

1 **Genetic manipulation and product shelf life: Is there a connection?**

2 **A developing world perspective**

3

4 **ABSTRACT**

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

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

20

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

23

24 **1. Introduction**

25

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

31

32 The recombinant DNA technique is whereby DNA is manipulated in
33 various ways and transferred from one organism to another. Transgenic
34 organisms are programmed to manufacture substances such as
35 monoclonal antibodies, hormones, nutrients, enzymes and various

36 pharmaceutical products like vaccines and drugs [4,5,1]. (Brown, 1996;
37 Campbell 1996, Uzogara 2000).

38 Cloning of organisms which include plants, bacteria, fish and livestock
39 have been done. The potential for gene splicing techniques, gene editing
40 and other biotechnological procedures [2]. (Tazeb, 2018) such as
41 cloning have been compared in popular press with the discovery of fire,
42 invention of the printing press and splitting of the atom [1]. (Uzogara,
43 2000).

44
45 Plant biotechnology involves the manipulation of biological systems to
46 solve problems in industry and agriculture, fundamental techniques that
47 affect various aspects of the regulation of gene expression [6]. (Kung
48 and Arntzen, 1989). Many food plants have been genetically engineered
49 for various purposes. Some fruits and vegetables have been genetically
50 manipulated to affect product shelf life [7,3].

51

52 **2. Importance of Fruits and Vegetables**

53 Plants are an important source of energy in developing countries and
54 developed countries. Fruits and vegetables are important for their
55 nutritional contribution as major sources of vitamins and minerals and
56 for fibre provision and hence ensure a balanced diet [8,9]. (Cook, 1992;
57 Kader, 2002). Broccoli and cauliflower are prime examples of
58 vegetables that have gained dramatically in popularity due to evidence
59 from the American Cancer Society that including them in a high-fiber,
60 low-fat diet may reduce the risk of cancer [9]. (Cook, 1992). Fruits and
61 vegetables are generally poor sources of protein because of low content
62 exceptions are legumes. Men and animals are supplied by plants with
63 nine essential amino acids which animals cannot synthesize. The nine
64 essential amino acids are histidine, leucine, isoleucine, lysine,
65 methionine, threonine, valine, tryptophan and phenylalanine [10].
66 (Reeds, 2000). Fruits and vegetables are generally not high in fats or oils,
67 exceptions are oil seeds. Fats are an energy source and are required for
68 the formation of protective layers. The good thing about vegetable oils is
69 that they are unsaturated oils (containing at least a double bond in the

70 carbon chain) which are good for the body especially the heart and
71 cardio-vascular system.

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

82 **3. History of Genetic Manipulation of Fruits and Vegetables**

83

84 Genetic manipulation of plants by man in order to obtain desired or
85 eliminate undesired attributes has been practiced since pre-historic
86 times. Genetic engineering has been practiced by resourceful farmers
87 who bred plants and animals to obtain certain attributes, by gathering

88 and planting seeds of fatter grains and by cross- fertilizing different
89 species of plants to create new varieties that exhibit the most desirable
90 characteristics of the parent plants [12,1]. (Schardt, 1994; Uzogara,
91 2000). Traditional plant breeding was largely by chance (imprecise),
92 slow and it took a long time to produce a valuable variety [2]. (Tazeb,
93 2018). In 1967 a new potato variety called Lenape potato was bred for
94 its high solids content which made it more suitable for making potato
95 chips [1]. (Uzogara, 2000). However it was withdrawn by the USDA
96 after it was found to be prone to development of an alkaloid (toxin)
97 called solanine. In this case biotechnology proved that it can lead to
98 unexpected outcomes.

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

106

107 **4. Potential Risks of GM Fruits and Vegetables.**

108

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

114

115

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

117 Risks or Concerns

118 Alteration in nutritional quality of foods

119 Antibiotic resistance

120 Potential toxicity from GM foods

121 Potential allergenicity from GM foods

122 Unintentional gene transfer to wild plants

- 123 Possible creation of new viruses and toxins
 - 124 Limited access to seeds through patenting of GM food plants
 - 125 Threat to crop genetic diversity
 - 126 Religious/cultural/ethical concerns
 - 127 Concerns of animal rights groups
 - 128 Concerns of organic and traditional farmers
 - 129 Fear of the unknown
-

130 Source: [1]Uzogara 2000

131

132 **5. Benefits of GM Fruits and Vegetables.**

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

139

140 **Table 2.** Potential benefits from GM technology.

141 Benefits of GM technology

142 Increase in food availability

143 Improved shelf life and organoleptic quality of foods

144 Improvement in nutritional quality and healthy benefits

145 Improved protein quality

146 Increase in food carbohydrate content

147 Improvement in quantity and quality of meat, milk and livestock

148 Increased crop yield.

149 Manufacture of edible vaccines and drugs

150 Biological defense against diseases, stresses, pests, weeds, herbicides

151 and viruses.

152 Bioremediation

153 Positive effect on farming/food product

154 Protection of the environment

155 GM crops function as bio-factories and source of industrial raw

156 materials

157 Source: [1]Uzogara 2000

158

159 **6. Extended fruit and vegetable shelf life and organoleptic quality**

160

161 The GM technology has led to extended shelf life and organoleptic

162 quality of some commodities including fruits and vegetables.

163 Calgene Corporation of California produced the first genetically

164 engineering tomato crop which was approved by the FDA [16, 17,

165 1]. (Redenbaugh et al; 1993; Waters 1994; Uzogara, 2000). Flevr

166 Savr tomato had its genes manipulated so that it can ripen on the

167 vine and have a relatively longer shelf life with delayed softening

168 and rotting processes. Ethylene control technologies may be used

169 like suppression of gene expression of ethylene synthesis or

170 inhibition of ethylene perception. The inhibitor of ethylene

171 perception, 1 methylcyclopropene (1-MCP) is the basis of a new

172 technology that is increasingly being used to improve storage

173 potential and maintain quality of fruit and vegetables. It is

174 registered for use on a number of crops including apricot, apple,

175 banana, apricots, avocado, kiwi fruit, broccoli, mango, pear, peach,

176 melon, persimmon, nectarine, tomato and plums [18,19].
177 (Watkins, 2002;Watkins, 2008). Genetic suppression of cell wall
178 degrading enzymes may be used i.e.pectin methylesterase (PME)
179 and polygalacturonase (PG) leading to longer shelf life, better
180 handling and shipping properties [20]. (BIC, 1998). The slow or
181 delayed ripening characteristics can be replicated in other crops
182 like strawberry, raspberry and pine-apple and can extended the
183 crops shelf life [1]. (Uzagara, 2000). Good shipping and handling
184 properties will also benefit farmers and consumers in developing
185 countries like those in Southern Africa where refrigeration is
186 unreliable, expensive and transportation network is rudimentary
187 [21]. (Phillips, 1994).

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

191

192

193

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

196	Disease	Vitamin C	Vitamin E	B-Carotene
197	Cardiovascular disease	+	+++	+
198	Cancer	++	++	+
199	Cataracts	++	++	++
200	Immune function	++	+++	++
201	Arthritis	+	+	+
202	Alzheimer's diseases	-	++	-

203 -Little or no evidence of relationship

204 +Some evidence of relationship

205 ++Good evidence of relationship

206 +++Excellent evidence of relationship

207 Source: [22]. Elliot, 1999

208

209

210

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

216 **7. GM Technology and Post-harvest crop protection**

217 After harvest fresh fruits and vegetables which are still alive face
218 challenges including disease infections and insect attack. Disease caused
219 by pathogenic fungi and bacteria infect fruits and vegetables in a
220 physiologically weakened state [25,26,27,28,29,30]. (Sommer, 1992;
221 Sugar, 2002; Korsten and Wehner, 2003; Bartz and Cheng-I Wei, 2003;
222 Sommer et al 2002; Okonji et al., 2019). GM technologies which
223 interfere with C₂H₄ production, perception and action delays senescence
224 and thus keep harvested fruits and vegetables in a state not prone to
225 attack by opportunistic pathogens hence prolonged shelf life. Healthy
226 harvested fruits and vegetables are prone to attack by post-harvest insect
227 pest like the fruit fly and weevils. Insects are attracted to fruit by the
228 release of ripening stimulants which attract insects like fruit flies
229 [31,32,33]. (Mitchel and Kader, 1992; Martison et al 2015; Marinez et
230 al., 2017). The GM technologies reduce activities associated with cell
231 wall degrading enzymes which prevent harvested fruits and vegetables
232 from attack by opportunistic diseases and insect pests. The integrity of
233 cell walls of harvested commodities is maintained relatively for some
234 time. The cell wall degrading enzymes of importance include pectin
235 methyl esterase (PME) and polygalacturonase (PG) which act on pectin
236 and polygalacturonic acid polymer units, respectively. Keeping the cell
237 walls relatively inactive (at bay) suppression of gene expression of cell
238 wall degrading enzymes [16,7,3]. (Redenbaugh et al., 1993; Seymour

239 and Manning, 2002; O' Donoghue and King, 2003) keeps the cell walls
240 relatively intact for some time and subsequently act as the first line of
241 defense of the harvested fruits and vegetables against post-harvest
242 opportunistic pathogens and insect pests. In this way the use of post-
243 harvest pesticides is avoided and this is not only good for human health
244 but also for the environment [34]. (Masarirambi et al., 2010).

245

246

247 **8.Implications to food security**

248 Food security, as defined by the United Nations' Committee on World

249 Food Security, means that all people, at all times, have physical,
250 social, and economic access to sufficient, safe, and nutritious food
251 that meets their food preferences and dietary needs for an active
252 and healthy life [35]. (IFPRI, 2019). There is need for adaptation
253 strategies to achieve nutritional and food security in countries of
254 the developing world including those of the Southern African
255 Development Community (SADC). Over the coming decades, a
256 changing climate, growing global population, rising food prices,
257 and environmental stressors will have significant yet uncertain
258 impacts on food security. Adaptation strategies and policy

259 responses to global change, including options for handling water
260 allocation, land use patterns, food trade, postharvest food
261 processing, and food prices and safety are urgently needed [36].
262 FAO 2019). Food security/insecurity issues are crucial. For
263 example food insecurity is now recognized as a major health crisis
264 in the United States of America [37]. (Gundersen and Ziliak,
265 2018). There is need to build momentum in SADC for a future
266 launching of a regional multi-stakeholder hunger-free initiative for
267 Southern Africa that builds upon existing policies and programmes
268 and amplifies the current political commitment [36]. (FAO, 2019).
269 By manipulating C_2H_4 control technologies and suppression of cell
270 degrading enzymes PME and PG the shelf life of fruits and vegetables
271 can be extended. When the shelf life of fruits and vegetables is extended
272 it means their availability in the post-harvest handling chain is improved
273 up to market and consumption and thus subsequent improved food
274 security. With improved food security SADCs efforts of attaining SDGs
275 are accelerated.

276

277 8. CONCLUSION

278 It appears that there are overallly more benefits of use of GM
279 technologies than perceived adverse effects in fruits and vegetables
280 pertaining to extended shelf life. The use of C₂H₄ control
281 technologies and suppression of gene expression of cell wall
282 degrading enzymes PME and PG has potential post-harvest
283 benefits environmentally, physiologically, pathologically and
284 entomologically. Extended shelf life is an added benefit in terms of
285 improving nutritional and food security towards achieving SDGs.

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