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Biofortification: An Imperative Bond for Nutritional Quality Enhancement in Vegetables

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Abstract

Myriad number of people is hungry, but many more are suffering from micronutrient malnutrition, also known as "secret hunger," and this problem particularly found in developing countries. Malnutrition of iodine, vitamin A, copper, and zinc is a significant concern. Mineral (Fe, Zn) and vitamin A deficiency are major food-related primary health problems in developing-world communities, including India, where there is a strong dependency upon the cereals for food rather than vegetables. So, for the redemption from the claws of malnutrition, biofortification is the best option in hand which can be applied on the various food commodities consumed by the population to enhance their nutritional content. Currently, three methods are often used: agronomic, organic, and transgenic biofortificationy.

Keywords

Biofortification; Malnutrition; Micronutrient; Nutrition; Transgenic

Introduction

Good health is essential to human happiness and well-being, and it contributes significantly to prosperity, wealth, and even economic progress, because healthy populations are more productive, save more, and live longer lives. It would not be an exaggeration to say that good health is core source of everything in your life, every chunk of your life totally relies on your sound health. Being healthy does not solely rely on physical fitness; being healthy often entails being psychologically and emotionally fit [1]. Being safe should be an integral part of the overall way of life. A safe lifestyle will aid in the prevention of chronic ailments and long-term illness. There is no single method which could sustain the health of individual, perhaps there are numerous methods which, when followed one by one in routine, have proved effective in maintaining the health. Among various methods of health sustaining, diet maintenance plays a vital role in accomplishment of this task. There is myriad of food products now-a-days available which claims to be best for supporting the health, but most of them fails during their laboratory tests. So, the question arises what should be consumed which is good in nutrition and supports the health. Answer to this question is simple i.e., any commodity which is having good amount of nutrients viz. carbohydrates, proteins, and different essential macronutrient as well as micronutrients (vitamins and minerals). The presence of antioxidants is also another important element which helps in vitalizing the individual. Antioxidants are used to avoid the development and to oppose the activities of nitrogen species and reactive oxygen, which are generated in vivo and cause damage to lipids, proteins, DNA, and other harmful biomolecules. Considering all the aforesaid nutritional requirements, no food commodity other than the vegetables can be the good example of such highly nutritional food. Comparatively vegetables, due to their high nutritional and antioxidant content, are also referred to as "protective food". The total vegetable production in 2019 was estimated around 1130 million metric tons, with population which is estimated across 7.9 billion as per the data disclosed by the United Nations. Keeping up the health of this much big population by providing healthy food to everyone is not merely a piece of cake. And in today's world, everyone is very aware about the circumstances out there. Prosperity of the environment is sinking down day by day and the responsibility of this is claimed by group of factors in which anthropogenic activities are the major one standing. So, from this ill environment, how we can expect to get out sound output from it? But it does not mean that we cannot get anything healthy from the environment. The agriculture sector from the past few decades has gained superiority in technical advances. It has brought upon the agriculture sector which once was nothing to something now. Various techniques and technologies have been put forward in use to mitigate the problems out there. Hydroponics, aeroponics, aquaponics, vertical framing etc. are some of those precious gems which in recent decade have kept the agriculture production back on the track. But producing food is not only the point to be focused upon; indeed it is also the quality of the produce which should be pondered upon as well. The nutritional quality of the crop is directly depended upon the type of cultivar used for cultivation, production methods, irrigation timing, fertilizer, and micronutrient application. Micronutrients are principal elements that all living entities need in differing amounts for coordination of physiological functions for maintenance of health [2]. Micronutrients are needed in quantities of less than 100 milligrams a day for human nutrition, while macronutrients are required in grams per day. Why here we are talking about nutrition, micronutrient etc.? Answer to this question lies in one word i.e., "Malnutrition." Nearly 49 nutrients including various proteins, lipids, vitamins, macro and micro molecules are needed by the human body for proper metabolic functioning and even if one of these micronutrients is not adequately given to the body, it will cause malfunctioning of metabolism which directs towards malnutrition. Malnutrition in any of its types involves undernutrition (wasting, stunting, and becoming underweight), insufficient vitamins and nutrients, becoming overweight or obese, and developing diet-related non-communicable diseases. According to 2021 fact sheet of WHO 1 Billion adults lie in the category of overweight/obese, whereas 462 million are still underweight. 47 million children under the age of five are wasting, 14.3 million are seriously wasted, 144 million are stunted, and 38.3 million are overweight/obese. Undernutrition is responsible for about 45% of deaths among children under the age of five. As malnutrition is a difficult challenge to address, but with rising levels of undernutrition and obesity, something substantial must be done. This tumor of malnutrition is not going to be removed that quickly from the population; rather this will be done gradually. There are so many initiations to mitigate this problem and one of such successful initiative is "Biofortification." This process is simply enhancing the

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nutritional values of food. Bio fortification is the process of increasing the bioavailable mineral content of food crops by genetic modification [3]. The biofortified crops have been also observed to perform very well even in soils which are depleted or are deficient in essential minerals [4]. Biofortification by conventional breeding methods is generally conducted in those plants which are having short juvenile cycles to fruiting viz. such as melons, cucumber, carrot etc. but for the crops having longer span are biofortified by other methods. Alternative methods imply searching for plant cultivars/varieties with decent amount of phytonutrient levels. This can highlight the lines that are already appropriate to customers, or else they can help in identification of potent donor parent which can be utilized for creation of superior cultivars with greater phytonutrient levels in crops. The cultivation of biofortified crops improves their growth efficiency in soils with little to no mineral content with the help of this outstanding strategy crops nutritional value viz [5]. Vitamins, minerals and protein can be enhanced. Various micronutrients enriched vegetables have also been released by various research centers. These micronutrients are very beneficial for health of humans; for example, Selenium is needed for better immune system function and appears to be a crucial nutrient in preventing the production of virulence and the proliferation of HIV to AIDS [6]. Other vegetables like Red Cabbage (RC), which is also known as purple cabbage, is low in saturated fat and cholesterol and rich in thiamin, riboflavin, folate, K, Ca, Fe, Mg, and Mn, dietary fibre, vitamins A, C, K, B, anthocyanins, and antioxidants, which can reduce the risk of cardiovascular disease, brain disorders, and cancer [7]. Biofortification has opened a whole new space for the development of new cultivars of vegetable crops. It is a very cost-effective, long-term way of supplying more vitamins and minerals in isolated rural areas, as well as distributing naturally fortified foods to populations that do not have access to widely sold fortified foods. While biofortified food crops cannot provide the same quantity of minerals and vitamins per day as industrially fortified foods, they can support individuals during their lives by expediting daily soundness of micronutrient intakes [5].

Literature Review

Significance of biofortifications

- It is more precisely essential for vulnerable rural communities who are having limited access to a diverse diet and fortified foods etc
- The biofortification will benefit people by escalating their daily micronutrient intake

Raw, edible weight portion. Percent Daily Values (%DV) are based on a 2,000 calorie diet.

Vegetables Serving Size (gram weight/ounce weight)	Calories	Calories from Fat	Total Fat g / %DV	Sodium mg / %DV	Potassium mg / %DV	Total Carbohydrate g / %DV	Dietary Fiber g / %DV	Sugars g	Protein g	Vitamin A %DV	Vitamin C %DV	Calcium %DV	Iron %DV
Asparagus 5 spears (93 g/3.3 oz)	20	0	0 / 0	0 / 0	230 / 7	4 / 1	2 / 8	2g	2g	10%	15%	2%	2%
Bell Pepper 1 medium (148 g/5.3 oz)	25	0	0 / 0	40 / 2	220 / 6	6 / 2	2 / 8	4g	1g	4%	190%	2%	4%
Broccoli 1 medium stalk (148 g/5.3 oz)	45	0	0.5 / 1	80 / 3	460 / 13	8 / 3	3 / 12	2g	4g	6%	220%	6%	6%
Carrot 1 carrot, 7" long, 1 1/4" diameter (78 g/2.8 oz)	30	0	0 / 0	60 / 3	250 / 7	7 / 2	2 / 8	5g	1g	110%	10%	2%	2%
Cauliflower 1/6 medium head (99 g/3.5 oz)	25	0	0 / 0	30 / 1	270 / 8	5 / 2	2 / 8	2g	2g	0%	100%	2%	2%
Celery 2 medium stalks (110 g/3.9 oz)	15	0	0 / 0	115 / 5	260 / 7	4 / 1	2 / 8	2g	0g	10%	15%	4%	2%
Cucumber 1/3 medium (99 g/3.5 oz)	10	0	0 / 0	0 / 0	140 / 4	2 / 1	1 / 4	1g	1g	4%	10%	2%	2%
Green (Snap) Beans 3/4 cup cut (83 g/3.0 oz)	20	0	0 / 0	0 / 0	200 / 6	5 / 2	3 / 12	2g	1g	4%	10%	4%	2%
Green Cabbage 1/12 medium head (84 g/3.0 oz)	25	0	0 / 0	20 / 1	190 / 5	5 / 2	2 / 8	3g	1g	0%	70%	4%	2%
Green Onion 1/4 cup chopped (25 g/0.9 oz)	10	0	0 / 0	10 / 0	70 / 2	2 / 1	1 / 4	1g	0g	2%	8%	2%	2%
Iceberg Lettuce 1/6 medium head (89 g/3.2 oz)	10	0	0 / 0	10 / 0	125 / 4	2 / 1	1 / 4	2g	1g	6%	6%	2%	2%
Leaf Lettuce 1 1/2 cups shredded (85 g/3.0 oz)	15	0	0 / 0	35 / 1	170 / 5	2 / 1	1 / 4	1g	1g	130%	6%	2%	4%
Mushrooms 5 medium (84 g/3.0 oz)	20	0	0 / 0	15 / 0	300 / 9	3 / 1	1 / 4	0g	3g	0%	2%	0%	2%
Onion 1 medium (148 g/5.3 oz)	45	0	0 / 0	5 / 0	190 / 5	11 / 4	3 / 12	9g	1g	0%	20%	4%	4%
Potato 1 medium (148 g/5.3 oz)	110	0	0 / 0	0 / 0	620 / 18	26 / 9	2 / 8	1g	3g	0%	45%	2%	6%
Radishes 7 radishes (85 g/3.0 oz)	10	0	0 / 0	55 / 2	190 / 5	3 / 1	1 / 4	2g	0g	0%	30%	2%	2%
Summer Squash 1/2 medium (98 g/3.5 oz)	20	0	0 / 0	0 / 0	260 / 7	4 / 1	2 / 8	2g	1g	6%	30%	2%	2%
Sweet Corn kernels from 1 medium ear (90 g/3.2 oz)	90	20	2.5 / 4	0 / 0	250 / 7	18 / 6	2 / 8	5g	4g	2%	10%	0%	2%
Sweet Potato 1 medium, 5" long, 2"diameter (130 g/4.6 oz)	100	0	0 / 0	70 / 3	440 / 13	23 / 8	4 / 16	7g	2g	120%	30%	4%	4%
Tomato 1 medium (148 g/5.3 oz)	25	0	0 / 0	20 / 1	340 / 10	5 / 2	1 / 4	3g	1g	20%	40%	2%	4%

Figure 1: Nutritional content of vegetable.

- It is most crucial for women and infants, who are at a higher risk of micronutrient malnutrition to increase food security

Vegetable nutrition

Fresh vegetables are low in cholesterol, salt, and sugar by nature, making them an outstanding food choice. Vegetables contain nutrition, vitamins, minerals, and fiber, and there is considerable evidence that a variety of phytonutrients provide additional health benefits. Few vegetables have higher carbohydrate content and are sometimes referred to as starchy vegetables e.g., potatoes, yams, taro, and sweet corn are examples of roots and tubers possessing reasonable carbohydrate quality, starchy vegetables also provide more energy (kilo joules). Non-starchy vegetables are those that do not have starch and have higher water content and are lower in energy, but they are often a good source of various vitamins and minerals. Every different vegetable is good source of one or other nutrient as shown in (Figure 1) [8].

Regardless of the fact that the plants are rich in minerals and vitamins, they too have some natural occurring plant compounds as well. Vegetables contain thousands of various phytonutrients, most of which are present in trace quantities. Plants create them to shield themselves from insects and bacteria, as pigments for photosynthesis (energy production), and for flavour. They are often responsible for the vibrant colours of fruits and vegetables, and research indicates that these compounds can help reduce disease risk and promote health. Lycopene in onions, beta-carotene in carrots, and glucosinolates in broccoli are examples of phytonutrients. These can protect against disease and promote health in a variety of ways. Anti-inflammatory function, enhancing the body's antioxidant defences, modulating gut microflora, lowering cholesterol, battling microbes, and promoting the body's immunity are all being studied. Some of the important phytonutrients are enlisted in the (Table 1).

Methods of biofortification

Biofortification is the technique, which is described as "enhancement of nutrition in the fields rather than factories" Crop nutritional benefit can be increased through a variety of biofortification methods, including agronomic biofortification, plant variety enhancement through traditional breeding, and nutritional genetic alteration [5,9].

- Genetic engineering
- Conventional plant breeding
- Agronomic biofortification

Genetic engineering

Genetic engineering is often defined as a game changer technology for essential food, feed, and energy needs. It is a record since the first large-scale launch of the tomato variety in 1996. Genetically Modified (GM) crops (transgenic crops) enable plant breeders to introduce beneficial genes into previously in-accessible cultivars, enhancing their appeal and providing exclusive opportunities to combat viruses, mosquitoes, and other diseases while also improving health benefits and nutritional efficiency. GE is a viable option for increasing the bioavailability and concentration of micro nutrients in edible crops when there is inadequate variation among genotypes for the desired character/trait within the population, or when the crop itself is unsuitable for conventional plant breeding (due to lack of sexuality). Genetic manipulation could be used by vegetable breeders to insert desired transgenes into novel cultivars, increasing their attractiveness. It offers a one-of-a-kind opportunity to improve diet quality while still growing health benefits. Flavor, nutritional value, bitterness, and sluggish ripening are all traits that have been genetically engineered into vegetable crops, increased sweetness, anti-nutritional factors and seedless berries.

Various transgenic approaches pertinent to biofortification

Tomato: A vivid research has been done on the tomato regarding its biofortification viz. increasing its antioxidants, research regarding increasing its flavonols content, carotenoids enhancement programmes and anthocyanin enhancement programmes, etc. A brief about these methods has been done below:

- Flavonols enhancement programmes: Tomato transformed with the chalcone isomerase-encoding Petunia chi-a gene. The resultant transgenic tomato lines had a 78-fold increase in fruit peel flavonols, owing to an accumulation of rutin. Ectopic expression of chalcone isomerase, a single biosynthetic enzyme, resulted in a 78-fold increase in total fruit flavonols.
- Antioxidants: Fruits and vegetables are high in antioxidants and carotenoids viz. lycopene and ß-carotene, as well as vitamins C and E. There are surplus amounts of glutathione and ascorbate, the soluble antioxidants of metabolic pathways, as well as overall antioxidant production in transgenic fruit that absorb trans resveratrol [10]
- Carotenoids enhancement programmes: Lycopene is a powerful antioxidant that has the potential to protect against epithelial cancers and improve human health. As a result, there is a possible interest in the carotenoids levels in tomato by genetic experimentation, which will improve the nutritional content of the tomato harvest. By generating phytoene from GGPP, the Psy-1 enzyme serves as a catalyst in the first step of the carotenoid biosynthesis pathway (geranylgeranyl diphosphate). The Psy-1 gene was expressed constitutively in tomato genome for enhancement of the carotenoid content of the fruit [11]
- Anthocyanin enhancement programmes:Via plant-specific expression of two transcription factors, Del and Ros1, Agrobacterium-mediated transformation was used to increase the anthocyanin content of the fruit of a profitable tomato cultivar, Arka Vikas. The overall anthocyanin accumulation in the transgenic fruit was 0.1 mg g-1 fresh weight, which was 70-100 times greater than the control fruit [12]

Potato: Overexpression of a single gene, encoding Chalcone Isomerase (CHI), Dihydroflavonol Reductase (DFR), and Chalcone Synthase (CHS), resulted in a large increase in measured anthocyanins and phenolic acids in potato.

- Protein content enhancement: Protein-rich potato expressing the seed protein gene AmA1 will increase nutritive value by expressing a non-allergenic seed-albumin gene i.e. AmA1 (Amaranth Albumin 1) from the Amaranthus hypochondriacus. At the biochemical stage, this gene expression in both types of transgenics results in a considerable increase in all essential amino acids, especially

Table 1: Some important Phytonutrients.

S.No.	Nutrient	Potential health benefits	Vegetable source
1.	Carotenoids (Pro vitamin A carotenoids: Alpha carotene, beta cryptoxanthin and beta carotene)	Our body, after consumption of these carotenoids, converts them into Vitamin A. More study is required to determine whether carotenes can help delay the ageing process, lower the risk of some forms of cancer, increase lung function, keep skin safe, and minimize diabetes complications.	Present in leafy vegetables, pumpkin and carrot
2.	Capsaicinoids	Capsaicinoids may have a variety of possible advantages, including pain relief, cancer prevention, and weight loss, as well as benefits for the cardiovascular and gastrointestinal systems to a minor extent.	Chilli and capsicum
3.	Lycopene	Some recent studies have indicated that the consumption lycopene rich food can help in reducing the risk of prostate cancer as well as heart diseases.	Watermelon and tomato
4.	Fructans	Phytosterols can compete with cholesterol for absorption, lowering cholesterol levels in the blood. There is also some evidence that phytosterols can help suppress cancer cell growth and combat atherosclerosis by regulating plaque formation.	Onion, garlic and leek
5.	Phytosterols	Phytosterols can compete with cholesterol for absorption, lowering cholesterol levels in the blood. There is also some evidence that phytosterols can help suppress cancer cell growth and combat atherosclerosis by regulating plaque formation.	Brassica family (cauliflower, swedes), lettuce, peas and asparagus
6.	Saponin	Saponins have been found to have a variety of beneficial effects in the human body, such as lowering cholesterol and avoiding heart disease.	Spinach and alfalfa sprouts
7.	Falcarindiol, Falcarinol	These compounds have piqued the attention of researchers due to their potential as anti-cancer agents. However, at high concentrations, these compounds can be poisonous.	Celery, fennel, parsley, parnship and carrot
8.	Betalains	The betalains have gained less recognition than the anthocyanins, which are the more popular natural red pigments. However, studies show that they have anti-inflammatory properties and can stimulate the body's detoxification enzymes.	Spinach (red yellow varieties), beetroot
9.	Anthocyanins	Anthocyanins seem to have a wide range of health advantages, including protection against the symptoms of ageing and a lower risk of cancer and diabetes, according to research. They can be neuroprotective, assisting in the prevention of neurological disorders and improving facets of vision.	Purple broccoli, eggplant, radish, rhubarb
10.	Phenolic Compounds	They reportedly have found to help in minimizing heart attacks and immune system boosting.	Potato
11.	Flavonoids	Scientists have been particularly interested in the potential for multiple dietary flavonoids to justify some of the health advantages associated with fruit and vegetable-rich diets over the last decade. Health benefits include lowering the risk of cancer, diabetes, and heart disease, as well as promoting bone, brain, and vision health.	Onions, beans, tomato and leady vegetables
12.	Xanthophyll: (Lutein and Zeaxanthin)	Lutein and zeaxanthin are present in the retina and lens of the eye, and they are believed to play a part in preserving normal vision as we mature, as well as lowering the risk of macular degeneration and cataracts.	Sweet corn, silver-beet, spinach, lettuce and other dark green leafy vegetables.
13.	Glucosinolates and Isothiocynates	By the activity of enzymes that detoxify carcinogens, glucosinolates (or their breakdown products, isothiocyanates) can reduce the incidence and severity of cancer.	All brassica vegetables.

tyrosine, lysine, , and sulphur amino acids, as well as a related increase in total protein content [13]

- Starch content enhancement: Starch is the primary starch storage factor in potato tubers, accounting for up to 70% of tuber dry matter. The gene glg C16 of Bacterium Escherichia coli encodes bacterial ADPGP. When transferred into potato, the transgenic plant developed tubers with a high starch content [14]
- Low sugar potato: The Czech Republic has also developed genetically modified potato plants. There are potatoes that have had a phosphofructokinase gene from the bacterium Lactobacillus bulgaricus added. Furthermore, potatoes with higher levels of simple sugars turn brown when fried, making them less appealing to customers. Transgenic potato plants have not only lower sugar content, but the chips made from them are lighter in color than those made from non-modified potatoes [15]

Carrot: Increased Ca levels in genetically engineered carrots can increase Ca uptake, lowering the incidence of Osteoporosis is caused by calcium deficiency. Carrots that had been transgenically engineered had higher levels of the plant Calcium transporter which is SCAX1 [16].

Cauliflower: The successful cloning of cauliflower "Or" gene depicts that by manipulating chromoplast formation to provide an efficient metabolic sink for the carotenoid sequestration and carotenoid accumulation. The use of this gene to improve carotenoid content in transgenic potatoes clarifies a novel approach to enhancing the carotenoid levels in food crops by focusing on the expression of carotenogenic genes [17]. Cabbage: Red cabbage has a high concentration of anthocyanins and decent antioxidant properties, which can cut-short the risk of brain disorders, cancer, and cardiovascular [7].

Pumpkin: The overall carotenoid and ß-carotene isomer contents accelerated as result of the cooking methods used, and pumpkin has high total carotenoids content [18].

Cassava: For the enhancement of the nutritional quality of cassava roots, which contain up to 85% starch in dry weight but are deprived of protein, a synthetic ASP1 gene which encodes a protein rich in essential amino acids around 80% was inserted into cassava embryogenic suspensions through Agrobacterium mediated gene transfer.

From the above discussed examples of the biofortified vegetables, it would have been quite clear that how much biofortification can help in evading the nutritional insecurity. But apart from its various benefits, there are so many potential risks from this Genetically Modified (GM) food crops viz. antibiotic resistance in pest, GM may become toxic or allergenic, Possibility that new toxins may starts to appear, threats to the crop genetic diversity etc. So before going for this fortification, it should be first free from all the potential risk mentioned above, only after this they can be available to people.

Conventional plant breeding

Traditional breeding has been mostly based on yield qualities and resistance breeding for the last four decades, and a lack of emphasis on nutritional issues has resulted in a decline in the amount of nutrient status in existing varieties. Fe, Zn, Cu, and Mg are examples of minerals whose mean concentration in dry matter has decreased in a variety of plant-based foods. Recent advances in traditional plant breeding have focused on the fortification of essential vitamins, enzymes, and micronutrients. The ability for traditional breeding to increase the micronutrient percentage in staple food which includes the sufficient genetic variance in concentrations of beta-carotene, other usable carotenoids, zinc, iron and various essential minerals present among other cultivars enabling us for selection of appropriate breeding strategy [19]. This conventional strategy has been utilized for biofortifying various important crops, some of them are discussed as below.

Cow pea

G.B. Pant University of Agriculture and Technology (India) has pioneered studies on cow pea biofortification. Conventional plant breeding has resulted in the development and release of two early maturing varieties with high iron and zinc percentage in them viz. Pant Lobia-1 (82 ppm Fe and 40 ppm Zn) and Pant Lobia-2 (100 ppm Fe and 37 ppm Zn) are evolved by aforesaid breeding method in year 2008 and 2010.

Beans

Beans are also referred to as the "poor man's beef" due to their low cost whereas having decent protein amount and their good mineral and vitamin content (especially Fe and Zn). Beginning with germplasm sampling, inheritance, physiological, or bioavailability tests, and concluding with product processing in the form of new biofortified varieties, the benefits and requirements of mineral biofortification in traditional bean are discussed [20]

Cassava

Cassava, a staple crop in many developed countries, produces only trace amounts of iron and zinc. Biofortification activities are thus concentrated exclusively on increasing concentrations of beta-carotene [21]. Analyzing 632 accessions of the 5500 accession CIAT germplasm sequence, germplasms with beta-carotene concentrations above 20 g/g show a high genetically diversity that would enable cassava to be successfully biofortified and meet the normal requirements of adults for retinol [22]. Inter-specific hybridization has been used to increase genuine protein on the amino acid content of cassava roots and 10 times more lysin and 3 times more methionine in inter-specific hybrid than traditional cassava cultivars [23].

Agronomic biofortification

Micronutrient-rich fertilizers are used to boost the micronutrient content of edible parts. Selenium (as selenate), iodine (soil iodide or iodine) and zinc are the main agricultural biofortification micronutrients (foliar applications of ZnSO4). The foliage method for applying micronutrient is an easy and quick way to strengthen micronutrient plants (Fe, Zn, Cu etc.). Several studies have suggested that crop plants with mycorrhiza have higher Se, Fe, Cu, and Zn concentrations. AM-fungi improve productivity and absorption of micronutrients such as Cu, Fe, Zn, and others. Sulphur oxidising bacteria increase the sulphur content of onion.

Biofortification for iron content enhancement

Tomato plants can tolerate elevated amounts of iodine, which is contained in both the vegetative tissues and the fruits at quantities that are more than adequate for human consumption, leading to the conclusion that tomato is an ideal crop for iodine-biofortification projects. The iodine content in the fruits of plants treated with 5 mM iodide was more than enough to meet a maximum human consumption of 150 g. He also stated that Spirulina platensis was used as a biofortifying agent to improve the iron status in Amaranthus gangeticus plants by using it as a microbial inoculant [24]. Biofortification could help in curing two billion people with iron deficiency-induced anaemia according to the World Health Organization (WHO) [25].

Biofortification for Selenium content enhancement

Se-enhanced S. pinnata is useful as a soil modification for providing beneficial types of organic-Se to broccoli and carrots. By the foliar application of a solution 77 Se (IV) enriched to 99.7 percent of 77 Se, onions and carrots were bio-fortified [26]. The application of selenium to brassica vegetables had little effect on yield or oil content [27]. Se accumulation in the seeds and meal was found to be high (1.92 g Se g1-1.96 g Se g1) [28].

Biofortification for Zinc content enhancement

A saturation curve, which reaches an estimated 30 mg zn kg-1 DM, followed a relationship between tuber Zn concentration and foliar zinc application of 1.08 g of plant-1. Following a 40-fold increase in Zn foliar fertilisation with the plant 2.16 g Zn-1 [29]. Biofortified plants produce 6.60-8.59% of the Zn rather than control was also found [30].

Conclusion

Adequate consumption of a broad variety of nutrients and other chemicals, at quantities and combinations that are not yet well known, is needed for healthy nutrition. Thus, increasing intake of a diverse variety of non-staple foods in developed countries is an appropriate approach to eliminating undernutrition as a public health issue. It takes decades, however, to implement informed policy and relatively significant investments in farm research and other public and agricultural infrastructure. Biofortification is a viable method of targeting malnourished communities in increasingly isolated rural areas by supplying naturally fortified foods to people who do not have easy access to commonly sold fortified foods, which are more widely accessible in urban areas. Since food staples predominate in the diets of the poor, the bio-fortification wills indirectly targets economically disadvantaged families. As a result, biofortification and industrial fortification are strongly compatible. In the words of M.S. Swaminathan, "GM foods will tackle numerous global problems of hunger and starvation and contribute to the protection and conservation of the environment by increased production, productivity and reduced toxic pesticide dependency." Policy makers, however, face various barriers, especially in safety testing, regulation, industrial policy and food labeling".

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