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Biofortification: way forward toward micronutrient deficiency

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Abstract
Half of the World's people are being affected by micronutrient-deficiencies. Mostly in developing countries, the human development, along with economic development are hindered by malnutrition. The World Health Organization (WHO) have made fighting micronutrient malnutrition, profoundly known as "hidden Hunger", the most important priority. The micronutrient deficiency like zinc, ironand vitamin A are the most demolishing among the World's poor. The organisation have focused on food fortification and supplementation to deal with micronutrient. Biofortification is a novel approach in this regard to provide nutrient enrich food staples. WHO emphasize on biofortification through the Harvest Plus-challenge-program to improve micronutrient of the food staple through biotechnological and breeding approaches. Biofortification is cost-effective approach for delivering of micronutrient enrich food crops to poor people, where people cannot afford to use supplementation. Biofortified crops c an be a good source of nutrition to the poor people of developing countries. Here, in this review we discussed the biofortification, its discovery leading to development, benefits and prospects towards the development of biofortified food-crops.

Keywords
biofortification, micronutrient malnutrition, iron, zinc

Rationale for biofortification

Throughout the globe, micronutrient malnutrition is responsible for more deaths, almost more than 20 million deaths annually (WHO and FAO, 2003). In developing countries, agriculture sector has successfully met the energy demands of poor population. In the past few decades, agricultural scientist has met Malthus's challenge by increasing cereal-production according to the demand. However, its need of the hour that scientist must focus on new prototype that will provide better-quality nutritious food. Biofortification can enhance the nutritional status of food crops, providing an environmentally friendly, cost-effective, comparatively inexpensive and easy way of providing nutrition to poor people. The current approach lowers the malnourished people through improving nutritional status. Furthermore, biofortification technique provides a reasonable way of approaching malnourished people who may have access to expensive commercially fortified market supplements and foods. Unlike the traditional fortification programs, a one-time investment in biofortification can provide opportunity for farming community to grow micronutrient enriched food around the globe especially in developing countries for poor people. That is the escalation aspect of biofortified crops across distance and time that make it cost effective approach.

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Biofortification is a process of providing nutrient enrich food crops, providing a reasonable, sustainable and cost-effective way of providing nutritious food crops. Although, biofortified crops cannot with supplements and industrial fortified crops in terms of providing mineral and vitamins, but biofortification can help improving the intake of micronutrient among individuals (Bouis et al., 2011; Bouis and Saltzman, 2017). It should be noted that biofortification is not expected to eliminate micronutrient deficiency in all population groups (Nestel et al., 2006). No single approach can solve micronutrient deficiency, however, biofortification accompaniment the existing techniques to provide micronutrients to vulnerable community on sustainable basis in a comparatively cost-effective and easy way (Meenakshi et al., 2010).

Biofortification, a reliable approach of feeding malnourished population, who don't have access to commercially fortified crops and supplements. Biofortification policy aims to put micronutrients traits in verities that already have consumption and agronomic traits like high yield. Marketed crops may make their way into peddle outlets, approaching consumers in rural community and then in urban areas, in distinction with complementary approaches like fortification and supplementation (Priyanka *et al*., 2018).

Presently, three most common approaches related to fortification are agronomic, conventional and transgenic. Agronomic biofortification only provide temporary increment in food crops through fertilizers. Zinc foliar application can increase Zn concentration up to 20-22 ppm in wheat-grain in Pakistan, but only in the running season when it is applied (Zou et al., 2012). This is almost the highest possible nutrient uptake as set by the scientists (Phattarakul et al., 2012). This approach can complement breeding efforts, but more research is needed (Zho et al., 2019).

A preview

Micronutrients are of utmost importance for the human beings. Deficiency of micronutrients leave severe negative impact on human health. Micronutrients malnutrition accounts for 3 million child-deaths annually. Among micronutrients, iron (Fe) deficiency affects more than 2 billion people around the globe, especially in developing countries. Pregnant women (50%) and pre-school children (40%) are more vulnerable to Fe deficiency anemia. Iron plays a principal role in immune system of humans. The current situation of COVID-19 demands a healthy immune system to defeat the virus infection. The iron deficiency anemia (IDA) can significantly reduce physical development and immunity. Most of the countries face the problem of micronutrient undernutrition than the low energy intake. There are several reasons of increasing anemia, most importantly in areas of malarial transmission. They include poor undernutrition and malarial infection itself, intestinal helminths and HIV during pregnancy. A recent report reveals a fact that iron deficiency within the first phase of life is accountable for poor brain development.

In developing and developed countries, food-fortification, pharmaceutical-supplementation and dietary-diversification are often used to tackle iron deficiency. These prevailing strategies are constrained by socioeconomic circumstance including insufficient amount to afford fortified foods, supplements, lack of access to diversified diets, lack of proper agricultural infrastructure and most importantly absence of long-term government policies. There comes another issue of public acceptance of fortified food because of flavor and color changes.

The WHO emphasizes on three approaches to cope with micronutrients deficiencies (Fig. 1);

a) Nutritional status improvement through prevention and control of vitamins deficiency.

b) Improving iron content in crop plants.

c) Infection control through control program and immunization.

Biofortification of crop plants is recommended, cost effective and sustainable strategy. Consultative Group on International Agricultural Research (CGIAR) through the HarvestPlus program put more emphasis on improved micronutrients content especially iron in potato, wheat, rice, beans and maize through biofortification (Sawicka et al., 2019). A strong knowledge of the molecular mechanisms involving in nutrient uptake and translocation is of extreme importance.

Iron food fortification

Food fortification, biofortification and pharmaceutical supplementation can be used to increase the intake of iron. In 2010, WHO declared as potential improver of iron deficiencies in undernourished third world countries. Countries with more infectious diseases are endemic required a proper line for iron supplementation. NaFeEDTA-fortified fish sauce for Vietnamese women is an example of iron fortified food (Thuy et al., 2003).

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Agronomic fertilization along with iron chelation can be used to improved iron contents of food, however, in developing countries this approach is not a sustainable common approach. Moreover, the excessive use of fertilizers also led towards environmental issues. Genetic engineering and conventional breeding have the potential to deliver iron enrich food to the undernourished population through the globe. In developing countries, these approaches are being used as these are cost-effective, environmentally friendly and sustainable. Biofortification is an economically feasible strategy to deliver iron enrich food even to peoples in third world countries (Zulifqar et al., 2019).

Iron-Paradox

Iron-deficiency anemia can be treated by increasing iron contents in the body, however, there are certain evidences that increasing iron content may promote growth of pathogens. In developed countries, optimum requirements of iron are easily fulfilled. However, in developing countries due to prevailing disease and more chances of infections make more difficult to attain iron supplements (Murgia et al., 2012). Supplements may improve iron deficiency and folic acid contents; however, this may lead towards enhanced neurodevelopment's (Murgia et al., 2012). Iron supplementation to iron replete children's and pregnant women's might be harmful, if they are suffering from infection diseases like malaria. The reason behind is the growth promotion of pathogens due to excessive iron.

Implementation of biofortification process

Currently, in developing countries there is dire need of a technique that can be used to deliver micronutrients to poor community to compete with micronutrient malnutrition. Biofortification is one of the ideal technique that can be used to overcome micronutrient deficiency. For biofortification to be implemented successfully, following questions must be directed.

- Is it possible to increase the micronutrient level in food-crops through biofortification up to measurable and acceptable level?
- Under controlled conditions, can the extra nutrients in the food stuff be absorbed at sufficient level to balance out the nutrient status?
- Will the farming community (initial source) accept the biofortification process to follow in their growing technologies?
- Will the consumer accept the biofortified crops?

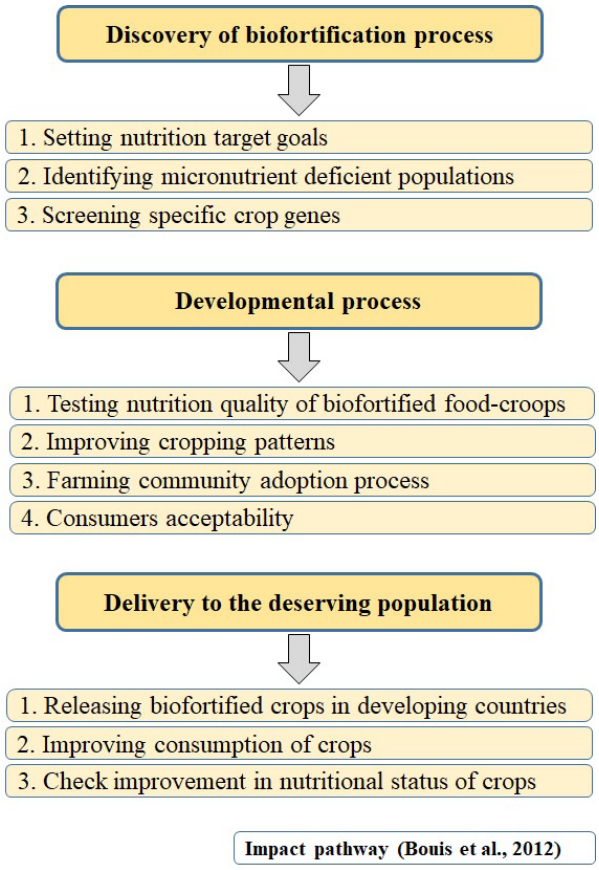

Figure 1. *Impact pathway for discovering biofortification process.*

The above mentioned simple but critical questions can be answered by the plant scientist through performing a series of experiment ended up with fortifying the food crops in a farmer's acceptable way through three phases of discovery, development and dissemination (impact pathway) (Bouis et al., 2011).

Introducing biofortification

The crossway of cropping schemes, micronutrient deficiencies and consumption trends determine the deficient crops along with targeted population. Nutritionist later work with breeders to develop breeding techniques to deal with malnutrition through setting the nutritional programs. The major focus of these nutritional programs involves the nutrition food intake, food consumption and food losses during processing and storage (Hotz and McClafferty, 2007). HarvestPlus are setting nutrition program according to different age groups. For children with age between 6-8 years, non-pregnant women and non-lactating women, the progressive amount of iron (Fe) might provide

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30% of the Estimated Average Requirement (EAR), for Vitamin A 50% and for zinc (Zn) 40%. Bio-available concentration for iron was assumed to be around 5-6% for iron in pearl millet, wheat and beans. Breeding technologies sort out crop varieties in global germplasm bank to find out whether sufficient genetic variability exist for a particular trait (Velu et al., 2012; Adeyeye et al., 2019)

Developmental processes

Improvement in cropping patterns mostly includes breeding techniques. Product development begins at international research stations to develop verities with improved agronomic practices and balance nutritional status, keeping in view the consumers demand. After the development of promising verities with desired characters, they are tested at national research stations and best performing ones are submitted to government for public release. Corresponding with crop improvement, researchers focus on nutrition and micronutrient in the food crops under typical cooking, storage and processing (Bouis et al., 2019).

Dissemination

At the end and most importantly, biofortified food-crops must be delivered to the developing countries to be available for deserving communities suffering from nutrient deficiencies, rather than their release to the target population group. Agricultural economist at the same time, focus on consumers adoption, acceptability, seed and grain value chain to make effective marketing techniques to maximize their consumption (stafen et al., 2019).

Relative advantages of biofortification

1) Delivering nutrient enrich foods in rural areas

Farming communities mostly grow biofortified crops developed through series of research programs, supported by Consultative Group on International Agricultural Research (CIGAR) and disseminated by government extension agenizes along with non-governmental organizations. The approach focusses on adding the micronutrient traits in high yielding crop varieties. The process is mostly set for the poor community that can afford to supplementation. Surpluses of these crops make their way into outlets both in rural and urban areas.

2) Environmental friendly and cost effective

Biofortified food-crops may not overcome the vitamin and minerals deficiency as the supplementation do, however they can bring millions of populations from malnourished to micronutrient deficiency. Through biofortification, micronutrients enrich food can be delivered to the most deserving community, which are unable to overcome nutrient deficiency through supplementation. The current approach is a onetime investment and results are for longer period.

3) Sustainable approach

Once implemented, the system is highly sustainable. The cost of producing verities, convincing the plant, soil and nutrition scientist are being covered through major program of Harvest Plus (www.harvestplus.org). At the same time, nutrition enrich verities will be grown year after year to benefit the community.

Constraints to biofortification

1) Varying impact throughout the life-cycle

Biofortified food-crops can deliver micronutrients to body such as iron, zinc etc. throughout the life cycle, including those of pre-Scholl children, elderly, women and men. The benefit of fortified food crops is however, not equivalent to those of supplementation.

2) Time dimensions to deliver biofortified food crops

This will take a lot of time to deliver first wave of biofortified crops in the developing countries. It is only when this happens, and impact is confirmed, as counted by significant reduction in iron, zinc, that the current approach will take place over supplementation and fortification.

Conclusions

Biofortification process take benefit of the daily consistent consumption of staple food by all family members, most importantly women and children, who are mostly at risk for malnutrition. Because of the prevalence of food-staples in the poor's diets, the biofortification process absolutely targets families of low-income. After initial investment in producing crop-seeds, that fortify themselves, subsequent costs are low as well as germplasm can be distributed through to the World. This is major aspect of plant-

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breeding through distance and time, which makes the current approach eco-friendly and cost-effective. Once started, consumption and production of nutritionally enriched verities are sustainable, even if international funding and government attention for micronutrient-malnutrition issues fail. Biofortification offers a practical way of providing nutrients to relatively malnourished communities mostly in rural areas. The approach of commercial-food fortification is highly recommended along with biofortification techniques. There is strong need to develop a balance diet plan keeping in view the nutrition requirements. Therefore, the most important solution to eliminate micronutrient malnutrition is to develop the process of biofortification to increase consumption of non-staple foods. But this will take a lot of time, an active government department for creating awareness and relatively a huge investment. To overcome nutritional disorders in less developed areas, a strong interdisciplinary approach between plant scientist and human nutritional diet holds a great impact.

Conflicts of interest

The authors declared that they have no conflict of interest.

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