Enhancement of Manufactured Foods with Biofortification

HarvestPlus
Better Crops • Better Nutrition

Integrating biofortification in the food industry

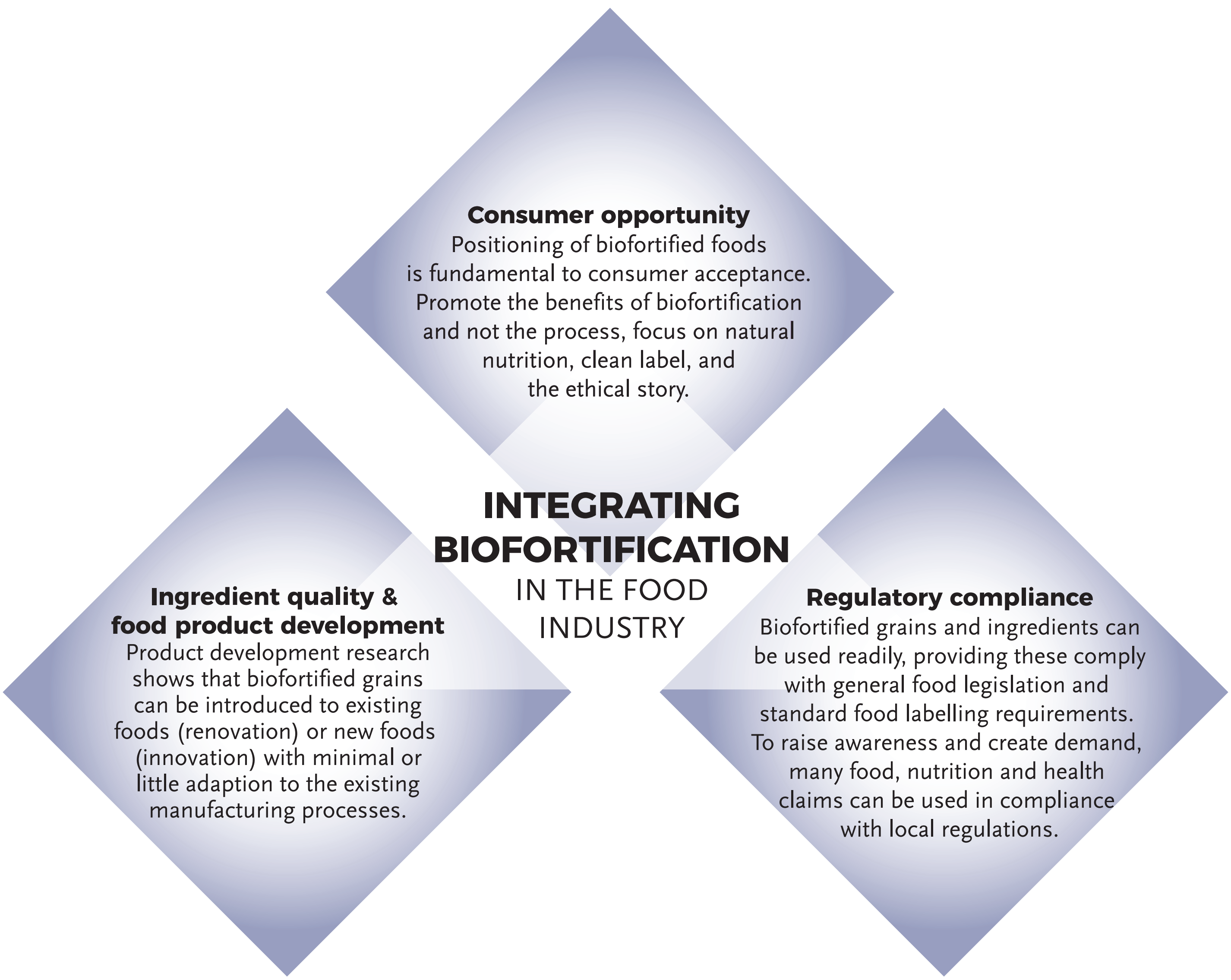
Enhancing the natural nutrient content of foods through biofortification is poised to be an impactful and profitable opportunity for the global food and beverage industry. High-iron pearl millet could be another quinoa phenomenon, and experts predict that by 2025, biofortification as a method to improve nutrition will be widespread.

Biofortification is a unique business opportunity for the global food industry. While biofortified crops and foods have most often been targeted at population segments that are at greatest risk of malnutrition, it is also relevant to the growing segment of health-conscious consumers who seek natural sources of nutrition through their regular diet.

HarvestPlus is an expert in biofortification and can assist food manufacturers of all sizes and types to integrate biofortified ingredients in their supply chains. We have produced a white paper series to support discussion of effective and efficient approaches to achieving this integration.

The three papers cover:

1. Consumer attitudes and perceptions of biofortification and biofortified foods;
2. Enhancement of manufactured foods with biofortification;
3. Differentiating and communicating biofortified products in the current regulatory landscape.



Enhancement of Manufactured Foods with Biofortification

Prepared in association with Leatherhead Food Research.

Biofortified grains, roots and tubers are naturally nutritious, created by means of conventional plant breeding methodologies. These are a source of micronutrients that will appeal to discerning consumers who are seeking to improve their health and well-being. Biofortified foods are also an opportunity for food manufacturers to increase their market share with healthier and more nutritious products, and become part of a global and philanthropic movement to address the serious health impacts of micronutrient malnutrition (or "hidden hunger").

Micronutrient deficiencies can lead to multiple health problems, including blindness, anemia, diminished stamina and work productivity, stunted growth, learning disabilities, and premature death. Scientific research has shown that consumption of biofortified foods can increase micronutrient levels and improve cognitive and health outcomes; the use of biofortified grains, roots, and tubers in mainstream products is a nascent but constructive and positive way forward.

Food manufacturers looking to use biofortified grains, roots, and tubers can elevate their mainstream products with valuable nutrition claims. The use of authorized claims on product packaging is a strong influential factor with respect to buying power among consumers and will also ensure that people are receiving the micronutrients they need.

To ensure the successful manufacture of products that are high in micronutrient content, food manufacturers should be cognizant of the factors that affect the level of micronutrient contents as well as the technologies available to optimize the micronutrients from farm to fork. Leatherhead Food Research was engaged by HarvestPlus to research, investigate, and identify in this White Paper the technical practicalities of using biofortified grains in mainstream products, and provides essential tips for the use of biofortified grains.

Confirm and safeguard your biofortified grain supply

Processing (including preparation) can make foods healthier, safer, tastier, and more shelf-stable. However, processing can also negatively affect nutritional quality (i.e. through blanching).

Some transformation processes will not necessarily affect micronutrient quality and content negatively, particularly for minerals (i.e. whole grain milling does not make minerals "sublimate" or disappear; cold blending of provitamin A crops increases bioavailability, etc.). As for minerals, some processes like ultra-fine milling that do not strip the crop of fiber, can improve bioavailability without reducing content. As with all crops, biofortified crops will be subjected to harvesting stresses and destabilizing conditions, both of which could negatively affect the micronutrient quality and content. It is therefore critical that technological solutions are utilized to minimize such losses.

The loss of these vital micronutrients could be due to either physical or chemical processes and is dependent on the micronutrient type:

- **Physical:** Related to actual loss brought about by harvesting methods, milling, sieving, pre-processing, storage & transport, soaking, and cooking.
- **Chemical:** Related to chemical degradation such as exposure to light, which would result in rancidity of fats or formation of off-flavors for instance, as shown in **Table I.** Iron and zinc are more prone to physical losses, whereas vitamin A is prone to chemical losses. **Table II** explains further the possible mechanisms for nutrient loss in high-iron beans and high-iron pearl millet.

Table I: Key mechanisms leading to lossess of micronutrients from crops

Iron and zinc	Vitamin A
Slightly susceptable to oxidation	Highly susceptiable to oxidation
Physical loss through soaking, cooking, and de-hulling milling processes	Highly susceptable to cis-isomerisation

Note: Zinc and iron can react with oxygen, but only to form oxides, which does not result in any losses. These minerals are rarely, if at all, found in elemental form in food.

Table II: Practical prevention of micronutrient losses from harvest to food manufacturer's site

Biofortified grain	Possible mechanisms of iron nutrient loss
Iron Beans	Iron beans show generally good stability with little or no special treatment needed for harvesting and storage (in bean form). However, the content and bio-availability of iron vary depending on pre-processing, soaking, and cooking conditions, which can lead to leaching of iron and reduction in iron content.
Iron pearl millet	Iron pearl millet has a high fat content, which can contribute to oxidative rancidity process; this can be accelerated by the presence of iron. Grain form is more stable than flour form. This is important to note but not related to iron losses during processing.

In addition to the physical and chemical causative factors, one should be aware of the presence of antinutrients that are intrinsically present within the grains. Examples of antinutrients include phytates/phytic acids, oxalates, phenolic compounds/polyphenols, tannins, and dietary fibres, all of which can form insoluble complexes with iron and therefore reduce the bio-availability of iron. Of all these compounds, phytic acid is the main inhibitor of zinc absorption. Phytic acid/phytates, for instance, are found in the bran fractions of the grains, whereas in the common beans, these are found in the cotyledons.

Technologies are available to protect the micronutrients in crops from the point of harvesting to the point of delivery at a food manufacturer. **Table III** provides an overview of some technological solutions that can be employed to protect micronutrient content, therefore enabling food manufacturers to manufacture products that would have a naturally high level of micronutrients upon completion of production and end-of-life shelf life.

Table III: Potential practical technological solutions for minimization of mineral losses

Key processing steps	Examples of some technological Solutions	Technology options for protection of common beans	Technology options for protection of pearl millets
Post-harvesting	Drying	Sun-drying and oven-drying technologies do not affect the iron contents or forms and result only in reduction of moisture content.	
	Decortication and de-hulling (with and without other processes)	De-hulling of beans can lead to removal of phytates and tannins.	Decortication (de-hulling) and dry milling could lead to removal of the lipid rich germ and bran from the grain, therefore increasing shelf life, but may also lead to significant loss of micronutrients and nutrients.
	Microbial fermentation	Fermentation technologies are available to reduce anti-nutrients. Fermentation can increase zinc absorption, also, iron absorption by reducing ph. and promoting the reduction of iron to Fe(II)	
Pre-processing (milling / conversion to flour form)	Addition of fortificants	Inclusion of ferrous sulphate, ethylenediamine tetraacetic acid (EDTA), and folic acid to cereal flours could potentially enhance iron absorption in the presence of phytates. The addition of phytase would also apply in this section and/or in the pre-cooking sections. Addition of EDTA with or without the iron attached, ascorbic acid, etc., can enhance bioavailability (at least in the short term)	
	Milling and heat treatment	Intense heat (as in canning) can reduce phytate in beans and enhance iron and zinc bioavailability	Application of heat will inactivate lipase enzymes, which convert lipids into glycerides, therefore causing rancidity.
Storage		Proper storage to avoid insects will minimize grain loss	Like oats, conditioning with saturated steam followed by kiln drying and with superheated steam (SS) may extend shelf life.
		Various packaging technologies (different lamination materials and modified atmospheric packaging, or MAP) are available to minimize or inhibit the common deterioration mechanisms associated with beans and grains, and their flour equivalents.	
Pre-treatment and soaking	Soaking	Soaking encourages leaching of phytates into soaking water; water imbibition also leads to activation of phytase enzymes to degrade and reduce phytate content. Germination, but not soaking, increases phytase activity 3 to 5-fold in some cereal grains and legume seeds, while the influence on phytic acid content was insignificant in most materials tested. Effects of soaking are not equal across all crops/food formats.	
Cooking	Steaming	Steaming can be used to remove phytates.	
	Blanching	Blanching can contribute to significant reduction of anti-nutrients in common beans.	
	Extrusion	Phytic acid and trypsin inhibitors levels could be reduced in bean extrudates.	

(note: studies need to be carried out to validate the performance of these solutions)

Assess your recipe and manufacturing process

A review of your recipe and manufacturing process is an essential step to ensure the fitness of key processing steps with respect to incorporation of biofortified crops. Relatively minor adjustments may be needed to ensure that the final product contains the minimum number of micronutrients; this is critically important if you want to promote your product with a "source of [micronutrient]" or "high in [micronutrient]" claim.

As a means of demonstration, Leatherhead has evaluated theoretical recipes and production processes for the manufacture of baked beans and porridge.

Adjustments may include:

- Relatively slight variations in the content of the grains;
- Optimization of processing steps to reduce the physical loss of the micronutrients; and
- Optimization of processing conditions to increase the bioavailability of the micronutrients.

Universal, well-loved baked beans up for renovation

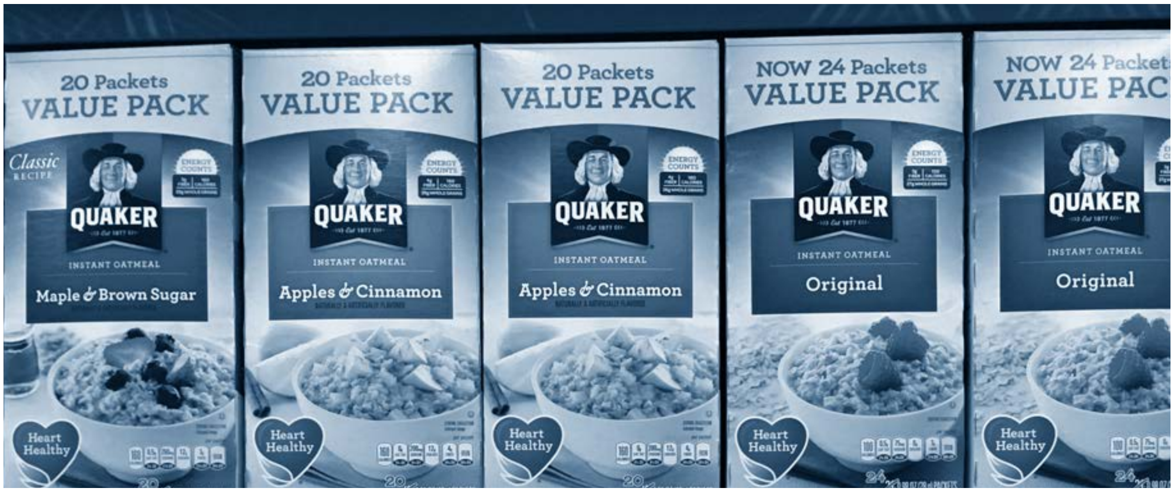
The baked bean product was selected as a potential model for the use of iron-biofortified common beans. Standard common beans typically have an iron content of about 6.2 mg/100g, whereas iron-biofortified common beans promoted by HarvestPlus could contain approximately 9.5 mg/100g.

The manufacturing process is relatively straightforward and in theory is expected to require minimal adjustment for the biofortified bean variety. In order to ensure production of baked beans with elevated iron content (as compared with a standard baked bean product), food manufacturers need to ensure that:

- the amount and the varieties of the common bean should be selected based on having the correct starting point of iron content to account for any potential losses during the cooking process;
- the right common bean varieties with the right sensory profiles are selected so as not to have a negative or detrimental impact on the flavor profile;
- the cooking times of the different varieties guarantee that all beans are cooked to the right consistency at the same time; and
- the cooking times are favorable towards optimization of iron bio-availability.

The comforting porridge up for innovation

Replacing oats with iron-biofortified pearl millet creates a new porridge concept that will have a high level of iron content. Pearl millet is commonly grown in India, throughout west Africa and Nigeria, China, and Russia but not much in the United States and the United Kingdom/European Union. Hence, pearl millet could be regarded as a "new" ingredient in the American and European markets. Iron-biofortified pearl millet, as promoted by HarvestPlus, contains approximately 7.7 mg of iron per /100g; by contrast, oat contains on average 4.5 mg iron/100g. The process for making iron pearl millet porridge is based on the production of oat-based porridge. As with baked beans, this process is expected to require minimal adjustment for use with iron-fortified pearl millet.



Endorse and protect your products' claims

The use of nutrition and health claims or structure-function claims on your products can be a powerful marketing tool appealing to consumers seeking to improve their health and well-being. However, the use of claims is highly regulated, and it is essential that the micronutrient contents in the final products meet regulatory requirements.

Using claims such as "source of" or "high in" is a powerful incentive for both manufacturers and consumers to be part of biofortification. Manufacturers need to ensure that the products contain the minimum amount of a given micronutrient based on the regulatory requirements of the country or region. For example, as shown in **Table IV,** in order to use the "source of iron" claim in the UK, a 100g product must contain at least 2.1 mg of iron, which is calculated based on 15 percent of the reference intake of 14 mg.

Table IV: Reference intakes for claims continuum on iron contents

	Reference intakes for Iron (mg)	% of reference intake for "source of" claim	% of reference intake for "high in" claim	Calculated iron content product for use of "source of" claim	Calculated iron content mg per 100g product for use of "high in" claim
UK (both products)	14	15	30	2.1 mg / 100 g product	4.2 mg / 100 g product
USA (baked beans)	18	10	20	1.8 mg per 130 g RACC[1]	3.6 mg per 130 g RACC
USA (dry cereal)				1.8 mg per 40 g RACC	3.6 mg per 40 g RACC

1. RACC – Reference amount customarily consumed

Looking at baked beans and porridge prepared with iron-biofortified common bean and pearl millet grains, respectively, and taking into consideration the likely micronutrient losses that may occur during the production of the final products, theoretical calculations were carried out to predict the iron contents of the final products. As shown in **Table V**, based on the final iron contents with assumptions of 5 percent and 20 percent losses for common beans and pearl millet grains respectively, the claim "source of" could be used. Such a claim will elevate and differentiate your products from your competitors in a highly competitive market.

Table V: Theoretical calculations for iron contents in final products prepared with iron-biofortified grains

	Typical micronutrient loss due to processing (%)	Micronutrient loss (%) for purposes of calculations*	Iron content in biofortified grain as promotedby HarvestPlus	Possible final iron content in baked beans prepared with grains biofortified with iron		Claim that can be used	
				UK	USA	UK	USA
Renovation of baked beans with iron- common beans	5 - 10	5	9.5 mg/ 100 g	2.1 mg of iron/ 100g	2.7 mg of iron/ 130 g	source of iron	source of iron
Innovation of porridge with iron- pearl millet	20 - 30	20	7.7 mg/ 100 g		2.4 mg/ 40 g		source of iron

*Cognet Food & Agr 2015; 1:1109171 (Sihag MK et al)

Validate your products

To protect your brand, it is essential to validate your products in terms of critical quality attributes, including sensory properties and physiochemical characteristics. Generally, biofortified cereals and legumes do not have altered sensory characteristics when compared with non-biofortified crops; and when differences exist, they are generally favorably assessed for the biofortified versions.

Sensory qualities of the grains themselves and the products prepared with biofortified grains are critical for consumer acceptance. Biofortified grains with increased levels of iron and zinc are regarded as having "invisible" nutrition traits in that these minerals do not change the color of the crops/grains, and therefore consumers cannot differentiate them visually from conventional crops.

However, crops with enhanced levels of vitamin A have "visible" traits in terms of changing color of the crops/ grains due to the increase in beta-carotene content. For instance, maize would be orange/yellow in color compared being creamy/white in color in non-biofortified varieties; therefore, consumers would be able to differentiate between biofortified and conventional crops.

With respect to the effect of biofortified grains on product characteristics, the review of published studies indicated that iron biofortification of the common bean and pearl millet crops would not necessarily have a negative impact on the sensory attributes of the ingredients and final end-products. Nonetheless, sensory evaluation and hedonic testing studies at the early stage of the product development process are recommended.

In the future, the food industry can participate in the breeding process by communicating the preferred cooking, nutritional, and sensory characteristics for a specific (line of) product(s) rather than take varieties that were developed for specific ecogeographic and even cultural/culinary settings.

Finally, physiochemical analysis of biofortified grains and products should be—as with normal grains and products—a regular part of quality control processes. In particular, the micronutrient content of the products must be continuously monitored as part of raw material supply, production, and shelf life storage to ensure compliance with the requirements behind the use of nutrition claims. Any deviations may harm brand reputation and loyalty.

Biofortification, which naturally increases the micronutrient content of foods, is potentially of great interest to consumers. The foods that are biofortified as part of the HarvetsPlus program offer the potential for food product renovation as well as food product innovation. The vitamin A crops bring with them additional color, which alone brings consumer interest without the need to talk about the nutrition benefits. HarvestPlus will continue to work with expert food researchers and food manufacturers to increase knowledge in this area and bring more biofortified foods to market.

For further information, please contact Jenny Walton at HarvestPlus: j.walton@cgiar.org

UKaid
from the British people

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Biofortification is a groundbreaking technology that was developed to reach the world's most vulnerable and malnourished. In order to reach these population groups quickly and efficiently, strategies are required to integrate biofortified foods in both local and global foods systems. By creating a global market for biofortification, the resulting growth in demand will stimulate investment in the science and commercialization of this technology. Smallholder farmers have always been and will remain the target beneficiary of the HarvestPlus program.

The research was conducted by Leatherhead Food Research on behalf of HarvestPlus, harvestplus.org