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Biofortified Cereal Crops: A Sustainable Approach for Food and Nutritional Security

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Authors' contributions

Both the authors designed the study, managed the literature searches, reviewed searched papers, prepared the manuscript in collaboration and read and approved the final manuscript.

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ABSTRACT

Introduction: A stealthier form of deficiency is known as hidden hunger which is caused due to the intake of cheap food and having the characteristic of fulfilness but actually lacked in essential vitamins and minerals. In underdeveloped and developing countries, over 900 million poor people are at a higher risk of hunger, suffered from food insecurity and more than 1 million children died every year.
Aims: To review and study the role of biofortified cereal crops to overcome malnutrition and in food and nutrition security.
Methodology: Agriculture is the key to achievement of self-sufficiency of food grains, but now a days, biofortification becomes a sustainable approach and food based solution to overcome malnutrition even at a low cost. Different research studies and various reports were reviewed to assess the role of biofortified cereal in reducing the risk of malnutrition.
Results: Biofortification is defined as the method of breeding crops to increase and improve nutrient contents of foods including micronutrients and their precursors. Quality protein maize has double the amount of lysine and tryptophan as well as protein bioavailability that rivals milk casein. Biofortified cereals can be used for various purposes such as bakery and convenience foods, emergency ration, health food mixes, infant, snack, specialty and traditional foods and to improve the status of

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food and nutritional security. Prepared value added products results in an increase in food availability, add the variety to foods to make them enrich in essential micronutrients and make them affordable by reducing the price which will help to get rid of poverty as well as hunger.
Conclusion: Biofortified cereals also play an important role in contributing to the country's food and nutritional security specifically to the poor population.

Keywords: Biofortification; cereals; hidden hunger; nutrition security; poverty; quality protein maize.

1. INTRODUCTION

Hidden hunger is defined as a stealthier form of deficiency which is caused due to the intake of cheap food and having the characteristic of fulfilness but actually lacking in important vitamins and other micronutrients [1]. Worldwide, more than 2 billion people suffer from hidden hunger and every year, more than 1 million children (<5 years) die because of vitamin A and zinc deficiency [2]. India ranked position 100th out of 119 countries in the Global Hunger Index calculated by IFPRI [3]. The population who suffered from hidden hunger may look like a healthy, basically they are more susceptible to illness and infections. Now a day, hidden hunger becomes a global problem. At a global level, over 900 million poor people who are living in underdeveloped and developing countries are at a higher risk of hunger and suffer from food insecurity every year. It has been observed that approximately 200 million children in the world are underfed of which at least 5 million die every year due to nutrient deficiency diseases [4]. According to Report [5], both the cause and effect relationship of hidden hunger is poverty and other important factors are unemployment, lack of sanitation facilities and unavailability of safe drinking water. To satisfy basic hunger, poor people consume staple foods. Due to rise in food prices, they cannot afford healthy and nutritive food which is needed for a healthy body. As a result, deprived health status not only reduces the productivity of individual. But it can also void the limited resources of household, community and finally the nation.

Nutritional insecurity is a primary hazard to the population, which is extremely reliable upon cereals based diet in the world. The essential substances present in food are micronutrients including vitamins and essential trace minerals that are required by the human body in small amounts. When the consumption of these bioavailable micronutrients becomes too less which is not sufficient for meeting requirements of the human body, micronutrient malnutrition develops. Deficiency of vitamin A, iron, iodine, zinc and vitamin B12 are the most common forms of micronutrient malnutrition and effects ⅓ to ½ of the world population. Other causes of malnutrition among children are poor mental and physical growth, decreased efficiency to perform various activities among adults, poor pregnancy outcomes and increased the rate of morbidity and mortality mainly in children and women [6]. Malnutrition is a major public health problem in India and affects a large segment of the population especially young children. It is an underlying cause of death of 2.6 million children each year, i.e. one-third of the global total of children's deaths [7]. The percentage of prevalence of stunting, wasting and underweight is 38, 21 and 36 among children in India [8]. Originally research efforts were made on the subject of agriculture for achievement of self-sufficiency of food grains were highlighted. Currently, the opportunity is also stretched to biofortify the main food crops as an approach to make sure nutritional security to minimize the adversities of malnutrition.

2. BIOFORTIFICATION

Biofortification has been derived from the Greek word "bios" meaning "life" and the Latin word "fortficare" meaning "to make strong". It is defined as the method of breeding crops to increase and improve nutrient contents of foods including micronutrients and their precursors. Its main aim is to raise the nutrient concentration in food crops only during growth of plants, not throughout the processing of the crops into foods. Nowadays, more than 20 million people involved in farm households in developing countries are growing as well as consuming biofortified food crops [9,10]. The combination of high yielding and high nutrient crop varieties is referred as biofortified food crops. Various biofortified cereal crops and their target level of nutrients are discussed in Table 1 [11]. There are three approaches of biofortification a) Agronomic practices, i.e. fertilizer application to the soils to increase plants selenium and zinc content b) Conventional plant breeding (increase in iron content in pearl millet and beans, zinc content in rice, maize and wheat, tryptophan and lysine in maize and pro-vitamin A content in maize and sweet potato and c) Genetic modification such as rise in β-carotene in rice and decrease in phytic acid in cereals [12].

Biofortification is actually different from conventional fortification because the main target of biofortification is an increment of nutrients in plant food crops when they are on the growing stage whereas fortification refers to Addition of nutrients in foods while processing. In case of farmers, sustainable approach of biofortification is vital because they can save and share propagation material and seeds with other farmers and also play an important role in the achievement of nutritional security along with complementary strategies such as commercial fortification, dietary diversification and supplementation. Biofortification is cost effective too due to their one time investment in research. Because of increment in germ plasm variability, improvement in quality of crop or plant was also reported. As the provision of nutrients to the body through food, mainly in natural form, matter of toxicity does not generally arise.

Advantage of biofortification is, with the increase in nutritional quality of the daily diets, it will help to overcome malnutrition, improve and maintain nutritional health status of the population even at low cost [13,14]. Pathway for Biofortified food crop is shown in Fig. 1.

2.1 Biofortification and Nutrient Bio-availability

The Population of the world is mainly dependent on three major cereal crops such as wheat, rice and maize that are deficient in essential nutrients. Biofortification can reduce stunting (height-for-age), build up the brain and immune system and lay down the basis for a strong, healthy and productive society. Biofortification is referred as the process of enhancing the nutritional content of food crops as they grow and worldwide, can offer a justifiable solution to reduce malnourishment or starvation by means of provision of bioavailable nutrients. Iron and zinc content as shown in Table 2 [15]. When Millennium Development Goals were established, the term biofortification was in its infant stage. But, at present, in Asia, Africa and Latin America, millions of smallholder farm families have started to grow more nutritious and healthy varieties of staple cereal crops. In various developing countries (approximately 30 in number), biofortified food crops are already being grown and consumed by more than 15 million people and multi-location testing in an additional 25 countries are being performed [16].

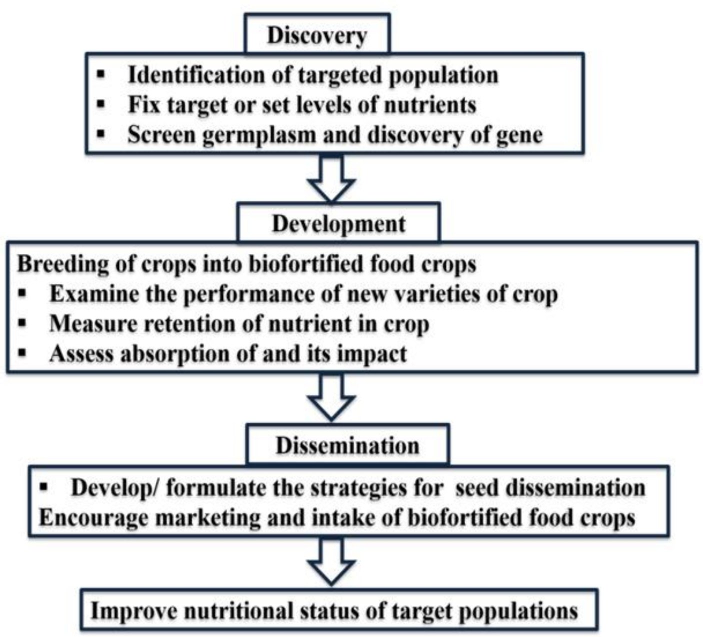

Fig. 1. Pathway for biofortified food crop [17]

Table 1. Biofortified cereal crops for improved human nutrition

Cereals	Released year	Enhanced nutrients	Countries first release	Target level
Wheat	2013	Zinc, iron	India, Pakistan	37 ppm (25 ppm baseline + 12 ppm increment)
Rice	2013	Zinc, iron	Bangladesh, India	28 ppm (16 ppm baseline + 12 ppm increment)
Maize	2012	Pro vitamin A	Zambia	15 ppm (0 ppm baseline + 15 ppm increment)
Pearl millet	2012	Iron, Zinc	India	77 ppm (47 ppm baseline + 30 ppm increment)
Sorghum	2003-2008	Iron, Zinc	India, Mali	Iron: 60 ppm (30 ppm baseline + 30 ppm increment) Zinc: 32 ppm (20 ppm baseline + 12 ppm increment)

Table 2. Mean and range of iron and zinc content in biofortified cereal crops

Cereals	No. of entries	Iron (mg/kg)		Zinc (mg/kg)	
		Mean	Range	Mean	Range
Pearl Millet	515	45.62	19.7-86.4	40.34	13.5-82.4
Wheat	928	39.46	17.5-68.8	41.94	13.5-73.8
Maize	52	27.0	11.3-60	28.4	15.1-53.0
Rice	340	5.4	4.8-44.0	26	9.9-43.7

2.2 Harvest Plus: Better Crops, Better Nutrition

A food based approach of biofortification is providing the nutrient rich food crops to the population who are living under poor conditions to minimize starvation. HarvestPlus is a biofortified challenge program of the Consultative Group for International Agricultural Research.

Since 2004, it has run the responsibility to breed and distribute nutrient dense biofortified food crops. An interdisciplinary program of communication and behavior change experts, economists, molecular biologists, nutritionists and plant breeders is also HarvestPlus. The primary focus of this program is to biofortify important staple food crops, i.e. wheat, rice, maize, pearl millet, beans, cassava and sweet potato with three lacking micronutrients (iron, zinc and vitamin A) targeting the deficient population especially in developing countries along with the cooperation of 200 scientists [18,19]. After an investment of 7 years in nutrition and breeding studies, HarvestPlus started to distribute biofortified food crops in different nine distinct countries. Breeding targets for different age groups such as preschool children (4-6 years), non-pregnant and non-lactating women of reproductive age groups are fixed according to HarvestPlus program. Initially, iron bioavailability was expected to be 5 percent for wheat, maize, pearl millet and beans and 10 percent for cassava, rice and sweet potato. Similarly for all staple food crops, zinc and Provitamin A bioavailability was 25 and 8.5 per cent. The amount of target level increment will provide iron, zinc and provitamin A nearly 30, 40 and 50 per cent of Estimated Average Requirement [20].

2.3 Initiatives in India for Biofortification

In the budget (2013-14), United Progressive Alliance (UPA) government drew a proposal to establish ‘Nutri-farms’ in India, where maize (rich in lysine and tryptophan), wheat and rice (rich in zinc) and pearl millet (rich in iron) will be grown. According to this plan, most affected malnourished districts (200) of India were selected to channelize ‘Nutri-farms’. In India, attainment of high quality research and fasten growth of biofortified crop varieties was possible with the joint efforts of the Indian council of Agricultural Research and Department of Biotechnology (DBT). A long standing scheme/project of the DBT is the India Biofortification Program (IBP), which extremely focuses on wheat, rice and maize and

HarvestPlus program works as a collaborator in the development of the above said cereal crops. HarvestPlus performed teamwork with ICRISAT to provide emphasis in the development of biofortified pearl millet and sorghum [21].

2.4 Biofortified Cereal Crops For Nutritional Security

2.4.1 Wheat

Plant foods constitute major part of the diet of the people of the developing nations which cannot be relied upon for providing a nutritionally adequate diet. Cereals play a significant role in the diet of humans as an important source of food and generally contain poor quality protein and the bioavailability of micronutrients present in them such as iron, zinc, iodine and vitamin A is very low [22]. Population who are consuming only cereal based diets which are lacking in essential micronutrients lead to negative impact on human health and ultimately result in malnutrition. The key micronutrients (iron, zinc and provitamin A) are necessary for the functional and structural integrity of biological structure. Worldwide, its deficiency troubles billions by destroying the immune system and hindering growth and development. To mitigate the status of malnutrition, enhancement of zinc in wheat (*Triticum aestivum L.*) varieties was done with the help of genetic variability in the germplasm but it would be possible only, when the condition of soil has an adequate zinc pool for its absorption. Results revealed that some varieties from India (BHU 19, 17 and 1) and from Pakistan (NR 421, 420 and 419) showed increase in zinc content ranging between 4 to 10 ppm. The use of zinc fertilizer along with the pesticide helpful in controlling yellow rust in wheat. Particularly, in severe zinc lacking soil areas, an immediate rise in concentration of zinc and production of wheat grain was noticed with the use of Agronomic biofortification strategies [23]. Similarly, there was an increase in the yield of wheat upto 6.4 to 50.1 per cent with application of zinc as a fertilizer in soil. Therefore, first approach of biofortification i.e. agronomic biofortification could be considered as economical, especially when used with a fungicide dependent upon the presence of a disease [24].

Cereals are not the chief sources of selenium on the basis of content, but on a dietary basis, they are possibly the main contributors to consumption. Agronomic biofortification with adequate amount of selenomethionine may possibly increase the nutritive value of wheat grains and becomes an attractive choice for improving the status of selenium in diets. Sodium selenate and selenite was added to bread wheat and durum wheat through the addition of soil and foliar at a rate of 100 g/hectare of field. Total selenium content ranged between 70 to 100 per cent among samples and inorganic selenium present was less than 5 per cent. Similar results were recorded for all wheat varieties supplementation methods [25].

2.4.2 Rice

In developing world, ingestion of biofortified rice is valuable in improving iron stores among the women with poor dietary iron intake. A study was conducted with 192 Filipino women who were selected from 10 convent schools from the Philippines and feeding trail was done in the period of 9 months. Experimental subjects were provided with high iron rice (3.21 mg/kg Fe), whereas subjects of the control group were fed local variety rice (0.57 mg/kg Fe). Along with this, daily intake of food was recorded. Results showed that biofortified rice and control rice contributed to 1.79 and 0.37 mg iron per day to the diet. There was a 17 per cent difference in consumption of total dietary iron as compared to control which lead to a modest increase in total body iron (P=.06) and serum ferritin (P=.10) but hemoglobin level did not increase. Though, a greater response for body iron and ferritin was observed in non-anemic women who had taken high iron rice [26]. An Increase in the yield of rice was upto 7.2 to 14.8 per cent using an agronomic biofortification approach (application of zinc as a fertilizer in mineral deficient soil) [24].

2.4.3 Golden rice

It was first invented in 1999 by two Professors of Germany (Professor Ingo, Potrykus, Institute of Plant Sciences, Swiss Federal Institute of Technology and Professor Peter Beyer, University of Freiburg). Both of them inserted bacterium and genes from daffodil to rice for development of golden rice prototype that can produce beta carotene. In 2005, Experts used genes from a common soil m/o and maize to develop the golden rice (current version) having approximately 20 times extra beta carotene than prototype in 1999. From 2006 to 2010, after selection of the main result of the current version of golden rice, progressed to the following phase of Research and development. Then conveyed to RRI, Philippines (Rice Research Institute) and in another places to start with the breeding of chief Asian varieties of rice to golden rice. From 2010 till date, field trials were conducted in limited and multi-location area helped the breeders to develop new varieties of golden rice, which maintain the same quality of grain, their yield and resistance to pest. Further, environmental and other type of data was generated using various field tests and other estimations that will help to evaluate the safety of golden rice [27]. Random selection of 68 children in the age group of 6 to 8 years was done. They were given β-carotene in golden rice or spinach or in an oil capsule was considered as experimental while the reference dose of Retinyl acetate in an oil capsule was provided. In comparison to reference dose of retinyl acetate (0.5 mg), conversion of β-carotene to retinol in pure form, golden rice and spinach from 0.5, 0.6 and 1.4 mg to 2.0, 2.3 and 7.5 by weight after 1, 3, 7, 14, and 21 days, respectively. It was noted that an amount of 50 g (dry weight) golden rice (cooked amount will be approximately 100 to 150 g) may deliver around 60 per cent vitamin A of the RNI (Recommended Nutrient Intake) among Chinese children. Hence, it is proved that β-carotene in golden rice is as good as pure β-carotene in oil and also helpful for providing vitamin A to children [28].

Data were collected from a total of about 8 efficacy (6) and effectiveness (2) trails and assessed the impact of daily intake of biofortified staple food crops in improving iron and vitamin A status. Among the population residing in Latin America, South Asia and Sub-Saharan Africa, falling the action of deficiencies of micronutrient were also recorded. Intake of biofortified maize on a regular basis, significantly improved serum β-carotene concentrations among marginally deficient population, but no superfluous improvement was found in status of vitamin A level. Further, children who have taken orange maize in their diet showed improvement in visual function. On the other hand, Positive impact of interventions of biofortified iron was observed among persons who were deficient in iron at the initial stage. A significant improvement in iron status, including hemoglobin, serum ferritin concentrations and total body iron and enlarged the probability to resolve the issue of iron deficiency. It was concluded that biofortified staple food crops act as a complementary intervention to control and prevent vitamin A and iron deficiency and also help to improve functional outcomes such as brain activity, cognitive performance and physical activity [10].

2.4.4 Pearl millet

After staple cereals, a major source of energy is millets especially in drought prone regions and semi-arid tropics of Africa and Asia. As the grains of millets contain large amount of proteins, essential amino acids, vitamins and minerals, these are called as nutritious superior grains. ICRISAT in support with HarvestPlus, introduced early matured biofortified pearl millet known as *Dhanashakti*. Expert of HarvestPlus said that those existing farmers whose nutrient intake is less are principally targeted so that biofortified millet were provided to them to overcome starvation. Some clinical studies showed that 300 gm of Dhanashakti is sufficient to meet 100 per cent RDA (Recommended Dietary Allowance) for iron [29, 18]. Selection of 40 children in the age group of 2 years from Karnataka, India was done and divided into two groups, i.e Test (21) and control (19). Supplementation of 3 test meals containing dry pearl millet flour (around 84 ± 17 g) for one day of zinc and two days for iron and absorption of these two nutrients was measured. Absorption of iron and zinc from test groups were 0.67 ± 0.48 and 0.95 ± 0.47 mg/d, whereas among the control group, the corresponding values were 0.23 ± 0.15 and 0.67 ± 0.24 mg/d. Feeding of iron and zinc biofortified pearl millet concluded that statistically significant results were useful for meeting the physiological requirements of children of test group [30]. Similarly, [31] conducted a study with 246 children in the age group of 11 to 18 years for a period of 6 months. Biofortified pearl millet was provided to an experimental group on a daily basis, but control group was not given any supplementary. Anthropometric and iron status was determined at an interval of 3 and 6 months. Before supplementation, about 28 per cent of subjects were anemic and 41 per cent were having a serum ferritin level was less than 15.0 µg/L. After supplementation of 3 months, a positive and statistically significant impact was found regarding serum ferritin. When compared with the control group, 65 per cent of the subjects of experimental group did not show iron deficiency. After 6 months of intervention, two-fold increase was observed.

2.4.5 Maize

Worldwide, sixth largest producer of maize (*Zea mays*) is India, which is contributing 2 per cent of the production globally. Maize production revealed a significant increase of about 16 per cent over the production of the year 2015-16 i.e.

estimated production in 2016-17 will be 25.3 million tonnes [32]. The third leading cereal after wheat and rice is maize and forms a substantial part of poultry feed (49%), followed by human food (25%), animal feed (12%), industrial products (12 %), brewery (1%) and seed (1%) [33]. Only 30–40 per cent of maize production is used for human consumption and the majority (60–70 per cent) is used as livestock feed domestically [34]. Andhra Pradesh, Bihar, Himachal Pradesh, Karnataka and Punjab are most important maize growing states. It is the staple food for more than 200 million people and provides 15 per cent of protein and 20 per cent of calories from diet [4]. Maize produced in India is processed into many types of products such as breakfast cereals, cornmeal, flour, grits, snacks starch and tortillas. Maize flour is widely used to make *chapatis* or flat breads in a few Northern states of India [35]. Three portions of maize porridge (250 g) with the addition of sunflower oil (8 g) were given to 6 healthy women. a) Biofortified maize porridge (527 µg total β-carotene) b) White maize porridge (595 µg β -carotene) c) White maize porridge with vitamin A (286 µg retinol activity corresponding to added retinyl palmitate). These three portions were separately consumed in random order for more than two weeks and collection of blood samples over 9 hours was done. It was observed that β-carotene rich biofortified maize porridge contained 6.48 µg of β-carotene while the reference dose of white maize porridge contained 2.34 µg of β-carotene which is equal to 1 µg retinol. As a plant source of vitamin A, biofortified maize along with β-carotene showed a highest bioavailability [36]. β-carotene in yellow maize is an operative source of vitamin A. Consumption of 300 g cooked porridge made from yellow maize (1.2 mg of β-carotene), along with added butter (20 g) and capsule of corn oil (0.5 g) exhibited the similar activity of vitamin A as retinol (0.38 mg) among eight healthy Zimbabwean men. When compared with the RDA, it contributed 40 to 50 per cent of adult vitamin A requirement [37].

2.4.6 Quality protein maize (QPM)

The nutritional profile of QPM has been improved with the help of the conventional breeding techniques, therefore, it is said to be a biofortified food and its comparison with other nutrients are shown in Table 3 [38]. Originally, The International Maize and Wheat Improvement Centre (CIMMYT), Mexico developed a quality protein maize (QPM) in the late 1990s, which is nutritionally superior over the normal maize [39]. In 1914, two scientists, T B Osborne and L B Mendel recorded deficiency of lysine and tryptophan in maize kernel protein. In view of above said statement, Dr Howard Jones revealed the opaque-2 *(o2),* first high lysine mutant and Mumm testified *floury-2* (*fl2*) which is second mutant required for change in composition of amino acid in 1935. In 1964, two investigators of Purdue University, Edwin Theodore Mertz and Oliver E. Nelson reinvented Opaque-2 (a recessive mutant) that produce enriched lysine and tryptophan levels. Protein in QPM has 55 and 30 per cent more tryptophan and lysine and 38 per cent less leucine than that of normal maize and biological value of its protein is just double (80%) than that of normal maize protein (40-47%) which is equivalent to milk protein casein i.e. 90 per cent [40]. Comparison in composition of essential amino acid content between regular maize and quality protein maize grain was shown in Table 5 [41]. There are nine hybrid varieties of QPM having different grain color developed and released for cultivation in different agro-climatic regions of India [38]. Released important cultivars of quality protein maize for commercial cultivation in India are shown in Table 4 [42,39]. It has an increased biological value despite its normal tastes and looks. Potassium and carotene content of QPM has a higher absorption rate along with higher concentration of niacin (vitamin B_3) which make it nutritionally better variety.

A study was conducted to evaluate acceptance of consumer for three different QPM variety based products such as Githeri, Injera and Ugali to be available in three different East African countries such as Kenya, Ethiopia and Tanzania. Sensory evaluation using 'Likert scale' was done by selecting men and women living in rural and urban areas (N=281) who are having different level of education. Results revealed that among acceptance of QPM based products, no barrier was there. On the contrary, when compared with its worthy agronomic performance, it may benefit to its application which leads to a positive effect among nutritionally vulnerable population [43]. Similarly, [4] added quality protein maize in traditional foods (*Idli*, *Dosa*, *Pittu* and *Adai*), convenience foods (*Papad* and Noodles), bakery foods (Cookies and Bread) and snack foods (*Vada* and *Pakoda*) in different proportions. Organoleptic evaluation of formulating foods was done with the help of 9 point hedonic scale. It revealed that quality protein maize based *dosa*, *adai*, *vada* got the highest scores (8.6± 0.56) and cookies and bread got the lowest score (8.1± 0.34). High calorie and protein content were found by *vada*, *pakoda* and cookies, whereas the value added recipe of noodles, which contained higher protein and fiber and could be stored for a longer period.

Table 3. Comparison of nutritional composition of quality protein maize with other staple cereal grains

Nutrients	Quality protein maize*	Maize**	Wheat**	Rice**
Moisture (%)	7.90	9.26	10.58	9.93
Protein (%)	9.72	8.80	10.59	7.94
Fat (%)	4.85	3.77	1.47	0.52
Ash (%)	1.50	1.17	1.42	0.56
Carbohydrate (%)	73.98	64.77	64.72	78.24
Energy (Kcal/100g)	378.6	334.13	322.0	356.3
Potassium (mg/100g)	361.9	291	366	108
Calcium (mg/100g)	23.7	8.91	39.36	7.49
Zinc (mg/100g)	14.45	2.27	2.85	1.21

*Source: * [38], ** [44]*

Table 4. Released important cultivars of quality protein maize for commercial cultivation in India

Name	Year of release	Maturity group	Centre's name
Shakti	1970	Full season	AICRP
Rattan	1970	Full season	AICRP
Protina	1970	Full season	AICRP
Shakti 1	1997	Full season	DMR
Shaktiman 1	2001	Full season	Dholi
Shaktiman 2	2004	Full season	Dholi
HQPM 1	2005	Full season	Uchani
Shaktiman 3	2006	Full season	Dholi
Shaktiman 4	2006	Full season	Dholi
HQPM 5	2007	Full season	Uchani
HQPM 7	2008	Full season	Uchani
Vivek QPM 9	2008	Extra early	Almora

Table 5. Composition of essential amino acid content in quality protein maize grain and regular maize (g/100g protein)

Amino acid	Quality Protein Maize	Maize
Lysine	4.0	2.0
Histidine	4.0	2.8
Argininge	6.3	3.8
Threonine	3.6	3.5
Serine	4.3	5.2
Tyrosine	3.3	5.3
Proline	10	9.7
Glycine	4.5	3.2
Valine	5.2	4.7
Methionine	1.8	2.8
Isoleucine	3.3	3.8
Leucine	9.6	14.3
Phenylalanine	4.9	5.3
Alanine	6.0	8.1

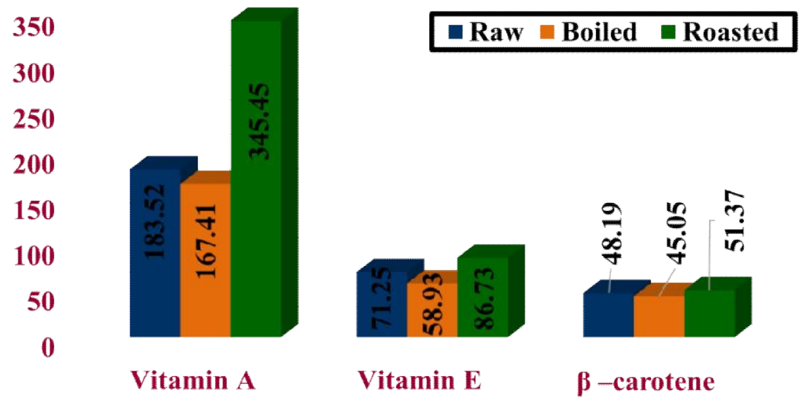

Fig. 2. Vitamin contents of raw and processed quality protein maize (in µg/100g) [45]

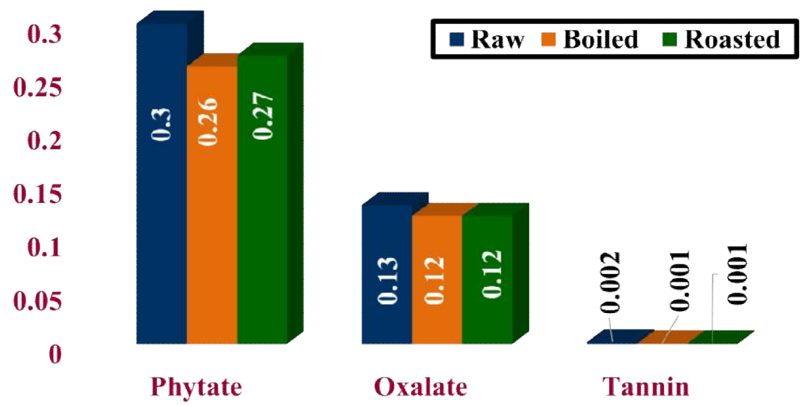

Fig. 3. Percentage composition of anti-nutrient factors of raw and processed quality protein maize [45]

Quick cooking convenience (QCC) products (instant corn soup mix -QSM, instant corn curry mix-QCM, instant corns-Q, multipurpose corn mix-QM) using quality protein maize (HQPM 1) was formulated and compared with similar products made using common maize variety i.e. *Pratap Makka*-3. The products were evaluated organoleptically and were analyzed for proximate composition, lysine and tryptophan, in vitro protein digestibility and also assessed the shelf-life. The overall scores were less than 8 or 9 and well accepted among all the standardized four products. Among the proximate composition, moisture and fat content was highest in instant corns and multipurpose corn mix, but the lowest among instant corn soup mix and instant corns, respectively. Regarding ash, crude fiber and carbohydrate contents, highest among instant corns followed by instant com curry mix, instant com soup mix and multipurpose com mix. Lysine and tryptophan content among standardized recipes were 3.56 and 3.54 (QSM), 0.81 and 1.54 (QCM), 3.53 and 3.69 (QM) and 1.54 and 1.89 (Q) g/100g, respectively, whereas the corresponding values for normal maize based products were 1.62 and 1.56, 0.35 and 0.41, 1.54 and 1.89 and 0.39 and 0.48 g/100g, respectively. The in vitro protein digestibility values were ranging between 64.0 and 74.0 per cent for both HQPM 1 and *Pratap Makka*-3 based product. Visually QPM based QCC products were highly acceptable throughout the whole study period but a slow increase in free fatty acid contents, moisture and peroxide value was observed. The study concluded that shelf stable, sensory acceptable and convenient in cooking QPM based products can help to combat the long term problem of malnourishment without performing any change in the dietary habits of the population [46].

Quality protein maize based *ladoo* was prepared using QPM, ragi, whole green gram, amaranthus and gingelly seeds and were analyzed for their nutritional content before and after processing. It was observed that the percentage of ash, crude protein, fat, crude fiber, carbohydrate, sugar and starch, calcium and iron was increased after processing, while reduction among moisture content was noticed by 82.7 per cent [47]. Quality protein maize as diminishing the protein inadequacy gap among vulnerable African children was reviewed. Maize was consumed for 30 per cent of energy and protein daily. So, quality protein maize was tested for decreasing malnutrition. It had high lysine and tryptophan content which helps in balancing amino acid profile. 23.8 g of maize/kg body weight provides an equivalent protein that is provided by the 7.6 g of quality protein maize/kg body weight. Quality protein maize contained high beta carotene content which will help in combating malnutrition. So substituting quality protein maize from common maize will provide more niacin content, more absorption of beta carotene etc. which helps in reducing malnutrition among children. An amount of 100 g/d of quality protein maize for children was required to maintain lysine content, the most limiting amino acid [48].

Two randomized and controlled studies of one year duration were conducted to assess the effect of quality protein maize to improve the nutritional status among 151 children aged 5 to 29 months in the first study and 211children aged 7 to 56 months in the second in the western Ethiopian highlands. Half of the households were provided with quality protein maize and the other half were provided with an improved conventional maize seed variety in both studies. In the first study, the children in quality protein maize group had a decreased weight-for-height but they recovered from it. No positive effect was found for height. In the second study, children who consumed conventional variety of maize had a lower growth in height, whereas children in QPM group did not show any significant change in their height for- age but their weight-for-age marginally increased [49]. QPM or conventional maize based snacks was supplemented to randomly select 48 malnourished children (1 to 5 years) from Nicaraguan day care center for five days per week for a period of three and half months. Results revealed that supplementation of quality protein maize based snacks positively influence growth of children. After supplementation, mean height and weight was increased by 2.02 cm and 0.80 kg among QPM group and for the conventional maize group, the increment was 1.23 cm and 0.19 kg. Further, improvement in Z score for height for age and weight for age was 0.06 and 0.17 among QPM group, whereas the corresponding values for conventional group was -0.23 and -0.26 Z. However, no impact was observed in the occurrence of respiratory infections and episodes of diarrhea with the use of QPM based snack [50].

3. CONCLUSION

A sustainable, long term and food based solution was offered by biofortification which will positively influence billions of world population in the future. This approach becomes a double challenge for researchers or scientists to develop more biofortified food crops. Therefore, they are looking for sustainable solutions to provide staple food crops enriched with essential micronutrients and other nutrients to fulfill all the physiological needs of the poor. To ensure a more nourishing future, investment in biofortification is a cost-effective approach. Quality protein maize would play an important role in contributing to the country's food and nutritional security, specifically to the poor population who are consuming maize as a staple food. It can be used for various purposes such as bakery and convenience foods, emergency ration, health food mixes, infant, snack, specialty and traditional and foods to improve the status of food and nutritional security. And also helpful in fulfilling the requirements of protein among vulnerable population mainly infants, lactating mothers and old persons to prevent them from malnutrition. Prepared value added products results in an increase in food availability, add variety to foods enrich them in essential micronutrients and make them affordable by reducing the price which will help to get rid of poverty as well as poverty.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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