GM Foods : Myths and Facts

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Higher plants, animals and human beings are generally made up of millions of cells. Inside each of these cells is a nucleus which contains genes. Gene is a natural unit of the hereditary material, which is the physical basis for the transmission of the characteristics of living organisms from one generation to another. The genetic information is stored in the base sequence of the DNA molecule which can either generate more copies of itself through replication or be copied by the process of transcription into RNAs. These RNAs act as intermediary in the flow of genetic information from the nucleotide language of nucleic acids to the amino acid language of proteins through **translation**.

The word **biotechnology**, coined in 1919 by Karl Ereky, was used to describe the interaction of biology with human technology. In simple terms, biotechnology is the means or way of manipulating life forms (organisms) to provide desirable products for human use. In this context, biotechnology is not new. Beekeeping and cattle breeding can be considered as biotechnology-related endeavours and making of beer, wine, bread, yoghurt and cheese was practised by ancient civilizations such as the Babylonians, the Romans and the Chinese. Production of basic chemicals like glycerol, citric acid and lactic acid and the development of antibiotics by exploiting the properties of microorganisms appeared in later times (For example, production of penicillin from *Penicillium* species). Use of the term biotechnology has come to mean all parts of an industry that knowingly create, develop and market a variety of products through the wilful manipulation of living organisms or their parts at molecular level.

Although, **recombinant DNA** is one of the many techniques used to derive products from organisms or parts of both plants and animals for the biotechnology industry, it is not the only area of biotechnology. Hence, biotechnology may include areas such as recombinant DNA, plant tissue culture, rDNA or gene splicing, enzyme systems, plant breeding, meristem culture, mammalian cell culture, immunology, molecular biology, fermentation and the like. With the development of gene manipulation techniques in the 1970s, there was a major paradigm shift. For the first time microorganisms were used to synthesize compounds that they had never synthesized before, e.g. insulin production in *E. coli*. One of the earliest commercial applications of gene-manipulation techniques using bacteria was the production of human proteins with therapeutic applications.

Genetically modified organisms (GMOs) are organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally. The initial focus of plant biotechnology was on improving agronomic traits through the protection of crops against pests, pathogens and weeds thereby increasing yields. Scientific approaches revealed that, in many cases, single genes transferred from another organism can provide high levels of protection. The technology is often called “modern biotechnology” or “gene technology” or else as mentioned above “recombinant DNA technology” or “genetic engineering”. It allows selected individual genes to be transferred from one organism into another or between non-related species. Genetically modified foods (GM) refer to those foods which are derived from GMOs. Genetically modified foods (GM foods) are the focus of a current public debate that asks whether we should be eating (and growing and selling) these foods. One side of the argument claims GM foods hold the potential to end world hunger and the use of pesticides. The other side claims the risks still are unclear, speaks of “frankenfoods” and warns of superpests or superweeds.

With all criticisms, GM foods are being accepted by the consumers in many countries, because there are some perceived advantages either to the producer or consumer of these foods such as lower price, improved qualities like nutritional value and pharmaceutical value etc. However, generally consumers like Sri Lankans consider that traditional foods that have often been eaten for thousands of years are safe. One of the major concerns about GM crops is whether they will have negative effects on health. Some giant Biotechnology companies have claimed that genetic engineering is no more unpredictable and dangerous than traditional cross-breeding, and as a result, GM crops should not be subjected to special or extensive safety assessments.

Public debate on the use of GMOs in seeds, crops and foods continues to be highly polarised. There are at least two sides for each problem if not multi-faceted. For example, medical professional and researchers appreciate aspirin one time and then rejects later depending on the updates of findings on the use of aspirin. This argument continues alternatively and endlessly. A negative view on a matter at one time can be turned into a positive acceptance later depending on perceptions of people, current scientific findings and the direct benefit that the people would get out of it. Hence, an optimistic belief in a food whether it is GM or natural can be a myth today and alternatively it can be a fact tomorrow. There is neither absolute truth nor fraudulence. Therefore, this article focuses on both good and bad sides of GM foods leaving the reader to decide on what myth is and what facts are. In order to do so, let's have a closer look at GM foods, their potential benefits and possible threats.

How GM foods are made?

As mentioned above, a GM plant is one that has had one of its genes altered. GM gives plants new, useful properties, like being able to resist insects or the cold and drought. Sometimes GM means putting a gene from another species into a plant. Innovations leading to an increased range of food products from currently available raw materials and introduction of new raw materials with better quality characteristics are the strategies to meet increasing consumer demand for high quality food products. In a way this is true specially when the world badly needs food to feed the people.

Herbicide tolerance of food crops

Weeds being real competitors against crop plants for nutrients, water and space severely affect the crop yield. Both crops and weeds carry out similar biochemical reactions within their cells. Therefore, developing herbicides that are selective for weeds is somewhat difficult. As an alternative measure, herbicide tolerance is achieved through the introduction of a gene from a bacterium conveying resistance to some herbicides. In situations where weed pressure is high, the use of such crops has resulted in a reduction in the quantity of the herbicides used. Hence, modifying crop plants to become resistant to broad-spectrum herbicides is more feasible and economical. This property can be achieved through two ways; in first instance, the target molecule in the cell either is rendered insensitive or is overproduced and in the second instance, a pathway that degrades or detoxifies the herbicide is introduced into the plant.

The benefit of herbicide-resistant transgenic crops reflects in the increased yield and seed quality as competing weed species are eliminated. Initially, there was a public concern saying that the use of herbicide-resistant transgenic crops would lead to excessive use of herbicides which in turn would have a serious impact on the environment. However, contrary to these predictions, the introduction of herbicide resistant plants has actually reduced chemical use by up to 80% in many areas, as farmers adopt better weed-control policies and switch to herbicides with low use rates. Another public concern was that these transgenic plants might transfer these genes in to weed species, resulting in a new breed of 'superweeds'. This may be true, but it is too early to make a conclusion on this issue. We have to think of both benefits and risks of herbicide-resistant crops on one hand and strategies to combat adverse effects associated with gene transfer to weeds on the other hand.

The availability of molecular-genetic techniques also enabled the insertion of specific genes that impart specific quality traits to fruits or inhibit degradation mediated by enzymes that otherwise would lead to rapid deterioration of the fruits. For example, some GM crops (e.g. Tomato) were modified with specific genes to inhibit ethylene biosynthesis and cell wall polymer degradation. Biotechnology has become one of the techniques available to the food industry, for increasing its competitiveness, quality, and range of products. Inhibition of cell wall degradation through genetic engineering has been used as a strategy to enhance the shelf life and firmness of tomato fruits and to improve the qualities of processed tomato products. The production of GM tomatoes with improved processing parameters (e.g. acceptable colour, flavour, firmness, texture, essential rheological properties and handling characteristics to satisfy consumer etc.) may offer such an opportunity in the near future.

Resistance to viruses

There is a useful phenomenon known as cross-protection, in which infection of a plant with one strain of virus protects against "super-infection" with a second, related strain. The mechanism of cross-protection is believed to be based on the viral coat protein. Different transgenic plants that express the Tobacco Mosaic Virus (TMV) coat protein and less vulnerability to virus infection have been developed. Transgenic squash containing multiple viral coat-protein genes and demonstrating resistance to cucumber mosaic virus, water-melon mosaic virus 2. It is worth while noticing that no control measures have been developed yet against viral diseases, by using conventional methods.

Resistance to insects and other pests

Insect pest problems represent one of the most serious biotic constraints to crop production. For example, more than a quarter of all the rice grown in the world is lost due to insect pest attacks. At present, almost all commercially produced insect-resistant transgenic crops express toxin proteins from the Gram-positive bacterium *Bacillus thuringiensis* (Bt). During sporulation, *B. thuringiensis* produces protoxins called crystal proteins. These proteins are potent and highly specific insecticides. Bt toxins have been used as topical insecticides since the 1930s, but it was not that popular because of their rapid breakdown rate on exposure to light.

As a solution to this problem, Bt genes were initially introduced into tomato and tobacco and later into cotton which enabled the production of insecticidal proteins remarkably. However, field tests of these plants revealed that higher levels of the toxin in the plant tissue would be required to obtain commercially useful plants. After a series of trials, first transgenic insect-resistant potato crop was released to the market by Monsanto company. The same company also released the first commercial transgenic, insect-resistant varieties of cotton and maize. Many other biotechnology companies have now produced Bt-transgenic crop plants resistant to a range of insects.

GM crops for modified starches

Food and other industries use a wide range of different starches. These different starches are obtained by sourcing the starch from different plant varieties coupled with chemical and enzymatic modification. The genetic modification of plants offers a new approach to creating novel starches with new functional properties.

Golden Rice

According to the World Health Organization (WHO), Vitamin A deficiency (VAD) affects millions of people worldwide and about 250,000 to 500,000 children go blind every year and half of them die within 12 months due to VAD. The creation of Golden Rice, a GM rice synthesising β-carotene, goes far back to 1984. A team from the Swiss Federal Institute of Technology in Zurich had succeeded in inducing genetically modified rice to produce β-carotene (provitamin A). The human body can use this provitamin A to bio-synthesise essential vitamin A. Since grains of rice took on a yellow colour from the provitamin, this variety was named as Golden Rice.

One argument brought up by opponents of Golden Rice is that it might interfere with existing vitamin A supplementation and fortification programs and campaigns. This argument suggests that we should opt for the status quo. Such an attitude disregards the potential of Golden Rice to provide viable, sustainable alternatives.

This new technology has also aroused controversial debates on its nutritional impact and cost-effectiveness which are remaining unclear. On the other hand, we need to assess the current burden of VAD in the world from a public health perspective, and simulate the potential alleviating impact of Golden Rice using representative household food consumption data. Assessing the health benefits and overall costs suggests that Golden Rice is very cost-effective. High-value-added crops like GM rice can promote human health remarkably. Hence, GM foods of this nature should be socially accepted irrespective of their genetic modification status by virtue of a net positive in any risk–benefit analysis.

Plant edible vaccines

Since recent past, edible vaccines have received considerable attention from researchers in both academia and industry. Scientists have pioneered edible vaccines by introducing selected genes into the plants to facilitate the production of the encoded protein. The main goal of an oral vaccine is to induce a mucosal immune response and a subsequent systemic immune response. For biotech and drug industries, biopharming offers economic and health benefits once the current cycle of product development reaches the commercialization stage (Table 1).

Table 1 Advantages and disadvantages of edible vaccines

Advantages	Disadvantages
The plants producing the edible vaccines can be grown in countries like Sri Lanka	Plants as living organisms can be subjected to changes and therefore the continuity of the vaccine production might not be guaranteed.
Plants are regularly used in pharmaceuticals, and there may be purification protocols established	The edible vaccines could be mistaken for regular fruits and consumed in larger amounts than might be safe.
Growing plants (edible vaccines) is much cheaper than producing vaccines.	The dosage of the vaccines might be variable depending of the size of the fruit.
Plants cannot host most human pathogens, so the vaccines will not pose a danger to humans.	If the vaccines were grown in fields or on trees, safety would become a big issue.

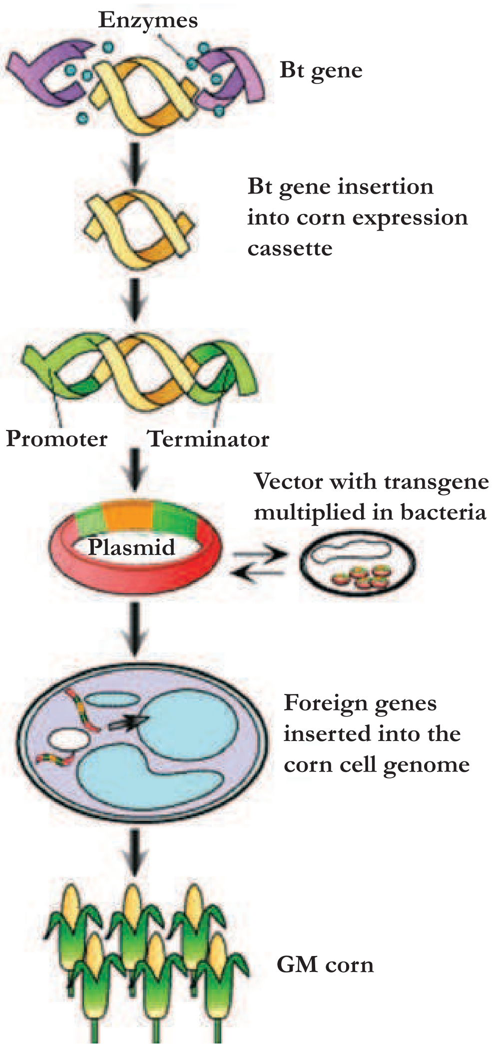
In this connection, study species include potatoes, tomatoes, bananas, lettuces, rice, wheat, soybean, corn and legumes. Fruits, vegetables and leafy salads can be suitable for the production of recombinant subunit vaccines, food additives and antibodies for tropical passive immunotherapy. Potatoe is being widely used for the production of plant-derived vaccines that have been administered to humans in most of the clinical trials. Tomatoes were used to produce the first plant-derived rabies vaccine. Bananas have been considered as hosts for the production of recombinant vaccines, since they are widely grown in those countries where vaccines are most needed Banana can be easily used as edible vaccines as it is often the first solid to be given to infants. In addition, banana does not require to be refrigerated as conventional vaccines do. The additional advantage of bananas is that they can be consumed raw or as a puree by both adults and children. Would not a normal layman prefer eating a banana or tomato rather than having an injection?

There can be two main concerns over edible vaccines; contamination of food crops through cross pollination and the vaccine itself in plant debris spreading as dust and as pollutants in surface and groundwater. The vaccine antigen may affect browsing animals and humans living in the area drinking vaccine-polluted water or breathing vaccine-polluted dust. Therefore, it is of paramount importance that the cultivation and production of pharmaceutical crops should be limited to controlled production facilities such as greenhouses or plant tissue culture laboratories. The main safety concern is that the oral vaccine preparations will induce "immune tolerance", thereby making the individual susceptible to, for example, the hepatitis B virus.

Plants have advantages compared with traditional systems for molecular farming of pharmaceutical proteins. However, for these benefits to be fully realized, issues like risk to the food industry and the environment need to be attended. A combination of strong and adaptable regulatory oversight with technological solutions are required in order to realise the full potential of plant molecular farming. For all, plants need to be viewed as a possibility among many for manufacturing therapeutic proteins.

Pharmaceutical production through GM animals

The first GM mammals (mice) were produced in the mid 1970. In 1982, a mouse was genetically modified to produce a foreign protein, rat growth hormone, which caused it to grow visibly oversize. Animals have been genetically modified by the insertion of human genes coding for therapeutic proteins, which are generally produced in the animal's milk. Similarly, there are attempts to modify chickens to produce drugs in eggs as well. There is a wide range of benefits that human can obtain from GM animals. But there are strong criticisms. Those opposing GM animals claim that the genetic modification of animals is an assault on the integrity of another species. Not only can genetic modification cause considerable suffering to the animals involved, but it also changes our relationship with the natural world and contributes to the commodification of animals by using them as we wish merely for maximum commercial gain.



General schematic of GM crop production

Do milk, eggs and meat from GM-fed animals contain GM material?

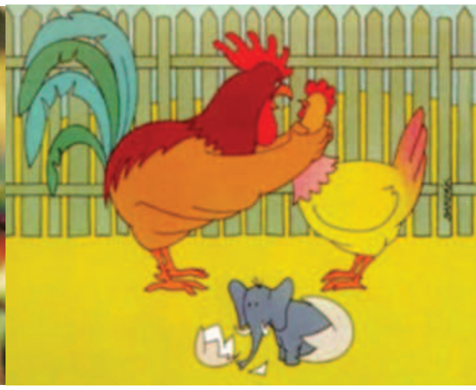
Earlier it was believed that GM crop material is degraded during processing into feed and during digestion. Some literature showed that no GM DNA materials were found in foods like the milk, eggs or meat of GM-fed animals. In recent past, several of these studies found that plant chloroplast DNA from animal feed is present in milk, eggs and meat.

Similarly, another study detected GM soya and GM sequences in shop-bought milk. Some studies have suggested that the DNA may have been a result of contamination of the milk by dust from the GM feed in the dairy. Whilst this is unproven, this points to a potential common source of contamination with the use of GM feed and does not change or undermine what was found with GM DNA in the milk. Nevertheless, biotechnology companies have claimed that genetic engineering is no more unpredictable and dangerous than traditional cross-breeding, and as a result GM crops should not be subjected to special or extensive safety assessments.

Food for thought

Production of GM plants/animals/foods usually involves introducing a package of genetic material derived from one organism (or several) into the DNA of another, often a completely different species. It is never based on the plant's normal reproductive processes. Instead, the foreign DNA is inserted into the plants own DNA either by using the infective process of a disease bacteria or by bombarding the

GM labelling issues


GM food; even sky is not the limit


Possibilities of GM crops

cells with fine metal particles coated with the foreign DNA. This artificial DNA insertion breaks down the natural biological mechanisms that normally maintain the genetic integrity of species.

Since the inserted genes usually come from other organisms such as bacteria or are synthetically produced, the proteins they produce are often new to the animal or human diet. The production of these proteins may also involve a new biochemical pathway in the plant or affect an existing one. This may result in the production of other novel protein or biochemical by-products, some of which could be allergenic or toxic. This explains why GMOs have been associated with allergic reactions.

Another issue is that, unlike naturally occurring genes which are generally only active at certain times and in certain cells, transgenes are usually active the whole time and in all cells. This means that the gene's products and any by-products are present in all of the plant's tissues. For example, unlike normal non-GM maize, the Bt toxin is present in all the cells in Bt maize, the main GM maize used in animal feed.

It has now been found that genes usually do not operate in isolation or completely dictate to the plant. Genes are instead themselves controlled by numerous interactive plant regulatory mechanisms, including other genes and cellular processes, in a complex system which is not yet understood fully. The result is that the same gene can behave in different ways at different locations, depending on the regulatory elements it ends up next to. As genetic engineers do not know the effects of the different locations and cannot control where the genes end up in the plant DNA, their unpredicted side effects may easily occur.

A study carried out by Australian scientists who inserted a previously harmless bean protein into a pea, which then caused allergic reactions in mice, revealed that a harmless protein in one organism can become harmful when inserted into another organism, even if its sequence of amino acids remains completely identical. This phenomenon is called "post-translation modification" according to which, different sugars, lipids or other molecules attach to the protein and modify its function.

The number of people who were in danger of malnutrition worldwide has decreased significantly in the past 30 years thanks in part to the Green Revolution of the 20th century. However, an estimated 800 million people still lack adequate access to food. The world now looks in to a second potential revolution; "Gene Revolution" in which the production of GM crops/animals/foods may be tailored to address ongoing agricultural problems. One may ask a question "Can the GM foods be useful or beneficial to the Humans?" The answer to this question is "Yes and No".

GM foods exhibit the potential to have much wider impact, solving many of the current problems in agriculture worldwide. Despite its attendant challenges and alternatives, the GM crop technology shows great promise. Like the Green Revolution which flourished in earlier times, the GM revolution has the potential

Dolly and surrogated mother (Born in February 1997)

Dolly, the first cloned sheep was born in February 1997

to achieve substantial production increases and to reduce the need for agricultural chemicals and scarce resources like water. Both the successes and failures of the Green Revolution provide useful lessons for how to make GM crop technology a desirable and sustainable agricultural concept applicable for the countries that suffer from less production than the local demand. As far as Sri Lanka is concerned, we have enough cultivatable lands and resources. With the end of 30-year war, now our cultivatable land in the country has increased back remarkably. If the policy makers and relevant authorities pay due attention to facilitate rational cultivation, distribution, value-addition and marketing of agricultural produce within the island and beyond, we will not have any issue. Hence, for Sri Lanka to switching to GM food production is not a burning issue yet. But if we need to produce foods for export market, we may need to be dependant on GM technology. In this context, as the Green Revolution demonstrated, in order for people to make GM crops truly beneficial to the developing world, plant breeders and other scientists must be familiar with the local environment and the planting methods of each district for which they are developing GM crops.

One of the most remarkable facts about the development of GM crops is that, despite years of immense public concern, political controversy and the developing scientific understanding of the risks of GMOs, very few of these risks are actually assessed in the official regulatory approval process. Those who are for GM foods merely want to introduce them without a thorough and systematic testing procedure as it is superiorly profitable. On the other hand, those opposed to GM foods generally believe that any overall assessment of the list of risks indicates that GM crops are currently far too risky to be used for food or animal feed. Within this debate we are talking about GM food myths and facts. Gene Revolution is a relatively new area based on molecular level techniques. This is hardly visible to normal layman and hence there is room for myths and insincere capitalisations.

A perceived safety concern on GM foods has been raised about unintended entry to the food chain. We need to treat foods as a valuable production factory for foods, vaccines and other pharmaceutical products as we have done for other food-producing organisms like microorganisms. Yeast, for example, is used to produce pharmaceuticals and vaccines, as well as bread and beer. In this way, we will bring beneficial products to the marketplace, to save lives without unnecessary risk. In this context, local and international authorities should allow the production of GM crops/animals/foods after having the produce assessed on a 'case-by-case' basis as there is no way that one can give a blanket endorsement to GM foods as a whole. The giant countries have begun the Gene Revolution. Willy-nilly, we are compelled to become victims or beneficiaries. We Sri Lankan, as an intelligent nation, should be able to select the good and to reject the bad. We may give green light to products like edible vaccines as new pharmaceuticals from botanical sources. Likewise, the world should prioritise what is to be promoted and what is not. In this context, institutions like media, decision-makers and Academia have an essential role to play in an unbiased manner. Still, one should remember that, GM foods or any other intervention alone will not eliminate hunger. It has to be a complementary approach. Then only can it be a true "Gene Revolution."

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