

Review

The role of biofortification in the reduction of micronutrient food insecurity in developing countries

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Micronutrient malnutrition is a global public health problem, especially in developing countries. Hunger and starvation which are causative agents of malnutrition are occasioned by poor food supply and low income purchasing power for the expensive animal sources of micronutrients. Access to adequate, safe and nutritious food required for a healthy and active life by all people at all times is limited, resulting in micronutrient food insecurity. The quantity and quality of food available for consumption to people determine their micronutrient security level. Inadequate quantity and quality of food available for consumption are causative agents for macronutrient and micronutrient deficiencies. Bio-fortification is an emerging method to increase the micronutrient values of crops in order to eradicate hidden hunger in developing nations. This paper therefore describes the contribution of biofortification in fighting micronutrient malnutrition in developing countries.

Key words: Micronutrient food insecurity, biofortification, developing nations, Micronutrients.

INTRODUCTION

Food insecurity and malnutrition in developing nations is an issue of global concern (IELRC, 2010). The global population size is currently 6 billion, and it is rising rapidly. The United Nations estimates that the world's population will grow to reach 8.1 billion by 2030 (InfoResources, 2006). In 2007, the number of hungry people in the world was said to have increased by 75 million because of rising food prices (FAO, 2008a). The world's hungry people are put at 963 million (Ruane, 2010). Meeting global food requirements at that point will necessitate an increase in production by 50%. If natural resources are continually used the way they are today, they will not suffice to fuel this increase (InfoResources, 2006).

Developing nations are having challenges of provision of adequate food for their population. For example, Nigeria is in dire need to feed its teeming population of

140 million that is increasing at an annual rate of at least 2% (Egesi, 2010). Poverty, hunger, starvation and malnutrition are grossly prevalent in developing countries. The rate of urbanization is very high in Nigeria. Many youths are rushing to mega cities in search of white collar jobs yet the jobs in these cities are not enough to go round due to population explosion, for example in Lagos state, many youths have resorted to riding a tricycle called "Okada" to make ends meet due to lack of job. At the end, they resort to riding "Okada" which is becoming a road menace despite the alternative means of transportation they provide. Yet these are the productive men that can engage in farming in the rural areas where we have arable farm lands. In urban Nigeria and most of Sub-Saharan Africa, employment in sectors that pay regular wages, such as manufacturing industries, accounts for less than 10% of total employment (Rondinelli

and Kasarda, 1993). The population of many villages now is made up of aged men and women who cannot farm. If they do at all, they maintain small farms around their compounds. So what is going on in most Nigerian villages is subsistence farming and not commercial farming and that can only feed a household and not a population. Even the few farm produces that are available are transported to the urban areas where they will yield more money for the farmer. This makes the left over farm in the villages expensive, sometimes more than what the prices are in the towns. Even the farm produces are not enough for the teaming populace in the urban areas due to over population. Due to the high population of urban areas most of the available lands for farming are inhabited including swamps and canals that would have been viable for local rice farming and vegetables.

Consequently, there is a growing incidence of hunger and malnutrition both in the rural and urban areas even though the former is worst hit. Both rural and urban poor people suffer from food insecurity and poor nutrition, caused in large measure by poverty and lack of nutritional balance in the diet they can afford (Tonukari and Omotor, 2010). Hunger and starvation are some of the reasons why some people are sick in many developing countries. It becomes imperative to increase farm yields in terms of quantity and quality to be able to ameliorate the pang of hunger and starvation in the country. Biotechnology which aims at increasing crop yield, early maturation of farm produces and enriching crops, livestock and fisheries with macro and micro nutrients is one way of eradicating malnutrition in developing nations.

The Nigerian Senate enacted the Biosafety Bill into law on June 1, 2011, after several years of stakeholders' discussion and debate (Ebegba and Gidado, 2011). The passing of the bill is a major step towards the safe and responsible use of biotechnology crops in the country.

CONTRIBUTION OF BIOTECHNOLOGY IN FIGHTING MICRONUTRIENT MALNUTRITION

Biofortification is the genetic or agronomic breeding of crops to enhance their nutritional composition (Uchendu, 2012). Commercial cultivation of genetically modified (GM) crops has been in existence since 1996. About 22 countries are growing GM crops. These include USA, Argentina, Brazil, Canada, China, Paraguay, India, South Africa, Uruguay, Australia, Mexico, Romania, the Philippines, Spain, Colombia, Iran, Honduras, Portugal, Germany, France, Czech Republic, and Nigeria.

Genetic modification technology can boost yields of crops such as cassava, potato, yam and maize, provide resistance to pests and diseases, improve crops' nutritional content and increase their shelf life (Bimbo, 2011). Currently, the most widespread GM crops in the market

are genetically modified varieties of soy, maize, cotton, and canola. An analogous GM rice variety was planted for the first time in 2005, in Iran (InfoResources, 2006). Maize is the most widely-consumed staple food crop in Zambia, but the regular white variety lacks micronutrients, and nearly 50 percent of Zambian children under five suffer from vitamin A deficiency. The improved maize varieties released by HarvestPlus in Zambia can meet up to 25 percent of daily vitamin A needs of the children (Okello, 2013).

Presently, Nigerian scientists and partners are conducting field trials on genetically modified cowpea and cassava (Flake and David, 2010; Ebegba and Gidado, 2011). These are among the important major staple crops in Nigeria and Sub-Saharan Africa as a whole. Table 1 shows the type of genetically modified crops that are being researched upon in various countries. Successful research and development on these crops will result in plenty quality foods and low level food insecurity in developing and some developed countries.

NUTRITIONAL CONTRIBUTION OF GENETICALLY MODIFIED FOODS (GMFS)

Eventual availability of genetically modified (GM) crops into the market will reduce food prices, create variety and plenty food for people to eat in terms of calorie. This will lead to national, state and household food security thus, preventing macro- and micro-nutrient food insecurity. Biotechnology crops only appeared in the market six years ago (James, 2001). Subsequent dates for release of more bio-fortified crops by Harvest Plus are as shown in Table 2.

Biofortified cassava released in Nigeria by the Nigerian National Varietal Release Committee, the vitamin A cassava varieties are named UMUCASS 36, UMUCASS 37, and UMUCASS 38; and are recognized as IITA genotypes TMS 01/1368, TMS 01/1412, and TMS 01/1371, respectively (Obinna, 2012). They can provide upto 25% of the EAR for women and preschool children (Bouis, 2003). Varieties of biofortified orange-fleshed sweetpotato were introduced in Mozambique and Uganda in 2002 and 2007 (Bouis, 2012). Provitamin A maize varieties that can provide up to 25 percent of the EAR for adult women and preschool children were released in Zambia and Nigeria in 2012. Large-scale delivery will begin in 2013. Varieties that can provide up to 50 percent of the EAR are in testing (Bouis et al. 2013).

1. High iron beans have been released in Rwanda and DRC; varieties that can provide an additional 30 percent of the iron EAR for women and preschool children are being disseminated to 250,000 households.
2. High zinc rice is in varietal release testing in Bangladesh and India. Candidate varieties would provide 25% of the

Table 1. GM crops being researched upon in developing countries.

Country	Research area
People's Republic of China	Rice, cotton, maize, wheat, and vegetables
India	Rice, maize, cotton, citrus, coffee, mangrove, vanilla, and cardamom
Indonesia	Rice, cassava, maize, cotton, soybean
Malaysia	Rice, papaya, orchid, chili, rubber, and oil palm
Pakistan	Rice, cotton, and chickpea
Philippines	Rice, maize, coconut, mango, and papaya
Thailand	Rice, shrimp, cassava, dairy cows, fruits, and vegetables
Vietnam	Rice, maize, potato, sweet potato, cassava, soybean, sugarcane, and cotton
Nigeria	Cowpea, maize and cassava
Asia	Rice, tropical maize, wheat, Sorghum, millet, banana, cassava, groundnut, oilseed, potato, Sweet potato, and soybean.

Zhang (2000), Sharman (2000), Dart et al. (2001), Nair and Abu Bakar (2001), Zafar (2001), de la Cruz, (2000), Tanticharoen (2000), Tuong-Van Nguyen (2000).

Table 2. Release dates for biofortified crops by HarvestPlus.

Crop	Nutrient	Country	Year
Sweet Potato	Vitamin A	Uganda, Mozambique	2007
Cassava	Vitamin A	DR Congo, Nigeria	2011
Bean	Iron	DR Congo	2012
Pearl millet	Iron	India	2012
Maize	Vitamin A	Zambia, Nigeria	2012
Rice	Zinc	Bangladesh, India	2013
Wheat	Zinc	India, Pakistan	2013

Levitt (2011).

zinc EAR for women and preschool children.

3. High zinc wheat is being testing in multilocation trials in both India and Pakistan and the first release is expected in India in 2013 (Bouis, 2003).

Biotechnology's ability to eliminate malnutrition and hunger through production of crops resistant to pests and diseases, having longer shelf-lives, refined textures and flavours, higher yields per units of land and time, tolerant to adverse weather and soil conditions, and generate employment, cannot be over-emphasized (Tonukari and Omotor, 2010). Cassava and white maize are high in carbohydrates but lacks essential micronutrients such as vitamin A.

GM crops have been used to give increased nutritional values to staples. Many of them have been loaded with vitamins and minerals used in fighting 'hidden hunger'. *Hidden hungers* are as a result of lack of vitamins and mineral needed by the body for physiological functions. Hidden hunger can result in micronutrient deficiencies

like vitamin A deficiency, Iron deficiency, zinc deficiency, etc. Biotechnology can be used to alter conventional crop varieties to enhance their micronutrient and protein contents (Mitchell, 2001).

Biofortification provides a truly feasible means of reaching malnourished populations in relatively remote rural areas, delivering naturally-fortified foods to population groups with limited access to commercially-marketed fortified foods that are more readily available in urban areas (Bouis, 2003).

BIOFORTIFICATION OF CROPS WITH VITAMINS AND MINERALS

Vitamin A

Vitamin A is a fat-soluble vitamin playing an important role in vision, bone growth, reproduction, and in the maintenance of healthy skin, hair, and mucous membranes



Figure 1. Yellow-colored biofortified cassava reveals the β -carotene content. Howe; Maziya-Dixon and Tanumihardjo (2009).



Figure 2. Golden Rice.

(FAO/WHO 2002). Vitamin A deficiency (VAD) is a global public health problem in 118 countries, especially in Africa and South-East Asia (Rostami et al., 2007). Vitamin A deficiency is the most common cause of childhood blindness. It is estimated that 228 million children are affected and 500 000 children become partially or totally blind every year as a result of vitamin A deficiency (WHO/FAO, 2003). The geographical areas most affected by vitamin A deficiency are tropical areas where cassava is a staple crop, for example, Brazil, Africa, and Asia (Shrimpton, 1989). Bio-fortification of staple crops with pro-vitamin A carotenoids is an emerging strategy to address the vitamin A status of the poor (Tanumihardjo, 2008; Tanumihardjo et al., 2008).

Bio-fortification breeds crops that are loaded with vitamins and minerals in their seeds and roots. A new approach also supported by the Gates Foundation, World

Bank and the European Commission is Harvest Plus, a biofortification program of the Consultative Group on International Agricultural Research. Netherland is taking a leading role here. An example is Golden rice (Figure 2), a bioengineered pro-vitamin A enriched rice in India, Philippine and Brazil. Up to 73% of energy intake in Asian countries can be from rice. Rice is a staple food in most West African countries, enjoyed by both children and Adults e. g Nigeria. So enrichment of rice with vitamin A has the potential to increase vitamin A intake of vulnerable groups in developing countries. It was suggested that vitamin A contribution from golden rice will provide 50% of the RDA. Biofortification of rice with iron, zinc and lutein are possible. Many research Institutes are developing Golden rice which will have higher vitamin A and iron contents (Mitchell, 2001). Genes are being inserted into rice to make it produce beta-carotene, which the body converts into vitamin A (FAO, 2010). This Golden rice is capable of reducing vitamin A deficiency, anaemia and zinc deficiency which causes childhood and maternal mortality and morbidity. Golden rice was developed by researchers in Germany and Switzerland in 1990s with financial assistance from Rockefeller Foundation (Mackey, 2002). This technology has been transferred to India, South East Asia, China, Africa, and Latin America.

More than 250 million Africans rely on the starchy root crop cassava (*Manihot esculenta*) as their staple source of calories. A typical cassava-based diet, however, provides less than 30% of the minimum daily requirement for protein and only 10 to 20% of that for iron, zinc, and vitamin A (Sayre, 2011). Carotenoid-rich yellow and orange cassava may be a foodstuff for delivering provitamin A to vitamin A depleted populations (Figure 1). Biofortified cassava could alleviate some aspects of food insecurity in developing countries if widely adopted (Montagnac et al. 2009)). Cassava is a target for biofortification because of its importance as a staple crop. It is a staple food and animal feed in tropical and subtropical Africa, Asia, and Latin America. Approximately 500 million people depend on it as a major carbohydrate (energy) source, in part because it yields more energy per hectare than other major crops (Table 3). Cassava is grown in areas where mineral and vitamin deficiencies are widespread, especially in Africa. While cassava was first introduced into Africa (Congo) by Portuguese traders from Brazil in the 16th century, maize was introduced into Africa in the 1500s. These two crops are staple foods in most African countries. Cassava is the primary food staple consumed in the Democratic Republic of Congo (D.R. Congo) and in the humid forest zones of Nigeria. While recent nutritional data are not available for D.R. Congo, a 1998 national nutrition survey indicated that the prevalence of low serum retinol among children 6 to 36 months of age was a tragic 61% (Harvestplus, 2012). In Nigeria, the prevalence of vitamin A deficiency in pre-school children is 29.5%. In both countries, cassava

Table 3. Maximum recorded yield and food energy of important tropical staple crops.^a

Crop	Annual yield (tons/hectare)	Daily energy production (kJ/hectare)
Fresh cassava root	71	1045
Maize grain ^b	20	836
Fresh sweet potato root	65	752
Rice grain	26	652
Sorghum grain	13	477
Wheat grain	12	460
Banana fruit	39	334

^aAdapted from EL-Sharkawy (2003); ^bAll grains reported as dry. Montagnac, J. A., Davis, C. R. and Tanumihardjo, S. A. (2009).

could be a highly effective delivery channel for provitamin A to populations at risk of vitamin A deficiency. HarvestPlus estimates that 10 years after the release of vitamin A fortified cassava, 20 million people in D.R. Congo, and 5 million in Nigeria, will be consuming provitamin A-rich cassava. Cassava is a major carbohydrate staple in Nigeria. It is used in making different delicacies such as eba/garri, fufu/akpu, abacha, etc. The average provitamin A content of cassava is 0.5 ($\mu\text{g/g}$) and HarvestPlus targeted value after biofortification is 15.5 ($\mu\text{g/g}$). This will provide about 7,750 $\mu\text{g RE/kg}$. Other African countries that are targeted to benefit from this improved vitamin A content of cassava are Republic of Congo, Central Africa Republic, Gabon, Cameroon, Benin, Togo, Ghana, Côte d'Ivoire, Guinea Conakry, Guinea Bissau, Liberia, Sierra Leone, and Angola.

The importance of biofortification of cassava can be seen in its wide production and consumption across African countries. Currently, about half of the world production of cassava is in Africa. Cassava is cultivated in around 40 African countries, stretching through a wide belt from Madagascar in the Southeast to Senegal and to Cape Verde in the Northwest. Around 70 percent of Africa's cassava output is harvested in Nigeria, the Congo and Tanzania (IFAD and FAO, 2000). Throughout the forest and transition zones of Africa, cassava is either a primary staple or a secondary food staple.

Cassava is a primary food staple in the Republic of Congo and secondary food staple in Côte d'Ivoire and Uganda (Nweke, 2012). Maize is the most important cereal crop in Sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (IITA, 2009). Worldwide consumption of maize is more than 116 million tons, with Africa consuming 30% and SSA 21%. However, Lesotho has the largest consumption per capita with 174 kg per year. Eastern and Southern Africa uses 85% of its production as food, while Africa as a whole uses 95%, compared to other world regions that use most of its maize as animal feed. Ninety percent of white maize consumption is in Africa and Central America (IITA, 2009). A marginal nutrient status increases the risk of

morbidity and mortality. Therefore, improving the nutritional value of cassava could alleviate some aspects of hidden hunger, that is, subclinical nutrient deficiencies without overt clinical signs of malnutrition (Montagnac et al., 2009). The Bill and Melinda Gates Foundation have supported a global effort to develop cassava germplasm enriched with bioavailable nutrients since 2005.

The BioCassava Plus initiative has 6 major objectives namely to increase the minerals zinc and iron, vitamins A and E, protein contents and decrease cyanogen content, delay postharvest deterioration, and develop virus-resistant varieties. Using hybridisation and selective breeding, researchers in Nigeria have developed three new yellow varieties of cassava (Figure 3) that naturally produce a higher level of beta-carotene, which they say will help fight malnutrition caused by vitamin A deficiency in the region (Busani, 2011). Orange-fleshed sweet potato has been genetically enhanced to be virus resistant and is being promoted to combat vitamin A deficiency in Kenya, Burkina Faso, Uganda, and South Africa (Vebamba, 2004; Kapinga, et al. 2004; van-Stuijvenberg, 2005). This project has been on in Kenya since 2001 (Mackey, 2002). Papaya (Pawpaw) which was almost decimated in Hawaii was genetically enhanced to resist the ring-spot virus. This virus-resistant technology has also been transferred to papayas in South East Asia, such as Indonesia, Malaysia, the Philippines, Thailand and Vietnam (Mackey, 2002). Papaya is rich in beta-carotene and its consumption can help to eradicate vitamin A deficiency.

Maize is a preferred staple in Africa where the average person consumes over 100 grams a day. Vitamin A deficiency affects over 32% of the African population. Thus, increasing the pro-vitamin A content of maize cultivars may greatly improve the nutrition of millions of Africans (HarvestPlus, 2011).

Private sector collaboration developed the technology to insert the enzymes of phytoene synthase pathway into *Brassica napus* (Canola). Concentrations of 1000 to 1500 $\mu\text{g Carotenoids/g}$ fresh weight of seeds were achieved (Chewmaker et al., 1999). The same technology has been transferred to different species of Canola known as



Figure 3. Biofortified cassava. Bill and Melinda Gate Foundation.

Brassica juncea (Mustard) (Mackey, 2002). Mustard is widely grown in India, Nepal, and Bangladesh. The oil from the mustard seed is expected to be an excellent source of beta-carotene which can be used in fighting vitamin A deficiency in a vulnerable population.

Zinc

Zinc content of cereals or food grains have been increased in India by either developing crop cultivars with high concentration of zinc in grains or by adequate zinc fertilization of crops grown on zinc-deficient soils (Rajendra, 2010). Zinc deficiency in preschool children and pregnant women is a public health problem. It can lead to stunted and retarded mental growth. FAO estimated that over 68% of Africa's population is affected by zinc deficiency. Zinc is a secondary nutrient being added into maize by HarvestPlus scientists with considerable success (HarvestPlus, 2011). More than 450 000 infant deaths were recorded in 2004 as a result of zinc deficiency (Rajendra, 2010; Black et al., 2008). Zinc deficiency and Vitamin A deficiency (VAD) coexist in malnourished children (Rahman, 2002). Zinc deficiency limits the bioavailability of vitamin A (Uchendu and Atinmo, 2011).

Rice has demonstrated its ability to be loaded with micronutrients such as vitamin A, zinc, and iron through the work of International agencies, such as Harvest Plus, Humanitarian Board and the International Rice Research Institute in Philippines (Guerta-Quijano et al., 2002). Bioavailability of iron in rice has been increased by inserting a gene for heat resistant phytase from fungal sources that degrades phytate in plants (Bhat and Vasanthi, 2005). This might enhance zinc bioavailability in rice. Impact assessment of this rice will show the

extent of the contribution to zinc RDA of the target population. Golden rice is bio-fortified with pro-vitamin A (beta-carotene) and zinc and is due to be rolled out in the Philippines in 2013 (Levitt, 2011).

EFFICACY TRIALS WITH BIOFORTIFIED FOOD

Many studies evaluating the efficacy of bio-fortified crops are on-going while some have been completed in countries like Mexico, Nigeria and Rwanda. High iron bio-fortified rice fed to a control group over a period of 9 months was shown to marginally improve the iron status of non-anaemic women in the Philippines (Egli, 2011). Beans have higher iron content than rice and this can be doubled through traditional plant breeding (Beebe et al., 2000).

The major drawback of beans is the low iron bioavailability due to the relatively high content of phytic acid and polyphenols inhibitors (Egli, 2011). About 2% iron absorption has been reported from single meal isotope studies (Donangelo et al., 2003; Beiseigel et al., 2007). Other studies have also confirmed that both phytic acid and polyphenols contribute to the reduced absorption of iron in bio-fortified beans (Petry et al., 2010).

To achieve high amounts of iron absorption from bio-fortified beans, breeding should also focus on reducing phytic acid and polyphenol content. The ability of high β -carotene cassava to prevent vitamin A deficiency has been determined in vitamin A depleted Mongolian gerbils (*Meriones unguiculatus*). Biofortified cassava adequately maintained vitamin A status and was as efficacious as β -carotene supplementation in the gerbil model (Howe et al., 2009).

Biofortified pearl millet bred to contain more iron has been found to provide the recommended dietary requirement of iron for young children. In the study, iron-deficient Indian pre-school children under three years who were fed traditionally-prepared porridges (sheera, uppama) and flat bread (roti) made from iron-rich pearl millet flour absorbed substantially more iron than from ordinary pearl millet flour, enough to meet their physiological requirements. The iron-rich pearl millet also contained more zinc, which was similarly absorbed in sufficient amounts to meet the children's full daily zinc requirements.

Lack of zinc in children can lead to stunting and impaired immune response against common infections (Kodkany et al. 2013). In another study, marginally iron-deficient Beninese women who ate a traditionally prepared iron-rich pearl millet paste were found to absorb twice the amount of iron than paste made from ordinary pearl millet with lower iron content.

The results indicated that less than 160g of iron-rich pearl millet flour daily is enough to provide Beninese women aged 18-45 with more than 70 percent of their daily iron needs. The equivalent amount of the ordinary pearl millet used in the study provided only 20 percent of their iron needs. Women, generally, have higher iron needs

than children (Colin, 2013).

CHALLENGES FACING GENETICALLY MODIFIED FOODS

A recent forecast estimates that biofortification is more cost-effective than supplementation or fortification in reducing the burden of micronutrient malnutrition, especially in Asia (Meenakshi et al., 2010). Despite this assertion, genetically modified foods are facing challenges of rejection by many poor developing countries. Many of them have doubts regarding the benefits and the safety of biotechnology. In many poor countries the knowhow with regard to biotechnology is very limited, and discussions on risks and advantages are virtually non-existent (InfoResources, 2006). There is also the fear that impacts on health and the environment are not sufficiently demonstrated. For example, Friends of the Earth Nigeria (FoEN), are concerned that biofortified cassava undermines biodiversity (Bafana, 2011). Others are worried about the risk of uncontrolled crossbreeding with traditional varieties. They could also be a possibility of toxicity due to overconsumption of these crops and fortified and natural sources of the nutrients. However, this fear is allayed because consumption of beta-carotene unlike vitamin A does not give rise to toxicity because it dose-dependent.

For GM foods to be accepted worldwide, these issues must be addressed. Research results must be disseminated through publications, nutrition education and communication, etc. The positive influence of GM crops on the safety and health of humans, animals, and natural environment must be proved. In the past, GM crops were mainly cultivated and used to produce animal fodders and textiles while small proportion was processed into food. Now that GM foods are emerging as one of the global sources of fighting hunger, starvation and malnutrition, their nutritional quality/value must march that of their natural varieties and even surpass it. The nutritional safety of the products must be guaranteed.

To achieve these, there must be collaboration between the stakeholders to subject biotech produces to continuous and extensive laboratory analyses, evaluation and impact studies to investigate whether the products caused demonstrable effects on the consumers better than the traditional varieties. This will remove doubts regarding the benefits and the safety of biotechnology foods. However, the G8 countries have pledged to improve nutritional outcomes in about 50 million poor Africans and reduce child stunting by "support[ing] the accelerated release, adoption, and consumption of biofortified crop varieties, crop diversification, and related technologies to improve nutritional quality of food in Africa (HarvestPlus, 2012).

Comprehensive research programmes on genetically modified foods are now going on in Argentina, Brazil, China, India and South Africa. Other developing coun-

tries that are implementing biotechnological research programmes on GM crops with a view to commercializing them include Egypt, Indonesia, and Costa Rica. Other countries should follow suit.

CONCLUSION

Biotechnology is an emerging way to fight malnutrition. In order to realize this objective, genetically modified foods must be affordable for it to substitute the expensive animal products in vulnerable groups. The original physical properties of the traditional crops must not be affected such as taste, flavour, texture, etc.

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