Nutrition

Food health quality of genetically modified crops – review of risks and benefits

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Summary

The present paper aims at synthesizing the existing knowledge on food health quality aspects of genetically modified crops. Food health quality concept have been defined as a combination of food safety (absence of hazard) and food security (nutritional value and physical and economic access to food). The review of over 50 relevant papers identified in ScienceDirect on the potential health effects of GM foods allowed to extract six main sources of risks and/or benefits to human health from GM foods. They include food allergens, changes in natural level of toxins, resistance to antibiotics, pesticide residues. abundancy of food and adequacy of nutrition. They have been discussed in terms of risks and benefits to the consumer health. Some of them display both risks and benefits, while some other are either beneficial or risky to the consumer health.

Key words: GMO, food, health quality, food safety, nutrition.

Introduction

Genetically modified food (also referred to as „GM food" or „transgenic food") is defined as foodstuff that includes, consists of or is produced of genetically modified organisms [1]. The introduction of GM organisms into food products has become the issue of an intense and conflict-ridden debate, particularly in Europe [2,3,4].

There is a general consensus among scientists that biotechnology has the potential to enhance nutrition, increase crop yields and reduce the use of toxic pesticides and herbicides. On the other hand, European consumers are consistently afraid of the presence of GMO in the food supply. The tension between scientific recommendations and public opinions has complicated the formulation of government policy with respect to GMOs, due to the fact that in a democratic system public opinion must be taken into account in addition to the scientific merits of the policy and the market pressures in the economy [3]. At the European level, the release of GM crops into the environment is regulated by Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms [5]. It provides a step-by-step approval process on a case-by-case assessment of the risks to human health and the environment

of GM products prior to the released into the environment or placed on the market. In addition, the *Codex Alimentarius* by FAO/WHO (2001) provides recommendations on how to protect the health of consumers [6].

Scope of the study

The main objective of this paper is to synthesize the extant knowledge on food health quality aspects of genetically modified crops. The term "food health quality" embraces three groups of factors, namely: food health safety defined as the absence of hazards in food, food security defined as physical and economic access to food for all people at all times and nutritional value of food. The term "food health quality" will be used here as including "food safety" (absence of hazards) and "food security" (access and nutrition). This term has been adapted from definition of "food security" provided by Bush & Lacy (1984) [7]. They asserted that "food security" has at least three facets: first, disposability, that is having enough food at one's disposal at any time (physical access to food); second, accessibility of food, defined as having access to a proper amount of food (economic access to food); third, adequacy, understood as nutritive and safe food (health adequacy) [8]. Knutson, Penn & Boehm (1983) use the term "food safety and nutrition" to emphasize the health aspect of food [9]. In the present work, the authors apply the term "food security" as indication of both nutrition (nutritive food) and availability of food (physical and economic access to food), while the term "food health safety" as demonstration of no health hazards in food. Both terms formed one concept: "food health quality", that will be used henceforth in this study.

Materials

Identifying factors that influence food health quality of GM foods has been the subject of sizeable research. Relevant publications from Science Direct, Blackwell Synergy, Ingenta Connect, Web of Science, Taylor and Francis, Scopus, Google and Google scholar have been identified. To retrieve relevant papers, main keywords used included 'GMO', 'biotechnology', 'transgenic', and their synonyms, in combination with the terms: *health, food, safety, toxicity, allergenicity, pesticides, pollutants, herbicides, soy, corn, potato, wheat, maize, efficiency, production*, as well as any combination and synonyms of the terms. The search was largely conducted on English language articles, but also involved articles in Polish.

Risks and benefits of GM foods with respect to health quality

This section discusses several aspects of food health safety and security in terms of risks and benefits. The most frequently mentioned aspects of food health safety with respect to GM crops are food allergens, changes in natural level of toxins, resistance to antibiotics and pesticide residues. The most often reported aspects of food health security include abudancy of food and nutritional value.

Food allergens. The prevalence of food allergy continues to raise worldwide [10]. Allergic reactions in humans occur when a normally harmless protein enters the body and stimulates an immune response [11]. There are food raw materials classified as 'top allergens', or 'major food allergens' namely: milk, eggs, peanuts, tree nuts (i.e. almonds, cashews, walnuts), fish (i.e. bass, cod, flounder), shellfish (i.e. crab, lobster shrimp), soybean, celery, sesame, and wheat [12].

Benefit: It is argued that high precision of gene alteration compared to conventional plant breeding processes allows better control over allergenicity [13]. Moreover, transgenic agriculture offers a possibility of preventing and treating allergy. It is possible to modify known allergens into hypoallergens (as it was done in rice and soy), which may play an important role in desensitization of individuals with allergies [14]. The research on the transgenic methods to eliminate peanut allergy is already underway [15]. Tada (1996) also suggested that enzyme exhibition via antisense techniques may be applied to reduce the allergenic potential of other crops [16,17].

Risk: There are two hypothetical scenarios of increased allergenicity of GMO: (i) creation of an allergen novel to the human diet, where de novo sensitization occurs in the population, and (ii) transfer of a known allergen into a so far non-allergenic target crop [14]. It was found that a nut allergen from Brazil nut can be transferred into soy bean, and the newly expressed protein

in transgenic soy maintained its allergenicity; yet the product was not commercially released [18].

Changes in level of natural toxins in plants. Toxicants are naturally present in certain crops and could be harmful to human health if their levels increased [19]. Most common inherent plant toxins include *solanin glycoalkaloid* in potatoes, *trypsin* in soybeans, and *mycotoxins* in grains [20].

Benefit: Biotechnology may reduce probability of unwanted toxic mutations in plants. More specifically, conventional farming techniques require the use of chemicals or strong radiation to achieve a desired effect, while biotechnology allows precise expression of the preferred quality without the use of potentially hazardous stimulators [13]. Besides, transgenic crops and particularly *Bt* crops may reduce or even eliminate the risk of mycotoxin in the food supply, due to protection of grains from insect damage and in turn limiting toxic mold [21].

Risk: Genetic modifications may either induce the production of known toxins in plants, i.e. solanin in potatoes, which is not however specific to GMOs, or cause some unknown toxic effects resulting from gene manipulation [22]. The loudest evidence on this matter toxicity matter was provided by Ewen & Pusztai (1999) [23]. The rats fed on the potatoes containing snowdrop lectin (GNA) displayed harm to their intestine and immune systems. These effects were not however observed in rats fed on unmodified potatoes, or mixture of unmodified potatoes and snowdrop lectin not inherent in the potato. It was explained as an effect of some random changes occurring during modification, not the snowdrop lectin per se. Another experiment produced similar findings [24]. However, such studies were severely criticized for many flaws [25].

Antibiotic resistance. Antibiotic resistant genes, mainly *kanamycin* or *neomycin*, serve as markers in genetic engineering, in order to select the cell into which the 'synthetic' gene is transferred ('selectable markers') [26].

Risk: Main concern related to the presence of antibiotic resistance genes in GM plants is the potential for immunization to antibiotics of humans, animals and other organisms in the wider environment [27]. When the final product is ingested, antibiotic resistant genes may be taken up by bacteria in human or animal organisms, making them resistant to antibiotics. Consequently, the role and effectiveness of antibiotic therapies in medicine may decline. However, a number of experimental studies have been published that all had not succeeded in demonstrating gene transfer from GM plants to bacteria [28,29,30]. Even if the intact *nptII* gene is taken up by the bacteria, it will be rapidly degraded by restriction endonucleases [31]. Given that it survives, the incorporation of *nptII* gene into the bacterial genome is still unlikely to happen. Moreover, antibiotic resistant markers (*nptII*) are obtained from bacteria naturally present in human and animal intestines. Given that the transfer occurs, which is highly improbable, these genes are already common in bacterial populations [32,33]. Besides, the current level of use of antibiotics is already high, and the *nptII* gene confers resistance only to specific antibiotics such as kanamycin and neomycin, which are rarely used in human and animal therapies, since they have been replaced by more effective ones, i.e. ampicillin [27]. In addition, the antibiotic resistant genes can either be eliminated or replaced by other non-antibiotic markers. Last but not least, in response to public opinion, EU authorities decided to withdraw GM crops with antibiotic resistance markers *nptII*, even though it was in contradiction with the opinion of various scientific committees [26].

Pesticide residues in foodstuffs. Pesticide residues in foodstuffs have become a key issue due to their intensive use in farming [34]. Substantial empirical studies and some nationwide programs carried out in different countries demonstrated the widespread presence of pesticides (notably organochlorine pesticide) in human tissues [35,36], and this occurs despite the prohibition of most persistent organochlorine pesticides in farming [37].

Benefit: Transgenic agriculture is considered as only economically viable alternative to conventional methods in reducing dietary and environmental exposure to pesticide residues. Lower levels of toxic chemicals used to prevent crops from insects, weeds and fungus will subsequently result in lower level of pesticide residues in food compared to conventional plants. Two applications, most common in transgenic

agriculture, determine the possibility of reduced use of synthetic chemicals in plant production: herbicide tolerance and insect resistance (*Bt*). Herbicide resistant plants contain a gene protecting the crop against harmful effects of weed killers. These plants can be sprayed with low amount of the specific herbicide which kills the weeds but the crop remains unharmed. Insect resistant (*Bt*) plants contain a gene isolated from the microorganism *Bacillus thuringiensis*, producing an insect-killing toxin. This modification allows the plants to produce their own toxin, so there is no more need to spray the crop [22].

Abundant food. Human health is not attainable unless adequate amounts of quality and safe food products are available during all stages of life. Conventional crops allow provision of large quantities of food, but at the cost of consumer exposure to pesticides [38], while organic and integrated production are likely to fail in satisfying the growing demand for food, especially in developing countries. It is therefore argued that transgenic crops are the only way to boost food production and meet the demand of an increasing world population.

Benefit: Upon the introduction of "golden rice", India turned out not only to be a country self-reliant of food, but also a food exporter [39]. On the other hand, it is often stressed that increased availability of food is not a universal benefit. While it may help fighting starvation in poor societies in Asia, Africa and South America, Europe and North America are facing a food surplus problem. At present, the world agriculture produces more food that ever before, so it is rather poverty and defective distribution system that leads to famine and malnourishment [40].

Nutritional value. The accessibility to diverse, affordable, nutritionally adequate and wholesome diet is crucial in maintaining the consumer health [41].

Benefit: Although the initial goal of transgenic plants was to achieve better productivity of crops, gene technology is expected to develop better nutritional, flavor and storage properties of foods. Increased nutritional value may either derive from traits enriching a plant with nutrient level or from a decreased level of antinutrients [42]. The most widely known GM plant with improved micronutritional value is "golden rice" with increased synthesis of beta-carotene (vitamin A) and iron accumulation. Its role is highly appreciated in the poor Asian populations, suffering from nutrient deficiencies [43,44]. Through genetically enhanced nutritional values, GM products exhibit health benefits equivalent to those of functional foods [42,45]. Hence, while genetically improved nutritional properties have been initially introduced to benefit poor countries, the current wave of functional foods in the Western societies raises the role of GMO in this respect [17]. Besides, undernutrition appears to be a growing problem also in developed countries [46]. Nutritional value of the plant can be also genetically improved via decreased level of antinutrients, which are present in conventional plants and block the ingestion of nutrients, i.e. low phytate wheat helps the organism absorb not only more phosphorus, but also other minerals naturally present in plants, i.e. zinc, manganese and iron, improving their nutritional value [47,48].

Risk: Some studies point to the increased level of antinutrients in GM plants, which ultimately reduces nutritional quality of foodstuffs [49]. Besides, GM technology promotes monocultures, which reduce diversity of many diets and make people dependent on a narrow scope of foods [50].

Conclusions

The paper reviewed and discussed six most frequently mentioned in the literature sources of risks and/or benefits to human health from genetically modified foods. They include food allergens, changes in natural level of toxins, resistance to antibiotics, pesticide residues. abudancy of food and adequacy of nutrition. Certain features of GM crops display both risks and benefits, while some other are either beneficial or potentially hazardous to the consumer health. All these aspects have been thoroughly reviewed and discussed. However, genetically modified organism are relatively new, as they appeared commercially in the mid 90's and are poorly addressed by current testing methods [51]. That is why, there is a need for further discussions on risks and benefits of GM crops not only in terms of health, but also in terms of the environmental and socio-economic effects. To obtain more valuable results, the presented factors must be also

evaluated in terms of their relative importance under specific conditions. For example, in poor and malnourished societies, "improved nutrition" and "food availability" may be considered a more important aspect of health sustainability than "changes in level of natural toxins" in plants, whereas in rich societies, this relation is likely to be the opposite. A major limitation of this review is the availability of the existing studies, showing results that were often conflicting and rooted in speculations. Thus, further research is needed to obtain more consistent outcome.

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