



Production and Consumption of Genetically Modified Food: An Islamic Perspective

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Abstract

The chemical composition of the genetic material or DNA (deoxyribo nucleic acid) of all living organisms is similar, and different organisms use the similar coding sequences of nucleotides, monomers of DNA, to synthesize proteins. These compositional and functional similarities of DNA have made it possible to transfer gene(s) from one organism to another, as well as to introduce into a given organism phenotypes that do not naturally occur in that organism. The products of such modification (genetic modification) are often directly or indirectly linked to human health; they include drugs and vaccines used in therapeutic and preventive medicine; modified or wild types of genes used in the treatment of hereditary disorders; and genetically modified (GM) food and food products for human consumption. This paper reviews the possible and observed impact of GM food and food products on human health from an Islamic perspective, and discusses two major issues. The first relates to the existence of scientific evidence that the consumption of GM food products resulting from manipulative processes that are contrary to or interfere with the processes of genetic change as they occur in nature (e.g. natural breeding or natural hybridisation) can change the natural balance or homeostasis in human physiology and metabolism. The second relates to the priority given to the principle of balance and equilibrium in Islam's teachings about Allah's creation; with regard to this second issue, the paper raises concerns as to the necessity as well as the permissible boundaries of GM in the Islamic framework.

Keywords: *genetically modified food, natural hybridization, equilibrium in human health, balance in Allah's creation.*

Abstrak

Komposisi kimia bahan genetik atau DNA (asid deoksiribonukleik) semua organisma hidup adalah sama. Pada masa yang sama, organisma yang berbeza menggunakan jujukan kod nukleotida yang sama yakni monomer DNA untuk mensintesis protein. Persamaan komposisi dan fungsi dalam DNA telah membolehkan pemindahan gen daripada satu organisma kepada yang lain dan memberi fenotip tambahan kepada sesuatu organisma yang mungkin tidak wujud secara semula jadi. Produk bagi modifikasi seperti ini (modifikasi genetik) yang secara langsung atau tidak langsung berkaitan dengan kesihatan manusia meliputi ubat-ubatan dan/atau vaksin yang digunakan untuk tujuan klinikal, gen termodifikasi atau liar untuk merawat penyakit keturunan dan makanan termodifikasi genetik yang diambil oleh manusia. Kertas ini meninjau impak makanan dan produk makanan termodifikasi genetik yang mungkin berlaku pada kesihatan manusia. Tindakan manusia memanipulasi modifikasi genetik adalah berbeza daripada perubahan genetik secara semula jadi seperti pembiakan atau penghibridan semula jadi yang terbukti dapat mengubah perimbangan natural atau homeostasis dalam fisiologi manusia dan metabolisme. Tambahan lagi, menekankan 'keseimbangan' dalam ciptaan Allah, kertas ini juga menimbulkan persoalan tentang keperluan dan batas yang mungkin dibenarkan dalam produk-produk yang termodifikasi secara genetik.

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Kata kunci: makanan termodifikasi genetik, penghibridan natural, keseimbangan dalam kesihatan manusia, imbalan dalam ciptaan Allah.

Introduction

The genetic material or DNAⁱ (deoxyribo nucleic acid) of all living organisms consists of four types of nucleotidesⁱⁱ. The number, order, sequence, and the length of the nucleotide sequence in DNA vary from one organism to another. Besides DNA, living organisms also contain another type of nucleic acid namely RNA (ribonucleic acid). Nucleotide sequences of the DNA are used to synthesize proteins for which building blocks are amino acids. A major group of RNA namely mRNA (messenger RNA) is the intermediate precursor for protein synthesis. Different organisms use the same (or with little variation) coding sequenceⁱⁱⁱ of nucleotides for synthesizing the same proteins. In other words, if different organisms, even distantly related, use the same protein for the same biological activity, they use the same sequence of nucleotides to synthesize that protein. These unique characteristics have made it possible to transfer gene(s) or genetic material from one organism to another. This in turn allows gene technologists to introduce change genetic characteristics into an organism which may not exist naturally. Organisms with the added or changed and sometimes considered as new, genetic characteristics are termed as genetically modified or transgenic organisms. The process itself is called genetic modification.

Gene technologists have aimed for different types of genetic modification by addition, deletion, or modification of nucleotide sequences of gene(s)^{iv} of one organism that can be expressed in the same or different organism. The products of modified genes which are directly or indirectly linked with human health can be broadly categorized as: (i) drugs and/or vaccines used for clinical purposes (ii) modified or wild type of genes used to treat hereditary disorders and (iii) genetically modified (GM) food and food products used for human consumption.

This paper aims to discuss the possible and observed impact of consumption of GM food and food products, on human health. Initially this paper will focus on the basic concepts of gene, gene technology, and genetic modification. Human manipulated genetic modification will then be compared with the natural course of genetic changes i.e., natural breeding or natural hybridization. While discussing the impact of GM products on human

health, emphasis will be given on how the natural balance or homeostasis in human physiology and metabolism is affected. Finally, stressing on the equilibrium in the creation of Allah, the necessity of and the possible allowable boundary of GM products will be discussed.

Gene, genetic technology and genetic modification

Modern gene technology was perhaps germinated in Mendel's^v pea garden. Eventually, the chemical nature of the genetic material (chromosome) as DNA and RNA; the building blocks of DNA or RNA i.e., the nucleotides, genetic code, and mechanism of control of gene expression and many other aspects of genetic material have been revealed. The genetic material or DNA is considered both as a storage and controlling repertoire of instruction and information for all phenotypes^{vi} of living organisms including animals, plants, bacteria, and viruses. The expression of biomolecules like proteins resulting in specific traits or phenotypes of living organisms are linked to the nucleotide sequences of DNA.

To date the complete genome (DNA) of a number of prokaryotic organisms such as viruses and bacteria and higher eukaryotic organisms such as rodents and humans have been sequenced. Knowledge of the sequence and composition of genetic material; controlling mechanism of gene expression and its transfer have eventually enabled gene technologists to use and manipulate genes for various purposes. Similarly, the chemical nature of the genetic material and a similar mechanism of action both in the control and expression of genes in all living organisms whether prokaryotic or eukaryotic have further contributed to such developments.

Although a wide range of genetic variation amongst living organisms exists, which includes the variation in number, order, sequence, and the length of the nucleotide chain in the DNA, the same protein from different organisms have the same (or with little variation) coding sequence and length of the nucleotides. In other words, the same protein in different organisms is usually expressed (synthesized) using the same universal nucleotide sequences (Figure 1). Expression of genetic sequences takes place in a tri-nucleotide sequence i.e., three consecutive nucleotides

in a sequence, called a genetic code, and determines which one of the naturally occurring twenty amino acids will be added to the polypeptide chain

These unique characteristics of genetic materials have made it possible to transfer gene(s) or genetic characteristics hence the phenotype of one organism to another. Because of the chemical nature it is also

possible to synthesize polynucleotide in vitro and to insert such polynucleotide sequence in the genome by an organism. Thus gene technology has enabled us to create genetically modified organisms by inserting, deleting, and/or replacing segments of gene sequence either synthesized or taken from a natural source to other living organisms.

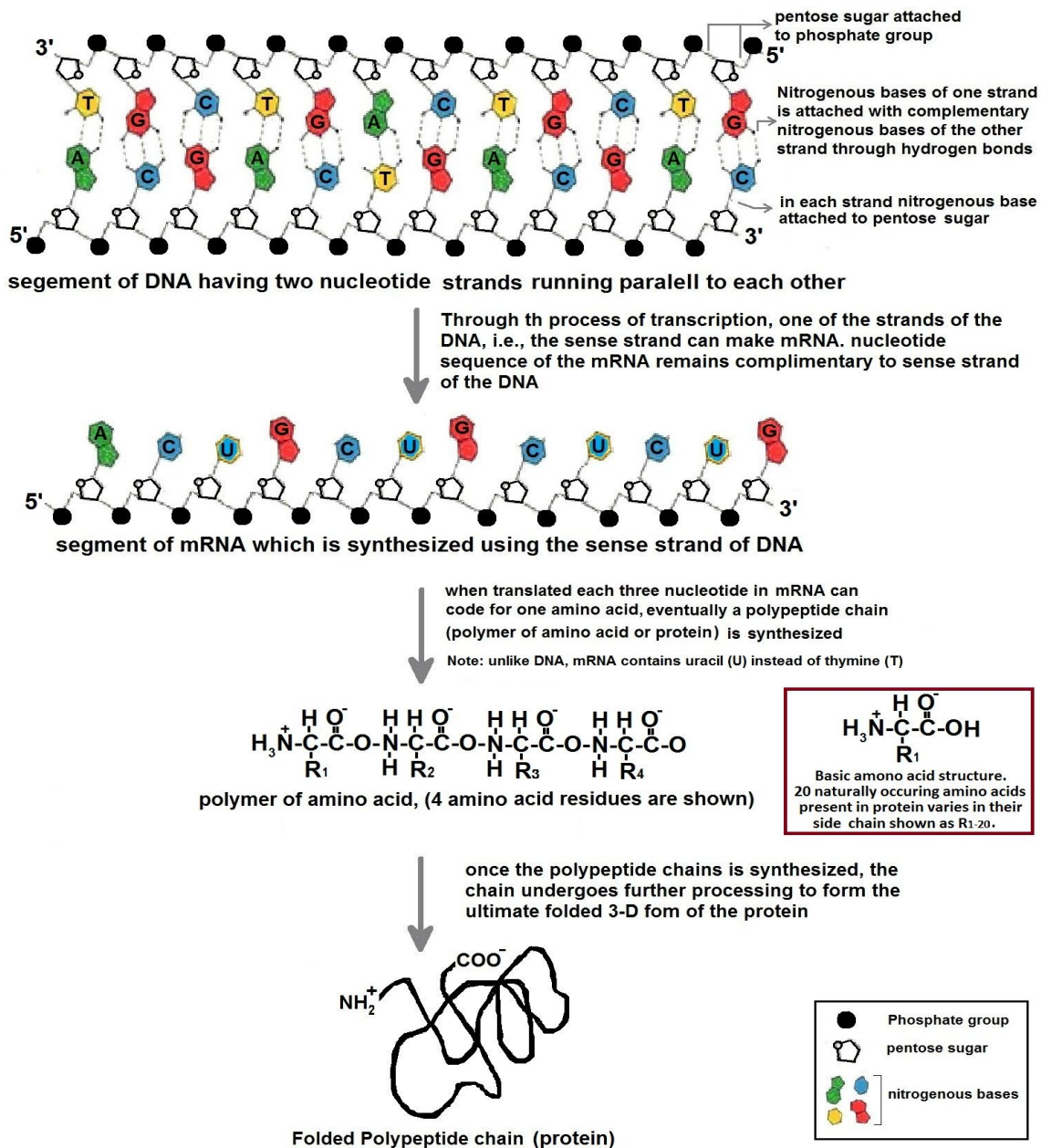


Figure 1. Major steps involved in synthesis of protein from nucleotide sequence of DNA. note: Human genome contain 2.91 Gbp nucleotides while average length of a gene is ~ 27 Kbp

Natural breeding is different from targeted genetic modification

Genetic modification aimed for specific change in genetic characteristics is often compared with natural breeding or natural hybridization. Indeed both these phenomena may lead to a generation of new genotypes and respective phenotypes (traits) through modification in genetic constituents. However, natural breeding and genetic modification through gene technology have major differences (Table 1). While genetic technology involves targeted transfer of genetic material for specific genetic modification, genetic modification in natural breeding takes place spontaneously. In case of natural breeding, new traits are achieved through genetic modification resulting from the exchange of genetic material between two species, often closely related or two individuals of the same species. Here, the nature and extent of genetic modification depends on

the naturally occurring spontaneous exchange of genetic materials, where the whole genome or genetic material is involved in the exchange process. In other words, the possibility to exchange a whole range of related genes from the genetic repertoire exists in the process of natural breeding. Therefore, the adaptation or fate of genetic modification, through natural breeding is determined naturally.

Targeted genetic modification achieved by trans-gene technology, on the other hand, does not exist. Using this technology, genetic modification is decided and manipulated by gene technologists better known as biotechnologists who tailor the target gene(s) or segment of a gene to produce transgenic plants/animals. Therefore, the transgenic species are those that contain new gene(s) or modified version of existing gene(s) that are not available in their natural counterpart.

Table 1: Comparison between Natural hybridization and Genetic modification

Features	Natural hybridization (Breeding)	Genetic modification through gene technology
Nature of transfer	Spontaneous transfer.	Targeted transfer.
Species or organisms involved in exchange of genetic material	Same or closely related. Breeding takes place between plants and plants or animals and animals. Natural breeding does not take place among different species (e.g., plant and animal).	Can be between distantly related organisms. For instance, genes from plants or microorganisms can be introduced into animals.
Type of exchanged genetic material	Exchange takes place between the closely related or similar chromosome/ genetic material.	Exchange can be targeted to unrelated chromosome/ genetic material.
Amount or quantity of genetic material exchanged	Determined naturally. A range of related genes can be exchanged.	Determined manually. Only the selected part is being exchanged.
Target site of modification	Determined naturally. Target site is often closely matched such as similar chromosomes.	Determined manually. Specific to what is being targeted.

Purpose of genetic modification of natural sources of food and food products

Food is one of the basic needs for human survival. Mankind is dependent on nature for the source of food such as plants, animals, and sea creatures. To make the natural source of food readily available for consumption, mankind has been harnessing nature to search, produce, and store their own choice of food and food products. This involves (i) the cultivation of crops and grains (ii) farming animals that can be used to get food and food products and (iii) searching for new varieties through natural hybridization of existing natural source of food. However, the demand for food has been ever increasing with the rising of population throughout human civilization. It has been predicted by the UN that global human population may reach 9 billion by the year 2300 (Whitaker, 2004). Therefore the increasing demand for food is expected to rise. As predicted by the UN, the increasing demand for food is the result of not only an increasing world population but also due to lower productivity of natural sources of food and food products.

While control over the population growth is limited for various reasons, increased productivity has been identified as a top priority to mitigate the anticipated scarcity of food. And genetically modified food with higher productivity has been given priority to this projected short supply of food. Moreover natural sources of food and food products are also deemed to have qualities that scientists want to improve through

human intervention. Hence, a group of biotechnologists (gene technologists) are immersed in relentless efforts to develop genetically modified animals and crops to overcome the alleged inadequacy and/or suboptimal quality of food and food products of wild/natural origin. Naturally available sources of food and food products are being genetically modified with several purposes as summarized in Table 2. It is important to mention that gene technology or genetic modification is also applied for the large-scale production of expensive medicinal products, e.g. antibodies, vaccines, and other medicinal proteins.

To fulfill the purposes, in other words to achieve these properties by genetic modification, related gene(s) are taken from one organism (or species) and transferred to another organism (or species). Therefore, GM products that are being used or planned for human consumption can be further grouped in different ways, for example, based on: (i) the origin of the gene being modified or incorporated (ii) the host organism where the modified or incorporated genes are being expressed (iii) the purpose of the genetic modification and (iv) the form of the genetically modified products being consumed or planned for consumption (Table 3). Consumable products from a genetically modified plant, for example, may contain the genes of microbial origin product which may not be intended for the human consumption but for other purposes like better survival of the plant from which the consumable product is obtained.

Table 2: Major purposes of genetic modification of natural origin of food and food products

Purpose of genetic modification	Examples
Environmental stress tolerance	To make the plants or crops such as rice and maize tolerant against salt, flood, and drought so that the modified plants can be grown in these adverse conditions.
Nutrient enrichment	To enrich nutrient content or composition of some animal- or plant-based food products, e.g., vitamin A or ferritin enrichment of rice, albumin enrichment of cow milk.
Pest, herbicide and parasite resistance	To protect crops from attacks by pest and parasite etc. For example, gene from the soil bacterium <i>Bacillus thuringiensis</i> , that code for a protein to protect the crop from being attacked by the corn borer is transferred to maize.
Higher productivity, shelf life (storage)	For example, slow-ripening tomato, super salmon that can grow in size for marketing in 18 months, somatotropin gene insertion for higher production of milk.

Table 3: Groups of GM products being used or planned for human consumption

Origin of the gene being used	Microorganisms	Plants	Animals
Host that harbor the foreign gene	Microorganisms	Plants	Animals
Purpose of the genetic modification	Nutrient enrichment	Better/Higher productivity	Clinical use
Form of consumption	Extracted or purified product	As a part or component	Unintentional

Genetic modification alters the natural composition of food and food products

Food and food products are generally categorized based on the content of nutrient such as carbohydrate, protein, fat, minerals, vitamins, etc. Each and every natural source of food is rich in one or more of these nutrients. For example, meat from cattle and poultry contain more protein while rice and wheat contain more carbohydrates. Again, both these sources of food contain minerals and other nutrients with varied content. It is important to note that each kind of food source has specific composition. In other words, nutrient contents and their ratio vary from one food source to another. Some natural sources of food and their nutrient compositions are shown in Table 4.

Targeted genetic modification through addition, deletion, or modification of one or part of a gene may result in change of the natural composition of the food

by the modified or added genes in GM foods can be broadly divided into two categories: protein and non-protein substances. Protein substances are generally the direct products of introduced or modified genes and are known as primary gene products. Non-protein substances in GM foods are produced in metabolic pathways catalyzed by the introduced or modified enzymatic proteins. Non-protein substances are known as secondary gene products and belong to a greater diversity of chemical classes. Depending on the reaction or response upon consumption of GM food these substances may be toxic, anti-nutritional, and/or allergenic. Toxic and anti-nutritional effects can be produced by protein and non-protein substances while allergenic effects are attributable primarily to protein substances (Kuiper et al., 2001; Cellini et al., 2004). Targeted genetic modification through addition or modification of one gene may also cause some

Table 4: Nutrient compositions in natural sources of food & food products

Food/ Food products	Mineral	Vitamin	Protein	Carbohydrate	Fat
Blossom Honey (g/100g) ^[Bogdanov et al., 2008]	0.2	2.3 [Vit C]	0.3	79.7	0
Goat's Milk (g/100 g) ^[Ohiokpehai 2003]	7-9		20-67 [Casein]	40-50 [Lactose]	30-38
Ripe Papaya (g/100g) ^[Krishna et al., 2008]	0.5		0.6	7.2	0.1

and food products. For instance, naturally occurring rice has a certain composition and ratio of all its minerals, vitamins and other bio-molecules. Addition of one component like vitamin A can change the overall composition and can cause imbalance to the overall natural ratio of vitamin A to other biochemical component(s) or minerals of rice. Regardless of the method of genetic modification, substances produced

unpredictable changes. These unpredictable changes are most likely to take place because of the unknown involvement or influence of the new or modified gene products within the myriads of molecular and biochemical events. Therefore, the altered nutrient compositions resulting from the targeted (or imposed) genetic modification are most likely to have direct influence on human health after consumption.

Transgenic organisms and plants are also most likely to alter the natural biodiversity resulting in extinction of natural plants and animals thus, the altered environments might also influence human health. In the following discussion, more specific examples are given to describe the consequences of genetic modification that are related to the altered composition of food and food products.

Human health – A dynamic equilibrium or state of balanced well being

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO). Such a state of complete well-being can be achieved only by ensuring ‘equilibrium’ or in other words by ‘proper maintenance of the balance’ within the physiological systems of the human body. As argued, health is also considered as a process of continuous adjustment to the changing demands of living and of the changing meanings we give to life rather than a ‘state’. This process of ‘continuous adjustment’ is required to achieve stability i.e., the balanced condition. Whichever of these statements suits best to define health, it is apparent that good health refers to a ‘balance’ that is maintained through the complicated interactions between the biochemical and molecular components and events within the physiological systems. The number of such biochemical and molecular events governed by biomolecules and the number of interactions between these events and biomolecules are countless.

Living organisms, including humans regulate their internal environment and maintain a constant stable condition or state of equilibrium (homeostasis) by means of multiple dynamic equilibria which are controlled by a complicated array of interrelated regulatory mechanisms. Each and every component and event needs to be in a state of homeostasis to ensure a proper and balanced physiological functioning. In a healthy state, all the necessary (bio)molecules including minerals and vitamins maintain a constant physiological range both quantitatively and qualitatively. Deviation from that range can be physiologically harmful. Notably such interactions are not only internally controlled within the body but are also influenced by external or environmental factors.

Balance in the creation of Allah

It is not only the human health which maintains dynamic equilibrium for a balanced healthy state, the rest of Allah’s creation also have been created in

balanced and due measurement. According to the teachings in Islam, the creations of Allah are approved as the balanced ones. In other words, Allah has created everything in measured proportion. Many verses of the Holy Qur’an mention this. To quote just a few:

And the earth We spread out, and placed therein firm mountains, and caused to grow therein all kinds of things in due proportion.

[The Qur’an 15:19]

He has created everything, and has measured it exactly according to its due measurements.

[The Qur’an, 25:2]

Verily, all things have We created in proportion and measure.

[The Qur’an, 54:49]

Therefore, essentially everything, as mentioned in the quoted verses, which is created by Allah, including the human being, is an epitome of measured proportion. Qur’an clearly declares this:

O man! what has made you careless concerning your Lord, the Most Generous? Who created you, fashioned you perfectly, and gave you due proportion.

[The Qur’an, 82:6-7]

The Balance that Allah has set up [The Qur’an, 55:7] is connected figuratively with the heavens and sustained by mathematical balance. Allah requires Man, His supreme creation, not to act contrary to the balance; as He says:

In order that you may not transgress (due) balance, and observe the weight with equity and do not make the balance deficient.

[The Qur’an, 55:8-9]

Thus, Man is entrusted with the responsibility of keeping balance in his conduct within every sphere of his life. Besides, Qur’an appeals to all people, not only the believers, that they should eat lawful and wholesome foods [The Qur’an 2:169]. The issue of Halal (allowed) and Haram (forbidden) might be raised concerning the origin of the gene (or the modified one)

and/or the host animal used to obtain the products of that gene. Any food or food products (Table 1) containing the gene(s) from a haram animal (e.g. pig) or is obtained using the haram animal as host would be open to doubt about its being lawful for Muslims. The consideration of complete alteration or modification of the nature of any objectionable ingredient for the final product being lawful does not seem plausible in the light the following Prophetic traditions regarding wine. "Allah did not make your cure in what He had made unlawful to you." Tariq bin Suwaid asked the Prophet (SAAS) about wine which he made only as a medicine; and he replied, "It is not a medicine; it is a disease." "If a big amount of anything causes intoxication, a small amount of it is prohibited."

Altered composition of GM foods – a threat to the balance in human health

Potential adverse health effects can result due to intentional and unintentional changes in the nature or the level of both protein and non-protein substances in GM crops. Changes include both the direct and indirect effects of primary and secondary gene products that can be predictable or unpredictable.

Many GM products developed for human consumption like rice, tomato, maize, cow milk supplemented with additional albumin have different (bio)chemical composition than their natural counterparts. Thus although GM products are aimed to resolve certain problems like scarcity of food and food products, its consumption might lead to an imbalance in physiological homeostasis. To elaborate this harmful effect of consuming GM products, the case of genetically modified vitamin A enriched rice is discussed below.

People in many developing countries are suffering from blindness related to vitamin A deficiency. Additional vitamin A supplement is essential to resolve this health concern. Genetically modified rice enriched with vitamin A is thought to be able to solve this health problem. GM products could offer a solution to this problem by making vitamin A enriched rice. Thus, adequate supply of vitamin A could be ensured at least to those who would consume this genetically modified rice. However, this may give rise to health concerns linked to excessive consumption of vitamin A. Notably, rice is a staple eaten in large quantities in many Asian developing countries. Therefore, GM rice enriched with vitamin A results in an excessive intake which, in turn leads to hypervitaminosis A. Children

given candy-like chewable vitamin supplements have suffered from vitamin A toxicity (Lam *et al.*, 2006). Hypercalcemia can also be caused by iatrogenic hypervitaminosis (Bhalla *et al.*, 2005). Acute or chronic toxicity of vitamin A due to excessive vitamin A consumption are reported to cause liver disease and osteoporosis (Castano *et al.*, 2006; Cheruvattath *et al.*, 2006). Thus GM products that could offer a solution to a health problem still might pose a threat for other health concerns.

Furthermore, benefits as was commonly believed of vitamins A, E, and C, alongside beta-carotene and selenium were disputable through a clinical trial, having 815 subjects, carried out by a research team at Copenhagen University. These supplements are usually taken as a source of anti-oxidant. The results from the study suggested that taking antioxidant supplements neither increased, nor reduced, the risk of early death. However, when the numbers of the clinical trials were adjusted, a higher risk of reducing life span was observed. Beta-carotene produced an approximate 7% increase in risk, vitamin E a 4% increase and vitamin A, a 16% increase. One of the most likely explanations for this increase in risk associates with the knocking out 'free radicals' that have an influence on the natural defense mechanism within the body of the organism. In summary these observations reveals that added nutrients or vitamins to any natural food products might lead to excessive supply of those than the optimum amount required for natural balance of human health and eventually pose potential threat to state of equilibrium of a healthy state.

Mazza *et al.* (2005), studied diet-derived DNA transfer to animal tissues after 35 days consumption of GM plants. They detected a small fragment of transgene (e.g. Cry1A) in blood, liver, spleen and kidney of the animals raised with the transgenic feed while the intact gene or its minimal functional unit was never detected. Their data also showed that the gene transfer is not higher from GM plants than that from conventional plants. Nonetheless, potential physiological effects of a small fragment of DNA cannot be ruled out, since short sequence of nucleic acids like silencing RNA (or siRNA) of around 20-22 nucleotides are involved in post-transcriptional gene silencing and also play vital role through interfering other pathways of gene expression (Hannon *et al.*, 2004).

A comparative analysis of approximately 60 biochemical parameters of blood and different organs of rats fed with three main commercialized GM maize

available globally as reported by de Vendômois et al. 2009. The affected organs include the kidney and liver, the major dietary detoxifying organs as well as the heart, adrenal glands, spleen and haematopoietic system. The signs of hepatorenal toxicity were attributed to the new pesticides specific to each GM corn used in the study. The unintended direct or indirect metabolic consequences of the genetic modification were also raised.

Equilibrium in Creation of Allah and GM products

The GM issues described in the preceding sections are discussed in light of some observable impact on human physiology related to GM induced changes in natural food and food products. The discussions are extended in light of some Quranic verses to expand our understanding of the issues related to balance in the creation of Allah SWT. Therefore, Believers, in particular, can reasonably be worried about GM that threatens balance as discussed. They may as well perceive the risk of falling victims to the snare of Iblis, the accursed, who in vengeance against man declared: "I will mislead them, and I will create in them false desires; I will order them to slit the ears of cattle and to deface the (fair) nature created by Allah" [The Qur'an, 4:118]. Changing the fair nature of Allah's creation is a manifestation of friendship with Satan and utter disobedience of Allah SWT; and its consequence is: "Whoever, forsaking Allah, takes Satan for a friend, hath of a surety suffered a loss that is manifest: [The Qur'an, 4:119].

The Qur'an also dictates the mankind to eat lawful (halal) and wholesome foods. Any food containing the products of gene(s) obtained from a forbidden animal (e.g. pig) or any food which is produced using the forbidden animal as host to express any particular gene of interest would be open to doubt about being lawful for Muslims. Apart from the requirement of Halal, remains the question of Tayyeba which means good, pure, clean, wholesome, nourishing, and pleasing to the taste^{vii}. As the GM consumable products do not match the natural products created by Allah SWT, all of their properties are less likely to be consistent with the multifarious meanings of Tayyeba. This likelihood turns to certainty when GM products in question are imbued with a high potential to adversely affect the balance in human health. Notably, Allah has created everything in measured proportion and balance thus environmental balance needed for human existence has been ensured. This has been revealed in many verses of the Holy Qur'an, one which is as below:

And the earth We have spread out (like a carpet); set thereon mountains firm and immovable; and produced therein all kinds of things in due balance.

[The Qur'an, 15:19]

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Endnotes

- i. DNA consists of two long chains (strands) of nucleotide polymers attached with alternative pentose sugar (five carbon sugar) and phosphate groups backbone joined by ester bonds. Nucleotide attached to each pentose sugar can be one of four types. Within cells, DNA is packed into chromosomes with other proteins like histones. In eukaryotic organisms such as animals and plants, DNA is also available in other cellular organelles, such as mitochondria or chloroplasts. However, in prokaryotic organisms such as bacteria and archaea, DNA is stored in the cytoplasm.
- ii. Nucleotides are the monomer of nucleic acid such as DNA and RNA. Each nucleotide contains one phosphate group, one pentose sugar and one of the nitrogenous bases. Nitrogenous bases are of five different types namely adenine (A), guanine (G), thymine (T) and cytosine (C) and uracil (U); RNA contains T instead of U. However, nucleotides are named after the names of the nitrogenous bases. Therefore, chemically nucleotides vary from each other only in terms of nitrogenous bases while all contain phosphate group and pentose sugars. When nucleotides in DNA contain deoxyribose pentose sugars, those of RNA contain oxyribose pentose sugars.
- iii. Coding sequence of a DNA refers to the segment or part of the DNA nucleotide sequence of which is used to code for amino acids, building blocks of protein. Notably, each three nucleotide in a sequence code for one amino acid which is called genetic code. All living organisms share common universal genetic codes to synthesize proteins i.e., to make polypeptide chains.
- iv. In general a gene refers to a segment of DNA that is responsible to synthesize a polypeptide chain, i.e., polymer of amino acids that provides structural basis of a subunit or a complete protein. A gene may also contain

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- the regulatory part of the DNA that are required for protein synthesis yet not coded for any amino acids.
- v. Gregor Johan Mendel (July 20, 1822 – January 6, 1884) who is known as the "father of modern genetics" was an Augustinian priest and scientist. Mendel was born into an in Heinzendorf bei Odrau, Austrian Empire (now Czech Republic). During his childhood, Mendel worked as a gardener, studied beekeeping, and as a young man attended the Philosophical Institute in Olomouc in 1840–1843. Later in 1843 he entered the Augustinian Abbey of St Thomas in Brno, where he conducted his study on law of inheritance using pea plants. His study on the inheritance of certain traits (phenotypes) in pea plants has laid the foundation of the field of modern day genetics. Mendel's law explains the law of inheritance of traits.
 - vi. Phenotypes: Any *observable characteristic* also described as trait of an organism such as morphological features like color, size, shape; developmental features; biochemical or physiological properties such as metabolic characteristics, blood grouping or behavior can be defined as phenotype. Phenotypes result from the expression of genetic information.
Abdullah Yusuf Ali. *The Meaning of the Holy Qur'an*. Note 169, p.67 Amana Corporation, USA. 1992.

Article history

Received : 31/12/2012

Accepted : 15/06/2013