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UNIT I – TOPIC 5

GENETICALLY MODIFIED FOODS

29.1 Introduction

With the recent advancements in the area of rDNA (Recombinant DNA technology) and Genetic Engineering(Genetic engineering is the process of altering an organism's DNA to change its characteristics. It can involve adding, removing, or repairing DNA. Genetic engineering is also known as gene manipulation or recombinant DNA technology), virtually any desired trait or gene from any organism or even the synthetic gene can be introduced / expressed in any organism including bacteria, yeast, insect cells, plants and mammals. These spectacular advances made in the area of rDNA technology have been successfully exploited in different sectors *viz.* agriculture, health care, food processing industry as well as environment.

Genetic modification process:

- GMOs are created using genetic engineering techniques that involve the manipulation of an organism's DNA in a laboratory setting.
- This manipulation can involve the insertion, deletion, or modification of specific genes within the organism's genome.
- Techniques such as gene splicing (Gene splicing is a process that involves cutting and recombining DNA to alter an organism's genetic structure), gene editing (e.G., Crispr-cas9), or recombinant DNA technology are commonly used.

Characteristics of GMO s:

1. **Insect resistance**:

Insect-pests are the major scourge of agriculture down the ages as important crops and high-yielding genotypes are susceptible to insect pests.

2. Resistance to abiotic stresses:

Abiotic stresses such as drought (water deficit), excessive watering (water-logging/ flooding), extreme temperatures (cold, frost, and heat), salinity (sodicity) and mineral (metal andmetalloid) toxicity negatively impact growth, development, yield, and seed quality of crop and other plants.

3. Improved quality:

To improve the quality characteristics of the plant,genetic engineering techniques are mainly focused upon developing plants with A longer shelf life of fruits, reducing the starch level and production of novel carbohydrates, modification of storage proteins, improving the amino acid compositions, improving fatty acid compositions and increasing nutritional factors.

PURPOSES OF GENETICALLY MODIFIED FOODS

- **1. Increased Crop Yield:** GMOs aim to enhance agricultural productivity by developing crops that produce higher yields per acre of cultivation.
- **2. Pest and Disease Resistance:** Genetic modification introduces traits that make crops more resistant to pests, pathogens, and diseases, reducing crop loss and the need for chemical pesticides.
- **3. Herbicide Tolerance:** GMOs are engineered to tolerate specific herbicides, allowing farmers to control weeds more effectively without harming the crop plants.
- **4. Improved Nutritional Content**: Genetic modification can enhance the nutritional profile of crops, enriching them with essential vitamins, minerals, and other beneficial compounds to address nutritional deficiencies.
- **5. Extended Shelf Life**: GMOs may exhibit traits such as delayed ripening or enhanced resistance to spoilage, prolonging their shelf life and reducing food waste.
- **6. Environmental Sustainability**: GMOs contribute to sustainable agriculture by reducing the environmental impact of farming practices, such as minimizing pesticide use and preserving soil health.
- **7. Adaptation to Climate Change**: Genetic modification helps develop crops resilient to climate change-induced challenges like heat, drought, and flooding, ensuring food security in a changing climate.

29.2 Definition of GMO

A genetically modified organism (GMO), referred to as a living modified organism or transgenic organism means any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology i.e genetic engineering or rDNA or the manipulation of an organism's genetic endowment by introducing or eliminating specific genes through modern molecular biology techniques.

Genetically modified organisms (GMO) have found tremendous applications in health care e.g. therapeutic proteins, vaccines, diagnostics and gene therapy. The health care products address life threatening situations wherein risks and benefits need to be balanced and hence generally no ethical issues arise. There is not much public debate on the use of medically important GMO products since they are purified from recombinant organisms in contained environment. On the other hand, genetic modification in agriculture is a sensitive issue and thus has raised lot of concerns with regard to human health.

29.3 Genetic Engineering in Health and Medicine

Genetic Engineering (GE) has tremendous applications in health and medicine. A number of recombinant pharmaceutical proteins to be used as potential drugs have been produced using GE. GE has been used to produce several useful proteins into sheep and cow's milk e.g. factor IX, alpha-1-antitrypsin, streptokinase etc. Moreover, genetic engineering has helped in development of vaccines, gene therapy, xenotransplantation, designer babies etc.

29.4 Genetic Engineering in Food and Agriculture

The application of genetic engineering in food and agriculture to produce genetically modified (GM) foods particularly transgenic plants has been very controversial in comparison to the products for human medical importance. Genetic engineering is mainly used in agriculture to make plants with enhanced yield, high nutritional value like golden rice with increased levels of beta carotene (to meet vitamin A deficiency), disease resistance, plants that can tolerate high salt, draught resistance, pest resistance like Bt genes to kill selectively pests that eat crops. GM crops have also been designed to produce pharmaceuticals and hence are also called "pharma crops." Ventria Biosciences (Sacramento) have launched GM rice with two synthetic human genes viz. human lactoferrin and lysozyme. However, there was fear among people that GM rice could cross-pollinate other crops and introduce foreign genes and proteins into the human food chain. INB Biotechnologies (Philadelphia) is developing a nontoxic anthrax vaccine through the transgenic modification of petunias, causing the plant to manufacture new proteins, which when eaten prompt the development of anti-anthrax antibodies.

Several countries of the world use GM crops for food production but in certain countries GM crops are not

acceptable. The ethical issues with regard to GM crops are being described below.

29.5 Ethical Issues on Use Of GMO

Risks arising from the application of GMOs in agriculture include risks to human health, environment besides ethical concerns. There are concerns, doubts and fears in the mind of common men about genetic engineering. There are people who are pro and anti genetic engineering. There is no doubt that genetic engineering offers great opportunity for solving hunger, food insecurity and malnutrition problems globally. On the other hand, some people think that genetic engineering is unnatural and people are scared to buy GM foods since they think that genes will be transmitted to them. Moreover, some of the companies even do not label GM foods. Although, people in US eat GM foods but in Europe, people are not willing to accept GM foods because of fears of risks and other ethical concerns. However, GMOs need to be tested extensively for toxicity to humans and animals before their release in the market. Sometimes, newer proteins may behave as allergens. GMOs are generally produced involving antibiotic resistance genes which raises the concerns of antibiotic resistance gene transfer on consumption. All these are discussed in the following section.

29.5.1 Antibiotic resistance

There have been several issues raised at different platforms on the use of antibiotic resistance markers in selection of recombinant organisms (GMOs).

i. It is generally assumed by people that eating foods with antibiotic resistance markers would reduce the effectiveness of an antibiotic since the antibiotic will be degraded. This issue was raised during the approval for Galgene's FlavrSavr and Ciba Giegy's Bt corn 176.

ii. The transfer of antibiotic resistance marker gene from GMO to intestinal microflora also poses risk of horizontal gene transfer which can lead to antibiotic resistant micro-organisms, although its probability in acidic environment is extremely rare.

In view of the above issues, antibiotic resistance markers are being replaced with auxotropic or food grade markers.

29.5.2 Eating exogenous/foreign DNA

There are also apprehensions regarding the ingestion of exogenous DNA while eating transgenic foods. However, there are no scientific reports that DNA from these transgenic crops or foods pose any risk to human health. Generally, the foreign DNA is destroyed by the body's defense mechanism. Generally, DNA present in micro-organisms, plants and animals are eaten by human beings all the time and does not pose any problem. Similarly, the exogenous DNA is not likely to pose any health problem.

29.5.3 Food safety

Consumers are sometimes wary of the safety of GM foods due to problems such as allergens, pesticide residues, microbiological contaminants and bovine spongiform encephalopathy (mad cow disease). There is also a common notion that GM crops are unsafe for other organisms that feed on them e.g. Bt toxin may kill Monarch butterfly larvae. However, there are no scientific evidences to support this.

29.5.4 Environmental concerns

GMOs are novel products which, when released, may cause ecosystems to get polluted unintentionally and may also result from out-crossing with wild populations. GMOs may get released in the environment and pose several risks such as transgene instability, transfer to weeds, persistence of transgene in the environment, loss of biodiversity, changes in soil ecology, generation of new live viruses etc. NGOs have also raised the concern that growing genetically engineered crops will be harmful for the environment e.g. if herbicide resistance genes from canola flows into weedy relatives will make them resistant to herbicides. There are no scientific studies to support this. Moreover, the risks to birds, insects and other non-target species that come into contact with or consume GM plants is not known. Hence, the extent of post-release monitoring of GMOs is required to protect ecosystems.

29.5.5 Risk of toxicity

GMOs need to be evaluated for toxicity rigorously in animal models before their release for human consumption. Sometimes, the companies hide the controversial data in this regard for getting clearance from regulatory authorities.

29.5.6 Risk of allergies

The proteins from GMO may become allergens and hence need to be tested for allergenicity. Since GM foods are not labeled, a person could suffer a potentially fatal allergic reaction e.g. an allergenic Brazil nut gene was transferred to a soybean variety, but the resultant modified crop was never released to the public because of this problem. The FDA considers potential allergens to be a very important issue. Developers are required to systematically evaluate this possibility. Special care is taken with genes derived from foods that commonly cause food allergies. For example, about 8% of the people are allergic to foods that contain milk, wheat, some seafood, or nuts. The FDA regulations state that proteins taken from commonly allergenic foods are presumed to be allergens unless demonstrated otherwise. So far, no products on the market contain such allergens. If they do, FDA requires that they be clearly labeled biotech.

29.5.7 Exploitation of farmers

Biotechnology offers considerable possibilities to increase the food demand and help eliminate the anticipated shortfall with increasing human population. However, there is considerable concern that small-scale farmers should not be exploited by large international companies. The possible use of 'terminator' genes (that make seeds sterile) is one such example. They would help to reduce the hazards of environmental dispersal, however farmers in developing countries traditionally save seed from one season to the next and cannot afford to buy new supplies every year. GE is very expensive and needs lot of investment and it would not be available to poor farmers. Moreover, there could be potential loss of traditional farming practices such as collecting, storing, and replanting seed.

29.5.8 Perceived risks and benefits

While accepting any new technology like GMO, consumers always weigh the perceived benefits of accepting it against the perceived risks. The scientific evidence is required to prove their benefits.

29.5.9 Accountability

Consumers should be involved in local, national and international debates and in policy guidance. There are very few for a available to the public to discuss the wide range of issues related to GMOs. Consumers comprising everyone in the world (and including future generations) also have a stake in the process. Consumers choices to buy non-GM or GM foods cannot be ignored. They are not forced to buy the food that they don't want. Keeping this in mind, some of the leading GM crop producers are reconsidering their production decisions and the agrifood industry is rapidly restructuring.

29.5.10 Loss of biodiversity

There is a concern among people that extensive use of GM crops / foods will lead to loss of our biodiversity. GM crops could compete or breed with wild species threatening biodiversity. We need to retain our traditional foods.

29.5.11 Soil fertility

It has been demonstrated scientifically that GM crops transfer their genes to soil fungi and bacteria. The affected fungi and bacteria then behave in abnormal ways and diminish their function in breaking down organic material, which makes nutrients available to plants. The soil becomes progressively less fertile. After a few seasons of planting GM crops, the soil will not be able to host any other conventional crop. If farmers wish to switch back to conventional crops, it could take a whole season to rehabilitate the soil. Hence, the economic consequences are unfavorable besides the added cost of nutrients and fertilizers which are necessary to regenerate the soil.

29.6 Entry of GM Farm Animals Versus GM Crops in the Market

Although, GM crops have entered the market, products derived from GM farm animals have not reached the market. The scientific developments of transgenic farm animals has been accompanied by manifestations of perturbed physiology, including impaired reproductive performance. These have raised ethical problems of animal welfare, hence dampened the consumer's interest. So far, the prospects of foods from transgenic farm

animals has not been well received by consumers. Consumers are accepting more of transgenic plants than of transgenic animals. Altering animals is a less acceptable practice and has broader implications since various cultures and religions restrict or prohibit the consumption of certain foods derived from animals. However, ingesting or injecting of certain pharmaceutical products from transgenic animals is more acceptable to the public. Pharmaceutical drugs produced using transgenic animals are acceptable since benefits overweigh the risks associated with them.

Although, all the above concerns are valid, there is no evidence that genetically engineered food is dangerous. We do not have any idea on long term consequences of eating GM foods on our health.

29.7 Potential Benefits of GMOs

Benefits of GMOs include:

- There are potential benefits to agricultural productivity through the development of crops which are more resistant to disease, pests and also to harsh weather conditions which decrease the risk of devastating crop failure.
- Genetically engineered pest and disease resistant crops could reduce the need for hazardous pesticides and other chemicals, thereby decreasing the environmental load and farmer exposure to such toxic chemicals which lead to human health risk to various dreadful diseases.
- GM crops with extended shelf life could decrease the gross wastage associated with transportation and storage.
- Allergenicity problem could be tackled through GE which could be used to remove genes associated with allergies, e.g., the blocking of the gene that produces the allergenic protein in peanuts.
- The GM crops with high nutritional value or healthier foods (eliminating trans fats or caffeine) could be produced through GE e.g. Golden rice and rice with human lactoferrin and lysozyme.
- GE could be used to develop pharmaceuticals and vaccines in plants, decrease the risk of adverse reactions and enable faster vaccination of large populations.

29.8 GM Crops in India

In India, field trials of GM crops have been carried out extensively and GM crops like the Golden Rice (which is rich in proteins) have been used. Unfortunately, the GM business is owned by top multinational companies

and agribusiness is only for vested interests. India is the third largest producer of cotton after China and the U.S. GEAC gave approval for commercial plantation of the genetically engineered Bt cotton (to enable it to resist bollworm, a major pest for cotton) in four states of southern and central India in 2002 following which famers decided to grow GM cotton. However, Bt cotton failure led to loss and Monsanto declined to even acknowledge. India is becoming a dumping ground for GE Crops As the world is waking up to human health and environment nuisance from the GM crops, International companies want to dump their products in India. In India on the other hand, besides cotton, genetic engineering experiments are being conducted on maize, mustard, sugarcane, sorghum, pigeonpea, chickpea, rice, tomato, brinjal, potato, banana, papaya, cauliflower, oilseeds, castor, soyabean and medicinal plants.

29.8.1 Bt Brinjal in India

The Bt brinjal is a transgenic brinjal (egg plant or aubergine, Fig. 29.1) created by inserting a crystal gene (Cry1Ac) from the soil bacterium *Bacillus thuringiensis* into the genome of various brinjal cultivars. The Bt brinjal has been developed to give resistance against lepidopteron insects, in particular the Brinjal Fruit and Shoot Borer (*Leucinodes orbonalis*) (FSB). It has been developed by global agri giant Monsanto's Indian partner, Maharashtra Hybrid Seed Company (Mahyco). India grows over eight million tonnes of brinjal annually and is the second largest grower of this vegetable in the world after China. The annual market for brinjal is estimated to be around Rs 8,000 crore ($1.8 billion) and nearly 40 percent of the crop is lost due to attack by a major pest, Fruit and Shoot Borer. The Bt variety would have offered resistance and killed this major pest. Seven major states which together account for more than 70 percent of brinjal cultivation in the country have declined to introduce Bt brinjal. Hence, Indian government has not permitted commercial cultivation of the country's first GM food product.

The anti-GM (genetically modified) groups have been successful in not allowing the introduction of the country's first GM food crop although the GEAC approval was accorded on October 14, 2009 based on the issues that it threatens biodiversity and is unsafe for human consumption as well as ethical concerns such as corporate control of the food supply and intellectual property rights.

However, proponents of GM technology believe that Bt brinjal will have positive effects for the Indian economy and the health of the farmers. Field trials conducted on research-managed farms carried out by

Mayhco and the Indian Council of Agricultural Research have indicated a 42% pesticide reduction with a doubling of the yield.. The economic gain for consumers, developers and farmers was estimated to potentially be US$108 million per year with an additional $3–4 million saved due to health benefits associated with decreased pesticide use.

The Foundation for Biotechnology Awareness and Education (FBAE), a non-profit organization formed to promote public awareness of scientific issues of biotechnology and to enhance levels of biotechnology education and training based in Bangalore has called for an immediate lift on the moratorium on the commercial release of Bt brinjal citing recent publications on the socio-economic benefits such as better living standards, health and education, and reduced tension, among the farming community and a healthier product to the consumer, that would accrue from the adoption of Bt brinjal.

29.9 Conclusion

Although weighing risks and benefits is necessary, it is neither easy nor the sole concern in considering the ethics of GM crops. Both human health and environment safety are of primary concern. All such issues should be dealt with before releasing GM crops. Scientists claim that GM foods will solve the problem of world hunger and malnutrition. Food scientists and technologists can support the introduction of GM technologies provided that issues of product safety, environmental concerns, ethics and information are satisfactorily addressed to so that the benefits that this technology can confer become available both to improve the quality of the food supply and to help feed the world's escalating population in the coming decades.