Genetic manipulation and product shelf life: Is there a connection? A developing world perspective

ABSTRACT

Genetic manipulation of plants is the science where there is deliberate modification of the genetic -make up of plants. Such plants are referred to as genetically modified (GM) organisms. The practice of genetic manipulation of organisms has been practiced since ancient times, its only that nowadays there is use of advanced technologies. However there are critics of GM technologies which include organic farmers, religious groups, environmentalists, trade protectionists, some politicians, some naturalists and African traditionalists. Some of the fears pertain to potential toxicity, allergenicity, possible antibiotic resistance, carcinogenicity and possible genetic contamination of other crops and wild flora. Other concerns include possible creation of new viruses, restriction of seed availability and fear of the unknown. On the other hand there are benefits which may outweigh the disadvantages of

GM technology. Benefits include improvement of shelf life of fruits and vegetables and their nutritional content.

Keywords: Genetic engineering, plant breeding, risks, benefits, shelf life, fruits and vegetables, African traditionalists, food security.

1. Introduction

Genetic engineering is described as the science and art whereby the characteristics of an organism are deliberately modified by the manipulation of the genetic material, especially DNA and transformation of certain genes to create new variations of life -[1,2,3] .(Uzogara,2000, Tazeb, 2018, O'donoghue, 2003).

The recombinant DNA technique is whereby DNA is manipulated in various ways and transferred from one organism to another. Transgenic organisms are programmed to manufacture substances such as monoclonal antibodies, hormones, nutrients, enzymes and various pharmaceutical products like vaccines and drugs [4,5,1]. (Brown, 1996; Campbell 1996, Uzogara 2000).

Cloning of organisms which include plants, bacteria, fish and livestock have been done. The potential for gene splicing techniques, gene editing and other biotechnological procedures [2]. (Tazeb, 2018) such as cloning have been compared in popular press with the discovery of fire, invention of the printing press and splitting of the atom [1]. (Uzogara, 2000).

Plant biotechnology involves the manipulation of biological systems to solve problems in industry and agriculture, fundamental techniques that affect various aspects of the regulation of gene expression [6]. (Kung and Arntzen, 1989). Many food plants have been genetically engineered for various purposes. Some fruits and vegetables have been genetically manipulated to affect product shelf life [7,3].

2. Importance of Fruits and Vegetables

Plants are an important source of energy in developing countries and developed countries. Fruits and vegetables are important for their nutritional contribution as major sources of vitamins and minerals and for fibre provision and hence ensure a balanced diet [8,9]. (Cook, 1992; Kader, 2002). Broccoli and cauliflower are prime examples of vegetables that have gained dramatically in popularity due to evidence from the American Cancer Society that including them in a high-fiber, low-fat diet may reduce the risk of cancer [9]. (Cook, 1992). Fruits and vegetables are generally poor sources of protein because of low content exceptions are legumes. Men and animals are supplied by plants with nine essential amino acids which animals cannot synthesize. The nine essential amino acids are histidine, leucine, isoleucine, lysine, methionine, threonine, valine, tryptophan and pheylalanine [10]. (Reeds, 200). Fruits and vegetables are generally not high in fats or oils, exceptions are oil seeds. Fats are an energy source and are required for the formation of protective layers. The good thing about vegetable oils is that they are unsaturated oils (containing at least a double bond in the carbon chain) which are good for the body especially the heart and cardio-vascular system.

Vitamins are the major contribution of fruits and vegetables to the human diet. Vitamin A- from B-carotene provided for by orange coloured fruits and vegetables, Vitamin A is important for proper eye function. Vitamin K, B complex and vitamin C obtained from fruits and vegetables are very important for proper body function [11]. (Zhuang an Barth, 2003. Fruits and vegetables are major sources of minerals eg. calcium and phosphorus- many fruits and vegetables are good sources while leafy vegetables are good sources of iron. In fact fruits and vegetables play as aesthetic role, providing interesting colour, texture and variety.

3. History of Genetic Manipulation of Fruits and Vegetables

Genetic manipulation of plants by man in order to obtain desired or eliminate undesired attributes has been practiced since pre-historic times. Genetic engineering has been practiced by resourceful farmers who bred plants and animals to obtain certain attributes, by gathering and planting seeds of fatter grains and by cross- fertilizing different species of plants to create new varieties that exhibit the most desirable characteristics of the parent plants [12,1]. (Schardt, 1994; Uzogara, 2000). Traditional plant breeding was largely by chance (imprecise), slow and it took a long time to produce a valuable variety [2]. (Tazeb, 2018). In 1967 a new potato variety called Lenape potato was bred for its high solids content which made it more suitable for making potato chips [1]. (Uzogara, 2000). However it was withdrawn by the USDA after it was found to be prone to development of an alkaloid (toxin) called solanine. In this case biotechnology proved that it can lead to unexpected outcomes.

In the 1980s researchers in West Germany (Max Planck Institute for Plant Breeding), Belgium and in the United States (Monsanto Corporation) found a method of creating transgenic plants using a pathogenic bacterium, Agrobacterium tumefaciens [13,14,1]. (Fraley et al., 1983; Zambrynsky et al. 1983; Uzagora, 2000). Many traits were introduced into other plants [15]. (Hinchee et al, 1983) including slow ripening of tomatoes [1].

4. Potential Risks of GM Fruits and Vegetables.

There are some potential risks of GM foods including GM fruits and vegetables. The critics of genetically manipulated foods have concerns, not only for safety, toxicity, allergernicity, carcinogenicity and altered nutritional quality of foods, but also for the environment (Table 1) as Eswatini strives to achieve sustainable development goals SDGS

Table 1. Potential risks or concerns from use of GM foods.

Risks or Concerns
Alteration in nutritional quality of foods
Antibiotic resistance
Potential toxicity from GM foods
Potential allergenicity from GM foods
Unintentional gene transfer to wild plants

Possible creation of new viruses and toxins

Limited access to seeds through patenting of GM food plants

Threat to crop genetic diversity

Religious/cultural/ethical concerns

Concerns of animal rights groups

Concerns of organic and traditional farmers

Fear of the unknown

Source: [1]Uzogara 2000

5. Benefits of GM Fruits and Vegetables.

There are several benefits of GM foods including GM fruits and vegetables. Supporters of the genetic manipulation of foods cite increased year-round availability, extended shelf life and improved nutritional quality as some of the reasons (Table 2) why they encourage the new science which will benefit farmers, consumers and the environment [1](Uzogara, 2000).

Table 2. Potential benefits from GM technology.

Benefits of GM technology
Increase in food availability
Improved shelf life and organoleptic quality of foods
Improvement in nutritional quality and healthy benefits
Improved protein quality
Increase in food carbohydrate content
Improvement in quantity and quality of meat, milk and livestock
Increased crop yield.
Manufacture of edible vaccines and drugs
Biological defense against diseases, stresses, pests, weeds, herbicides and viruses.
Bioremediation
Positive effect on farming/food product
Protection of the environment
GM crops function as bio-factories and source of industrial raw materials

Source: [1]Uzogara 2000

6. Extended fruit and vegetable shelf life and organoleptic quality

The GM technology has led to extended shelf life and organoleptic quality of some commodities including fruits and vegetables. Calgene Corporation of California produced the first genetically engineering tomato crop which was approved by the FDA [16, 17, 1]. (Redenbaugh et al; 1993; Waters 1994; Uzogara, 2000). Flevr Savr tomato had its genes manipulated so that it can ripen on the vine and have a relatively longer shelf life with delayed softening and rotting processes. Ethylene control technologies may be used like suppression of gene expression of ethylene synthesis or inhibition of ethylene perception. The inhibitor of ethylene perception, 1 methylcyclopropene (1-MCP) is the basis of a new technology that is increasingly being used to improve storage potential and maintain quality of fruit and vegetables. It is registered for use on a number of crops including apricot, apple, banana, apricots, avocado, kiwi fruit, broccoli, mango, pear, peach,

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melon, persimmon, nectarine, tomato and plums [18,19]. (Watkins, 2002;Watkins, 2008). Genetic suppression of cell wall degrading enzymes may be used i.e.pectin methylesterase (PME) and polygalacturonase (PG) leading to longer shelf life, better handling and shipping properties [20]. (BIC, 1998). The slow or delayed ripening characteristics can be replicated in other crops like strawberry, raspberry and pine-apple and can extended the crops shelf life [1]. (Uzagara, 2000). Good shipping and handling properties will also benefit farmers and consumers in developing countries like those in Southern Africa where refrigeration is unreliable, expensive and transportation network is rudimentary [21]. (Phillips, 1994).

Improved nutritional quality and health benefits. Genetic manipulation may help increase levels of minerals and naturally occurring anti-oxidant (Table 3).

Table 3: Scientific evidence for observed health benefits of antioxidant vitamins in chronic disease

Disease	Vitamin C	Vitamin E	B-Carotene
Cardiovascular disease	+	+++	+
Cancer	++	++	+
Cataracts	++	++	++
Immune function	++	+++	++
Arthritis	+	+	+
Alzheimer's diseases	-	++	-

-Little or no evidence of relationship

+Some evidence of relationship

++Good evidence of relationship

+++Excellent evidence of relationship

Source: [22]. Elliot, 1999

Vitamins (flavonoids, carotenoids, Vitamin A, C and E), compounds that can shut down or slow biological oxidation, a damaging chemical reaction, that appears to promote the development of some cancers, blindness and heart diseases [23,24]. (Ames, 1998; Sinaglik, 1999).

7. GM Technology and Post-harvest crop protection

After harvest fresh fruits and vegetables which are still alive face challenges including disease infections and insect attack. Disease caused by pathogenic fungi and bacteria infect fruits and vegetables in a physiologically weakened state [25,26,27,28,29,30]. (Sommer, 1992; Sugar, 2002; Korsten and Wehner, 2003; Bartz and Cheng-I Wei, 2003; Sommer et al 2002; Okonji et al., 2019). GM technologies which interfere with C_2H_4 production, perception and action delays senescence and thus keep harvested fruits and vegetables in a state not prone to attack by opportunistic pathogens hence prolonged shelf life. Healthy harvested fruits and vegetables are prone to attack by post-harvest insect pest like the fruit fly and weevils. Insects are attracted to fruit by the release of ripening stimulants which attract insects like fruit flies [31,32,33]. (Mitchel and Kader, 1992; Martison et al 2015; Marinez et al., 2017). The GM technologies reduce activities associated with cell wall degrading enzymes which prevent harvested fruits and vegetables from attack by opportunistic diseases and insect pests. The integrity of cell walls of harvested commodities is maintained relatively for some time. The cell wall degrading enzymes of importance include pectin methyl esterase (PME) and polygalacturonase (PG) which act on pectin and polygalacturonic acid polymer units, respectively. Keeping the cell walls relatively inactive (at bay) suppression of gene expression of cell wall degrading enzymes [16,7,3]. (Redenbaugh et al., 1993; Seymour and Manning, 2002; O' Donoghue and King, 2003) keeps the cell walls relatively intact for some time and subsequently act as the first line of defense of the harvested fruits and vegetables against post-harvest opportunistic pathogens and insect pests. In this way the use of post-harvest pesticides is avoided and this is not only good for human health but also for the environment [34]. (Masarirambi et al., 2010).

8.Implications to food security

Food security, as defined by the United Nations' Committee on World Food Security, means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their food preferences and dietary needs for an active and healthy life [35]. (IFPRI, 2019). There is need for adaptation strategies to achieve nutritional and food security in countries of the developing world including those of the Southern African Development Community (SADC). Over the coming decades, a changing climate, growing global population, rising food prices, and environmental stressors will have significant yet uncertain impacts on food security. Adaptation strategies and policy responses to global change, including options for handling water allocation, land use patterns, food trade, postharvest food processing, and food prices and safety are urgently needed [36]. FAO 2019). Food security/insecurity issues are crucial. For example food insecurity is now recognized as a major health crisis in the United States of America [37]. (Gundersen and Ziliak, 2018).There is need to build momentum in SADC for a future launching of a regional multi-stakeholder hunger-free initiative for Southern Africa that builds upon existing policies and programmes and amplifies the current political commitment [36]. (FAO, 2019).

By manipulating C_2H_4 control technologies and suppression of cell degrading enzymes PME and PG the shelf life of fruits and vegetables can be extended. When the shelf life of fruits and vegetables is extended it means their availability in the post-harvest handling chain is improved up to market and consumption and thus subsequent improved food security. With improved food security SADCs efforts of attaining SDGs are accelerated.

8. CONCLUSION

It appears that there are overally more benefits of use of GM technologies than perceived adverse effects in fruits and vegetables pertaining to extended shelf life. The use of C_2H_4 control technologies and suppression of gene expression of cell wall degrading enzymes PME and PG has potential post-harvest benefits environmentally, physiologically, pathologically and entomologically. Extended shelf life is an added benefit in terms of improving nutritional and food security towards achieving SDGs.

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