizers can improve soil health and address deficiencies in plants and humans. Micronutrients Targeted in bio-fortification are Iron, zinc, and vitamin A. Focus on these essential micronutrients due to their widespread deficiencies.

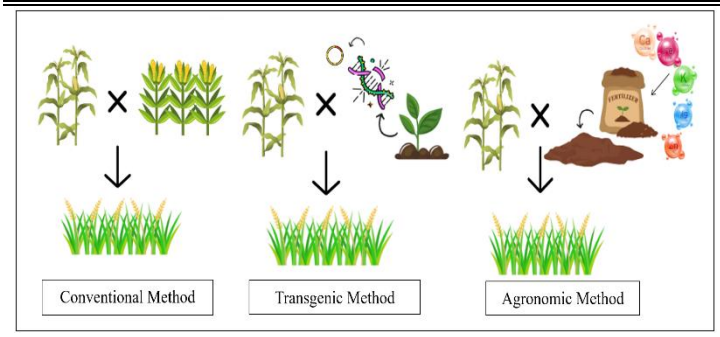

Fig 1: Various methods of crop bio-fortification

Global and national advancements in crop bio-fortification

International trends

According to the International Agricultural Research Centers (CGIAR), more than 350 biofortified varieties were released between 2004 and 2019, with hundreds more currently being tested, and more than 50 million people in small-scale farming households in 41 nations worldwide now benefit from biofortified crops. In 2007, the very first biofortified crop variety, a vitamin A-fortified sweet potato, was delivered to farmers in Uganda. So far, 422 biofortified cultivars of 12 climate-smart staple crops have been produced. African countries have published 278 of the 422 kinds, followed by Asian countries with 79 and Latin American countries with 65. Examples of globally developed biofortified crops are beans, lentil, pearl millet, cowpea, banana, cassava, maize, orange sweet potato, rice, wheat, sorghum, and potato (PwC, 2023).

National trends

The Indian Council of Agricultural Research (ICAR) promotes crop research and development for food grain production in India. ICAR is a pioneer in enhancing the nutrient content of high-yielding grains, pulses, oilseeds, vegetables, and fruits through breeding methods. The government has implemented multiple initiatives to combat micronutrient malnutrition, including Integrated Child Development Services (ICDS), mid-day meal programs, the National Nutrition Mission, and iron, vitamin A, and folic acid supplements. The government has selected and promoted a few nutrient-rich crops as one of the most efficient strategies for Addressing micronutrient deficiency. In addition, using the proofs of concept produced by private companies in the in the topic of bio-fortification, numerous organizations in India have conducted research and development projects towards biofortified cereals supported by national and international institutions (Yadava *et al*, 2022).

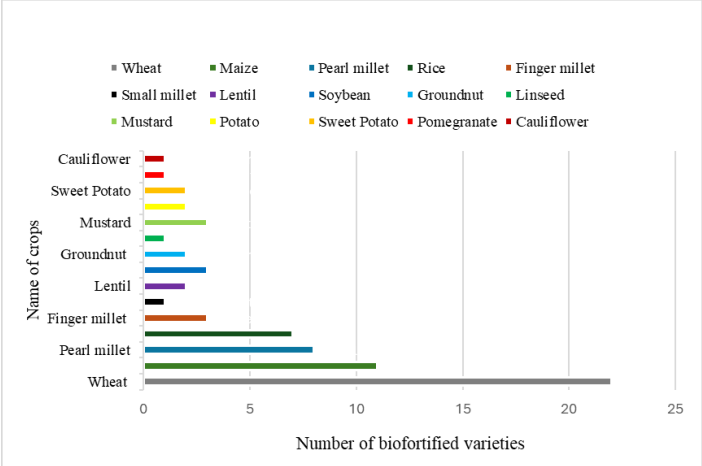

Fig. 2: Number of biofortified varieties of different crops developed in India

Why Bio-fortification is necessary in India?

According to the FAO, India is a top producer of milk and pulses, as well as the second-largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruits, and cotton. Children aged six months to six years were recognized as having severe acute malnutrition, regardless of their status. Our country's food and nutrition system is deteriorating due to a concentration on calories and a lack of knowledge about food's nutritious components. Malnutrition is the main concern in India, not food scarcity. The goal is to eliminate both hidden and actual hunger. To address the issue of hunger, regulations ought to put better food quality above relying on supplements and public distribution networks. Bio-fortification, a farming-based technique to generate and spread micronutrient-rich crops, offers potential in reducing malnutrition and hidden hunger. Biofortified pearl millet flat bread was found to have a positive effect on serum ferritin levels and iron levels in iron-deficient young boys and girls in Maharashtra who taken it twice every day for a duration of four months.

India currently offers a number of biofortified crops that address micronutrient deficiencies, including iron pearl millet, zinc wheat, zinc rice, zinc sorghum, and iron/zinc lentil. deficiencies by raising the dietary intake of iron and zinc. While efforts have been made to develop and market this feasible option, India still requires a comprehensive and well-coordinated policy support system to satisfy the dietary needs of its occupants. Bio-fortification may possess important impact on food systems, particularly in developing countries where main crops like wheat, rice, maize and cassava which supply majority of a person's daily

calorie intake. Biofortified varieties of different crops shows environmentally friendly approach to enhance the nutritional level of crops.

Potential for Food Processing

Bio-fortification of crops and food processing jointly possess the perfect chance to develop new product in market enriched in nutrients. The following are key areas where both bio-fortification and food processing can have significant applications:

Enhanced nutritional content of product: Biofortified grains can be used for development of special food products which are high in nutrients that can appeal to health-conscious consumers and also helpful to fight malnutrition. The various types of processed foods like fortified snacks, drinks full of nutrients can be prepared from biofortified crops.

Commercial differentiation: As consumers getting more aware of nutritional content of food products, biofortified products might stand out in marketplace. By developing meals high in essential nutrients, biofortified products can establish a unique place in market for clients who are interested in health and wellness of one.

Development of value-added products: Biofortified crops can be processed into various forms like flours, pastes, powders, grits, flakes, puffs or even ready-to-eat meals. These value-added products can be used in making of more versatile culinary applications. For example, the biofortified legumes can be used for making of protein rich snacks while, grains can be used for making of bread, pastries, pasta and various bakery items.

Consumer knowledge and recognition: To spread awareness about the benefits of biofortified crops, a few activities such as community involvement, food processors, labeling, and marketing initiatives may help spread the awareness about the benefits of crops. Educating customers about the benefits of biofortified crops to preserve the increasing demand for nutritionally superior products.

Applications in Food Industry

Baked items and flours

Bio-fortification can rise the nutritional level of basic crops like wheat, maize and few millets which can be commonly utilized for making flours, grits and flakes. For example, zinc enriched wheat or vitamin A rich corn or lysine and tryptophan rich maize can be utilized to make flour for different types of breads, pastas and snacks. These developed products from biofortified grains enhances the nutrition of product without changing the consumer's sensory palate and functional properties of the baked products.

Cereals and Appetizer Foods

The term 'Hidden Hunger' depicts consumption of enough calories but inadequate amount of essential nutrients which is crucial for healthy body functioning. Biofortified grains, such as zinc-enhanced wheat or iron-rich millet, beta-carotene enriched sweet potato can be processed to meet nutrient-dense breakfast cereals and snacks. Bio-fortification has enormous potential benefits for the cereal and snack industries. Nutrient-rich puffs, chips, or extruded snacks made from biofortified maize, for instance, might be a better choice for consumers than traditional processed snacks. Children, who are especially susceptible to micronutrient deficiencies, can also receive vital vitamins and minerals from biofortified cereals and various cereal value-added products.

Dairy substitute and Drinks

In recent times plant sources like rice, almond and oat are being used for manufacturing of milk which has been used as replacement for conventional milks and are categorised as vegan food. The different plant-based sources such as zinc enriched rice or vitamin-A fortified oat, can be utilized to create nutrient rich, fortified dairy replacements in health drinks, and smoothies. The products deliver required nutrition with vegan benefits and satisfy consumer demand for smart nutrition products.

Challenges and Considerations

Considering its potential, bio-fortification has some limitations. Significant financial resources are needed for research and development, and consumer acceptance can differ depending on cultural views and tastes. Strong infrastructure and regulations are also required to promote the use of biofortified crops in agricultural systems and the food processing sector. However, despite these obstacles, there are still opportunities for further research and development, which might give rise to developments in the field.

1. Inadequate awareness in farmers about the new cultivation and processing technology of biofortified crops.
2. Food processing industries lack sufficient knowledge for processing of biofortified crops.
3. The limited capabilities of regional seed companies and insufficient government incentives.

4. Price misconception
5. Stability of bio-fortified nutrients over time

Conclusion

Bio-fortification provides a sustainable, feasible solution to the malnutrition issue, particularly in regions where deficiencies in specific micronutrients are common. By incorporating biofortified crops into everyday products like cereals, snacks, bakery foods, flours etc.. Food processors may effectively contribute to achieving nutritional sustainability in society along with satisfying the growing demand for nutritious products. Bio-fortification holds a great promise for the food processing industry, society and farmers to tackle nutritional deficiency. To take full advantage of the promise of bio-fortification in food processing, supply chain, consumer, and legal barriers must be overcome. With the correct support, financing, and education, biofortified crops could play a crucial role towards developing a more nutrient-dense global food system.

References

Akindoyeni I., Adefegha S., Oyeleye S., Oboh G (2022) Food Bio-fortification: A Transition from Nutrient Enrichment to Physiological Significance. *Tropical Journal of Natural Product Research*. 5(12).2051-2056.

Ashoka P., Spandana B., Saikanth D., Kesarwani A., Nain M., Pandey S., Singh B. and Maurya C. (2023) Bio-fortification and Its Impact on Global Health. *International Journal of Experimental Agriculture*. Volume 45, Issue 10, Page 106-115.

Bhardwaj A., Chejara S., Malik K, Raj Kumar, Ashwani Kumar and Yadav R. (2022) Agronomic bio-fortification of food crops: An emerging opportunity for global food. *Frontiers in Plant science*. 1-23.

PwC. (FICCI) Federation of Indian Chambers of Commerce & Industry. (2023). Bio-fortification: A pathway to strengthen food systems through nutrient-rich crops.

Tora Mitra-Ganguli, Wolfgang H. Pfeiffer, Jenny Walton (2022). The global regulatory framework for the commercialization of nutrient enriched biofortified foods. *Annals of New York academy science*. 517:154–166.

Sheoran S., Kumar S., Ramtekey V., Priyajoy Kar, Ram Swaroop Meena and Jangir C. (2022) Current Status and Potential of Bio-fortification to Enhance Crop Nutritional Quality: An Overview. *Sustainability*. 14, 3301.

Yadava D.K., Choudhury P.R., Hossain F., Kumar D. and Mohapatra T. (2022). Biofortified Varieties: Sustainable Way to Alleviate Malnutrition (Fourth Edition). Indian Council of Agricultural Research, New Delhi. 19p.

* * * * * * * * *