Functional Foods and Biotechnology

"Functional Foods" are foods or dietary components that claim to provide health benefits aside from basic nutrition[1]. These foods contain biologically active substances such as antioxidants that may lower the risks from certain diseases associated with aging. Examples of functional foods include fruits and vegetables, whole grains, soy, milk, enhanced foods and beverages and some dietary supplements.

Diet and health are closely related. Thus, crops are now being enhanced through biotechnology to increase levels of important biologically active substances for improved nutrition, to increase body's resistance to illnesses, and to remove undesirable food components. Which substances are the ones targeted by biotechnology for improved health benefits of crops?

Higher Levels of Phytosterols for Reduced Cholesterol

Phytosterols and phytostanols are cholesterol-like molecules found in all plant foods, but the highest concentrations occur in unrefined plant oils, including vegetable, nut and olive oils. Nuts, seeds, whole grains and legumes are also good dietary sources of phytosterols[2]. Studies have shown that these compounds can lower the risk of cardiovascular diseases and the levels of "bad cholesterol".
As phytostanols are more stable than phytosterols during food processing, genetic engineering has been applied for the development of rapeseed and soybean oils with modified ratios of phytosterols to phytostanols[3]. Plants were transformed with a gene from yeast encoding the enzyme 3-hydroxysteroid oxidase, which converts phytosterols to phytostanols.

Higher Levels of Carotenoids for Increased Vitamin A

Carotenoids are yellow, orange, and red pigments found in plants. Some carotenoids are converted by the body into vitamin A. Vitamin A is essential for normal growth and development, immune system function, and vision[4]. Examples of carotenoids present in plants include α- and β-carotene from carrots and pumpkins, lycopene from tomatoes and lutein and zeaxanthin from dark green leafy vegetables.

Transgenic plants that have been developed with increased carotenoid production include:

- β-carotene fortified rice ("Golden Rice");
- Canola (*Brassica rapa*) with increased carotenoids developed by introducing a gene coding for an enzyme responsible for lycopene biosynthesis[5];
- Tomatoes with increased β-carotene developed by inserting bacterial genes that code for enzymes in the carotenoid pathway[6,7]

Higher Levels of Antioxidants

One of the reasons why pollution, radiation, cigarette smoke and herbicides are bad for our health is because they generate harmful free radicals in our body. Free radicals can cause damage to the DNA and proteins, harm cellular components like the cell membrane, and can eventually lead to degenerative diseases such as cancer.

Antioxidants are important biological compounds that can protect the body by neutralizing the activity of free radicals. Antioxidants occur in different forms, phenolic compounds such as flavonoids and tocopherols being the most common. They are found in most fruits and vegetables such as cabbage, carrots, broccoli, aubergine, berries, and potatoes and plentiful in coffee, tea, and red wine.

To enhance the flavonoid content of potatoes, Lukaszewicz and colleagues conducted single and multiple-gene transformations for the enzymes in the biosynthesis of flavonoids[8]. Transgenic plants exhibited significantly increased levels of phenolics, and improved antioxidant capacity.

Higher Levels of Essential Fatty Acids

Essential fatty acids, “good fats” include, but are not limited to, linoleic acid (LA), alpha-linolenic acid (ALA) and other polyunsaturated fatty acids (PUFAs). These fatty acids are considered essential because they cannot be synthesized by our body. A large number of scientific research studies suggest that higher dietary essential fatty acid intakes are associated with reductions in cardiovascular disease risk[9].

The main food sources of the long-chain omega-3 fatty acids are fish. Plants lack the enzymes to make long-chain fatty acids needed by mammals[7]. Scientists at the University of Bristol modified *Arabidopsis thaliana* to produce long-chain PUFAs. The transgenic plants were modified with three genes encoding different enzymes that convert linoleic and alpha-linolenic acids to the long-chain PUFAs[7]. This experiment opened the possibility for the improvement of crops.

Other Biotech Functional Foods

Low-Linolenic Soybean

Soybean is one of the major sources of edible oil. Oil from soybean seeds contains the unstable linoleic and linolenic acids, which affect its stability and result in the production of harmful fatty components during processing[10].

Genotypes with elevated oleic acid content and reduced linoleic and linolenic acid levels are therefore desirable to improve the functionality of soybean oil by increasing oil utility at higher temperatures11, and by extending its shelf-life. In 2004, Monsanto launched the

VISTIVE™ soybean, which has the Roundup Ready® trait. It contains less than 3% linolenic acid, compared to 8% for traditional soybeans[12].

Other GM soybeans were developed by DuPont to contain high oleic acid: transgenic lines G94-1, G94-19, and G168. The soybean lines were produced by silencing a gene that controls the activity of an enzyme responsible for the conversion of linolenic acid from oleic acid[13]. The result is a more heat stable soybean oil which may be used in food applications such as frying.

High-Lysine Maize

The poor nutritional quality of corn is due to the low-lysine and low-tryptophan content of its major seed storage proteins, zeins. Lysine is an important component of animal feeds, especially for swine and poultry. Kernels with reduced levels of zein proteins have been shown to have increased levels of lysine and tryptophan[14].

Recently, a high lysine and high tryptophan transgenic maize was developed by inserting gene constructs that reduced formation and accumulation of α-zeins. In addition, a large increase of accumulated free amino acids, such as asparagine, aspartate and glutamate, was observed in the zein-reduced kernels[14].

Opportunities and Challenges for Developing Countries

Functional foods through biotechnology can provide developing countries food sources with increased nutritional value. Staple starchy crops such as cassava and yams have been modified to lower the amylopectin content of starch, which has been associated with diet-related conditions such as type 2 diabetes. In areas of drought and poor soil quality, where high quality proteins are scarce, genetic modification has been undertaken on some legumes and in soybean to increase the levels of high quality proteins[15].

Currently, commercialization of genetically-modified nutritionally-enhanced crop is very limited due to many factors that include the cost of introducing a new product to the market and the lack of suitable regulatory controls. In addition, the development and marketing of functional foods require significant research efforts because most markets require scientific evidence and proof of functionality[16].

Conclusion

Functional foods sprung from the desire to prevent the onset of diseases associated with an ageing population. Developing countries, especially China and countries in Latin America, face increasing health problems related to life style: diabetes and cardiovascular diseases among others. In these cases foods with improved nutritional qualities and added function would be useful; hence, developing countries need to increase the investment on rigorous scientific research on potential functional foods.

References

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