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Benefits and risks associated with genetically modified food products

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Abstract

Scientists employing methods of genetic engineering have developed a new group of living organisms, termed 'modified organisms', which found application in, among others, medicine, the pharmaceutical industry and food distribution. The introduction of transgenic products to the food market resulted in them becoming a controversial topic, with their proponents and contestants. The presented study aims to systematize objective data on the potential benefits and risks resulting from the consumption of transgenic food. Genetic modifications of plants and animals are justified by the potential for improvement of the food situation worldwide, an increase in yield crops, an increase in the nutritional value of food, and the development of pharmaceutical preparations of proven clinical significance. In the opinions of critics, however, transgenic food may unfavourably affect the health of consumers. Therefore, particular attention was devoted to the short- and long-lasting undesirable effects, such as alimentary allergies, synthesis of toxic agents or resistance to antibiotics. Examples arguing for the justified character of genetic modifications and cases proving that their use can be dangerous are innumerable. In view of the presented facts, however, complex studies are indispensable which, in a reliable way, evaluate effects linked to the consumption of food produced with the application of genetic engineering techniques. Whether one backs up or negates transgenic products, the choice between traditional and non-conventional food remains to be decided exclusively by the consumers.

Key words

transgenic food, genetically modified organisms, GMO

INTRODUCTION

In parallel with an intense development of genetic engineering techniques and altering the needs of contemporary economy an increased interest is devoted to food products obtained using transgenesis processes. The new type of food, termed genetically modified or transgenic food,[1] permitted the commercialization of crops, allowed in parallel to avoid restrictions linked to traditional cultivation. In line with Regulation 1829/2003 of the European Parliament the term of 'genetically modified food' denotes food which itself is a GMO[2] or 'food containing or composed of a GMO, or food produced using GMO' [1, 2, 3].

The origins of plant and animal modification date back to the 1970s. In 1973, Stanley Cohen and Herbert Boyer obtained for the first time recombined DNA, starting the era of genetic engineering. The pioneer plants subjected to the process of transgenesis involved tobacco and petunia, but a real success proved to be introduction to the market in 1994 of a modified FlavrSavr tomato plant, which forecasted the commercialization of transgenesis products. The assortment of genetically modified food includes first of all plants, and much narrower range of animals and microbes. The most frequently transformed plants include soybean, maize and rape. Moreover, potatoes, tomatoes, cotton and tobacco used to be subjected to the process of transgenesis, and among animals, species such as cattle and pigs. The genetic modifications aim at improving utilizable and technological traits, nutritional enrichment of the obtained products, as well as providing potential for the synthesis of therapeutic substances using transgenic organisms [3, 4, 5, 6, 7, 8]. The introduction of genetically modified components for general use is linked to the obligation of their appropriate labelling, in line with European Union (UE) law. The labelling imperative pertains to all trade goods which contain GM components and products produced with use of GMO, in which the contents of transgenic components exceeds 0.9%. Detection of GM components becomes an inseparable element of legislative procedure and the introduction to the market of genetically modified food, ensuring, in parallel, appropriate labelling of products, subject to respective official control [2, 3, 9, 10, 11, 12].

The procedure of certification genetically modified food is controlled by a number of legal acts and requirements, the fulfilling of which provides conditions for allowing GMO to enter trade turnover. Not only the traits of the parental organism, source and expression products of genes used for modification are evaluated, but also new, non-existing earlier properties of the transgenic organism. The analysis includes effects of GMO on living bodies, the environment and biodiversity, with particular attention paid to the risks of using a GMO. In European Union countries, genetically modified food is required to fulfil respective legal Acts, among them Directive 1829/2003/WE on genetically modified food and fodder, and Directive 1830/2003/WE, related with the potential for monitoring and labelling genetically modified organisms, while in the individual Member States the appropriate legal and normative Acts. It should be added that the procedure for obtaining consent for the legalization of GMO is complex and includes acceptance of consecutive supervising bodies,

1. In this study, the terms 'transgenic food' or 'GM food' will be used instead of 'genetically modified food'.
2. GMO – genetically modified organism.

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both at the European level, first of all of the European Food Safety Authority (EFSA), and at the national level [3, 13, 14].

The process of introducing genetically modified food to consumer markets is preceded by a detailed technological and toxicological analysis, aimed at evaluation of safety linked to its use. A number of methods are distinguished which allow to evaluate the precisely GMO content in a studied sample. Molecular biology techniques are based, first of all, on analysis of nucleotide sequence in the chain of genetic information, protein analysis, or on physicochemical reactions. The need for monitoring products containing components with modified genetic information promoted development of networks of laboratories, including, among others, the European Network of GMO Laboratories (ENGL), formed on the grounds of European Union law, the principal purpose of which involves the development of standards in sampling, detection and quantitative analysis of genetic material contained in a studied sample. Beyond doubt, genetically modified food products allowed to enter worldwide trade are scrupulously tested for potential effects resulting from their consumption [2, 3, 15].

Compared with global producers of transgenic food (such as the United States, Argentina, Brazil, India, Canada or China), the countries of United Europe manifest a slower increase in the assortment of food originating from genetic modifications, which reflects the principle of restricted confidence to products of genetic engineering. Therefore, a proportion of EU member States strive to eliminate GMO. Nevertheless, the European countries which in agriculture take advantage of transgenesis products include Poland, due to the fact that territory of this country still continues to be free of the rigorous orders making it a GMO-free zone, although, in accordance with superiority of the European law, Poland cannot block trade involving GM products placed in the EU market and permitted to enter trade turnover by decision of the European Commission. It should be mentioned that legal rules related to cultivation and trade involving transgenic food in Poland and countries of the UE continue to undergo dynamic alterations [5, 6, 7, 8, 16, 17].

Problems associated with biotechnology, including genetically modified food, represent a very current topic, evoking several inverse feelings in scientific circles and in society [1, 7, 18]. The principal investigative problem involves the effect of genetically modified alimentation on the human body. The study aims at presenting objective data on the advantages and disadvantages of GM food, the potential for taking advantage of such food, reliable benefits and risks linked to it.

Benefits resulting from genetic modification of food products. The increasing number of transgenic food products on the food market induces the belief that genetic modification of plants and animals provides profits. The potential for improvement of agronomic, technological or utilitarian traits prompts food producers to an increasingly frequent use of achievements provided by genetic engineering. The groundwork of every modification performed involves a complex procedure of altering genome structure which, in effect, is responsible for the expression and manifestation of the desired utilitarian trait [19, 20, 21, 22].

Modification of chemical composition in transgenic food. Among numerous modifications induced in plants, transformations resulting in altered chemical composition of food products deserve particular attention. Enrichment of transgenic food in specific alimentary products results in such food frequently having a much higher utility value than traditional food products. Moreover, it provides a concentrated source of nutraceutics, or substances carrying high therapeutic and pro-health value, representing a desirable element of a differentiated diet. The group of nutraceutics contains, first of all, vitamins A, C, E, plant pigments, indispensable unsaturated fatty acids (IUFA), alimentary cellulose, and pre- and probiotics [20].

The achievements of genetic engineering include the significant example of Golden Rice, the genome of which was modified by the introduction of additional copies of genes conditioning the synthesis of provitamin A (Tab. 1). Carotenoids, including, among other, β-carotene, vitamin A and its provitamin, represent a group of biologically active compounds responsible for normal sight and body resistance [9, 18, 23]. The project of enriching rice in food products involved the isolation and transfer of genes from *Erwinia uredovora* bacteria and jonquil flowers directly to rice grains. A change in expression of individual alleles resulted in an increased activity of the enzyme of phytoene synthase, translated to an increased amount of synthesized β-carotene. The success of the project was followed by subsequent modifications, achieving parallel augmentation of the level and bioavailability of iron. In this way, Golden Rice proved to provide the product of choice for the reduction of malnutrition, due to its high nutritive value and low price [22, 24, 25].

Using the techniques for the biotechnological improvement of plants, other modifications of traits were conducted in transgenic food, targeted at the altered content of specific proteins, lipids and carbohydrates. The mentioned food components, manifesting suitability for the process of genetic transformation, permitted the development of desirable quality traits, with parallel improvement of nutritive value in individual products of transgenesis. In particular, an altered profile of amino acids, lysine, methionine, cysteine and tryptophan caused plant varieties of – until now – low value to possibly become a source of exogenous protein. This can be exemplified by cultures of sweet lupine, enriched with additional molecules of methionine [19, 26].

Genetic modifications were also prompted by the desire to improve the structure of alimentary lipids. An increasing share of saturated fatty acids, paralleled by a decreasing consumption of mono- and polyunsaturated fatty acids, prompted scientists to transform the natural composition of oil plants. Laboratory investigations resulted in soybean varieties with a few-fold increased content of oleinic (oleic) acid – a monounsaturated fatty acid – and varieties of rape rich in stearic acid – a saturated fatty acid free of unfavorable effects for health. The introduction to plant cells of genes responsible for synthesis of unsaturated fatty acids promoted also the alternative production of omega-3 acids (polyunsaturated fatty acids), highly valued for their pro-health properties, e.g. for reduction of LDL-cholesterol and triglyceride levels in serum and for reduction of cardiovascular diseases risk. This group of plants includes rape, the principal object of studies in this branch of transgenesis [7, 19, 27].

New nutritional values in transgenesis products were obtained also due to changes in the composition of carbohydrates. An interesting example of such a process involves the genetically modified potato variety, Amflora. The

bulk of potato bulb-contained polysaccharides is formed by starch, consisting of two elements, amylose and amylopectine. While in the processing industry amylose represents a useless element, amylopectine is widely used in the production of starch, paper, and in the processing of textiles. The synthesis of starch requires various enzymes, which include granule bound starch synthase (GSBB), the primary function of which involves the production of amylose. In the absence of GSBB, amylopectin is produced exclusively. The above information permitted the working out of a modification allowing alteration of the composition of potato starch. The transgenesis process involved the introduction to potato bulbs of an additional copy of the GSBB-coding gene. The transferred and recipient genome-integrated genetic material, acting by co-suppression or gene silencing, produced the effect of decreasing synthesis of the enzyme, and in this way promoting the production of amyloseless starch. Although the Amflora potato was permitted to be grown in European countries exclusively for industrial purposes, nevertheless it induced a widespread protest from society [17, 28, 29, 30, 31]. The application of techniques aimed at improving plant composition due to their content of specific alimentary components and an increased nutritional value, represents an increasingly broad branch in food technology.

Improvement in technological and utility trends. The aim of plant cell genetic transformation involves not only modification of the chemical composition and nutritional value of transgenic products, but also alterations in functional traits, important in the technological and processing processes. The highest interest is attracted by varieties in which the introduced change manifests certain practical importance. One of the first achievements in perfecting food on the molecular level involved the above-mentioned FlavrSavr tomato, the genetic material of which was transformed with respect to activity of the enzyme of polygalacturonase. A reaction of silencing gene expression, responsible for the phenomenon of ripening, resulted in the tomato manifesting a slowed-down metabolism at the stage when the process progressed rapidly and, due to the slowing, it gained longevity, permitting its long storage (Tab. 1) [7, 16, 19, 24, 32].

Potato bulbs, because they are easily modified, became important objects of studies. Their transformation included not only their quantitative composition but, first of all, their technological parameters. The most important alterations included decrease in the amount of reducing sugars, paralleled by an increased content of cyclodextrins, change in the activity of polyphenol oxidase responsible for the phenomenon of potato darkening, and a reduced content of alkaloids which negatively affect the process of potato storage. A potato was successfully cultivated in which the Bt gene, isolated from *Bacillus thuringiensis* bacteria, conditioning resistance to potato beetle, allowed an increase in the potato crop (Tab. 1) [28, 33]. The same resistance gene was used for the transgenesis of maize. It is assumed that a toxin coded by a bacterial chromosome, after transferring to plant tissues, allows the development of resistance to noxious insects which reduce crops, but exert no negative influence on the health of humans and animals consuming the plants. Due to such procedures, the maize became resistant to corn borer (*Pyrausta mirilabilis*), while its commercial variety (MON810) was admitted to cultivation worldwide, including Poland and other countries of the European Union [17, 24, 29, 33, 34, 35].

Another type of component in genetically modified food involves products from the transgenesis of animal products. The rationale for altering the structure of the genes includes attempts to improve utility traits of farm animals and attainment of the highest economical profits. Farm animal modifications encompass several branches of contemporary economy, including agriculture, the food industry, pharmacy and medicine. The principal objects in studies on transgenesis processes include cattle and pigs, while the main directions of transformation involve optimization of their alimentary potential and parameters of breeding. Modification of genetic material aimed at enrichment of its fraction responsible for synthesis of growth hormone resulted in the production of animals manifesting a higher growth rate and greater increases in body weight. At present, attempts are being made to obtain varieties of the animals with low feed demand, compared to their rate of growth. Such attempts have been successful in the production of transgenic fish, such as carp, trout and salmon [7, 24, 36]. Extensive interest was devoted to improvement of the nutritive value of milk originating from genetically modified cows, goats and sheep (Tab. 1). Through the introduction or elimination of respective genes, a milk was produced with augmented tolerance of high temperatures, containing an altered content of casein or a decreased content of lactose, representing one of causes of alimentary intolerance. An important aspect involved the humanization of bovine milk using human proteins and reduction of β-lactoglobulin content, the principal allergen of milk which induces allergic reactions [7, 28].

An important achievement of biotechnology was the production of transgenic mammals, capable of producing polyunsaturated fatty acids of the omega-3 and omega-6 families, highly valued in prophylaxis against certain civilization-linked diseases, such as dyslipidaemias, arteriosclerosis or arterial hypertension [37]. Transgenic animals providing food raw materials point to the novel potential of production involving valuable food products. Nevertheless, it should be added that the efficiency of genetic transformation used to be relatively low and its cost is high, while the very process of manipulation within the genomes of living organisms has to encounter lack of acceptance on the consumer markets [7, 37].

Table 1. Advantageous technological and utilitarian features of genetically modified food.

FOOD	BENEFITS FROM GENETIC MODIFICATIONS
Rice	Higher content of β-carotene Higher iron bioavailability
Tomato	Higher content of dry matter Delayed ripening process Aroma intensification Virus resistance
Potato	Higher amylopectin content Cyclodextrin production Resistance to viruses and potato beetle Lower alkaloids content
Milk (cow, goat, sheep)	Increased tolerance for high temperature Modified casein content Lower lactose content
Transgenic fishes (carp, salmon, trout)	Faster growth rate

Source: own modifications based on: [7, 19, 22, 33, 37].

Production of therapeutic substances. The purposefulness of genetic modification involving plant raw material, is planned to provide therapeutic substances, opening fully novel perspectives for pharmacy and medicine. Transgenic varieties of potato, salad, tomato and spinach are capable of producing the so-called oral vaccines, or substances stimulating the human immune system in response to specific pathogens. Using genetic engineering techniques, humans have succeeded in transferring the genes responsible for expression of viral or bacterial antigens directly to plant cell nuclei or chloroplasts. The antigens stimulate whole body response which results in the production of antibodies, providing stable immunity toward selected pathological microflora [22, 36, 38]. It is required that the active substances in transgenic vaccines are contained in edible portions of vegetables and fruits, and that they stimulate mucosal immunity, due to digestion and absorption in alimentary tract of humans and/or animals. The recommended commercial form of the resistance-stimulating plants involves a lyophilizate (a freeze-dried form), manifesting lowered risk of contamination and more favourable storage conditions [3, 21, 36]. The leading examples of cultivable edible vaccines are exemplified by varieties of rice, maize, soybean or potato, capable of producing antigens immunizing against various infections, including the effects of *Escherichia coli* toxins, rabies, infections with *Helicobacter pylori* bacteria, and viral type B hepatitis [3, 22, 24, 38, 39].

Here, it is worth mentioning the achievement of Polish scientists who developed a GM salad containing vaccine against viral type B hepatitis [36]. However, due to insufficient investigative effort, pharmaceuticals produced by transgenic plants are still not used on an industrial scale.

The positive effects of the culture and cultivation of transgenic organisms are thought to include the potential for obtaining recombined proteins, broadly used as a source of therapeutic substances. One of trends in plant biotechnology involves modification of plant varieties for the purpose of synthesis of biologically active compounds, providing grounds for the production of drugs, enzymes, antibodies and hormones of specific pro-health effects. The most frequent objects for such studies are varieties of tobacco, tomato, potato, maize, soybean, rice and lucerne. The production of biopharmaceutical agents brings about several economic advantages, due to their low costs, ease of modification, extensive yield and seed production. The recombined proteins obtained by the genetic engineering approach include, among others, lactoferrin, lysozyme, insulin and insulin-resembling growth factor-1 (IGF-1) [22, 36, 38, 40].

An important part of 'pharming' (the production of therapeutic substances using transgenic organisms) involves the use of animals as bioreactors of therapeutic compounds. A properly conducted transgenesis includes transformation of genes permitting expression of the protein exclusively in the target organ of the animal under condition that the product is fully innocuous. Very frequently, the therapeutic proteins are produced in mammary milk glands. As a result of experimental studies, researchers have succeeded in obtaining alpha-1-antitrypsin, erythropoetin, plasminogen activator, and clotting factors of interferon, produced by transgenic goats, sheep or cattle. Production of recombined proteins may also take place in the blood or urinary bladder of genetically modified animals. In this way, among others, human haemoglobin was obtained, manifesting oxygen-binding activity identical to native haemoglobin. It should be mentioned that the breeding of transgenic farm animals is fully safe for the environment since such animals cannot propagate or survive outside the site devoted to their stay [3, 7, 28, 36, 39, 41, 42, 43]. Thus, GMO opens an interesting perspective for a more economic production of drugs needed by patients.

Potential risks linked to genetically modified food. The dissemination of genetically modified food in various branches of human activities promoted the introduction of detailed controls related to transgenesis products, particularly in the scope of evaluating the safety of their use, and specification of possible risks associated with the consumption of such products [44]. The anxiety of consumers is induced both by the effects of genetic modifications, including effects of molecular biology techniques which, in interfering with the process of natural recombination, disturb the ability for normal propagation. The problem of taking advantage of transgenic food reflects misgivings of both a biological nature, related to the complexity of the involved processes, and ethical principles linked to problems of the existence of living organisms [20, 45, 46].

Risk of food allergy. The transfer of genes from the cells of one organism to the cell nuclei of another organism results in the expression and synthesis of new proteins, absent till then in parental cells. The amino acid sequence forming structure of a given protein poses the main risk of food allergy development due to exposure to transgenic food. The term allergy denotes a pathological immune reaction, resulting from a response to antigen carried by a specific food component. The main allergens are thought to involve alimentary proteins, the consumption of which may induce sequentially skin reactions, alterations in the respiratory system and the circulatory system, up to induction of an anaphylactic shock, creating serious negative effects for health [7, 20, 47, 48]. Proteins obtained due to genetic modifications are thought to carry an allergizing potential if its sequence is homologous to another, defined allergen, inducing unfavourable immune body reactions. It is estimated that food components allergize approximately 2% of the world's adults and as many as 6% of children [7, 47, 49].

Extensive attention is devoted to cases of allergy following previous consumption of a transgenic food. The widely publicized example of unfavourable GMO effects involved the case of Aventis, the American producer of maize given the utility name of StarLink. The modified plant contained an additional gene, conditioning natural resistance to pesticides. The transfer of genetic information from *Bacillus thuringiensis* bacteria to the cell nuclei of maize yielded the expression product of Cry9c protein, manifesting strong allergizing properties. Due to its specificity, StarLink maize gained the acceptance of the Environmental Protection Agency (EPA) and was permitted to enter the trade market exclusively as an animal fodder. Soon after commercialization of the transgenic plant, StarLink maize was detected in food products generally accessible on consumer markets (e.g. in tacos). Spread of the information through mass media was followed by numerous reports by consumers related to symptoms of food allergy in the form of headaches, diarrhoeas, nausea and vomiting, which were supposed to develop following consumption of products containing the genetically modified maize (Tab. 2) [7, 45, 47, 50, 51].

Another example of the risk of food allergy development involved the production of soybean enriched in methionine,

the amino acid obtained by synthesis as a product of the gene isolated from a Brazil nut. According to reports of various medical organizations, both peanuts and tree-nuts represent one of main causes for the development of allergic reactions. Therefore, negative health effects following consumption of transgenic soybean in humans earlier sensitized to nuts represents a serious danger (Tab. 2) [7, 20, 23, 52].

Examples of allergy induced by GM food are most frequently related to varieties equipped with new expression genes, originating from organisms with a specific allergizing potential. In the case of lupine and lucerne, the introduction of genetic material originating from seeds of sunflower resulted in the appearance of allergy resembling that developing after the consumption of Brazil nuts [52].

Synthesis of toxic compounds. A significant problem linked to the effects of GMO to consumers' health and life is the potential for synthesis in their cells and tissues of anti-alimentary, toxic products or products which increase risk of activating neoplastic processes. This can be exemplified by events which took place in Spain in 1983, when a modified rape oil with a pronounced toxic effect was permitted to enter the general market. Despite earlier results obtained on rats, which failed to demonstrate any disturbances in physiology, consumption of the oil resulted in the deaths of a marked number of the consumers. This tragedy caused various investigatory centres to undertake efforts to explain the phenomenon. It was speculated that the intoxication induced the so-called toxic oil syndrome (TOS), reflecting contamination of the oil with aniline or its derivatives, responsible for the toxic signs. Experiments by Suarez et al. conducted on rats fed for 2 months with oil contaminated with oleoylanilide, failed to demonstrate significant differences with rats of a control group which received food with pure oil, although the situation might have reflected an insufficient supply of the supposedly toxic agent. Other studies performed by Quero et al., pointed to the possibility of genetic diversity in response to TOS [7, 53, 54]. Potentially toxic effects of transgenic food were also recorded in the United States in 1989, when transgenic tryptophan caused death and pain (mainly in muscles and joints) in many people. The compound, distributed by a Japanese producer, was produced by genetically modified bacteria, altered with respect to production efficacy. The L-tryptophan, playing the role of a food supplement and used for the treatment of, among others, insomnia or depression, induced undesirable body reactions in the form of eosinophilia-myalgia syndrome (EMS). The causes of the intoxication are thought to be associated, first of all, with altered production technology and altered purification of the compound, which took place just in 1989 [4, 7, 9].

The risk of an increased morbidity to tumours resulting from the consumption of GM food seems to be equally alarming. In 2002, results were published which demonstrated that milk from genetically modified cows increases levels of IGF-1 factor in consumers, showing a positive correlation with development of tumours in lungs, breast and colon. Experiments are being conducted to evaluate links between cultivable plants rendered resistant to pesticides with the frequency of lymphoma development in humans and animals consuming products resulting from the transformation of such plants (Tab. 2) [7, 9].

The relationships of transgenic food effects on human body are being investigated by conducting numerous tests on animals. Thus, a few independently working groups of researchers have presented data on the potentially harmful influences of MON810 maize (resistant to corn borer) on cells of the pancreas, intestines, liver and kidneys in rodents (Tab. 2) [44]. Results of other studies testing the effects of different varieties of transgenic maize (MON810 and MON863) on living bodies – the maize producing Bt toxin making it resistant to insects, and NK603, maize, resistant to the Roundup herbicide – pointed to the potential for induction of histopathological lesions first of all in liver and kidneys and, thus, in the principal detoxifying organs. This was confirmed by experiments on rats fed for 90 days with 11% or 33%, respectively, of components of transgenic maize, and compared to a control group of rats fed the unmodified analogue. However, attention was drawn to the fact that the low number of rats (80) which consumed the genetically modified maize, compared to the number of rats consuming the non-transgenic equivalents (a four-fold higher group numerically). Moreover, the chronic toxic effects should be evaluated after long-term monitoring – for a period of about two years – while the quoted studies lasted for only three months [55, 56].

In order to define the health effects of chronic alimentation with transgenic products a group of rats was studies, fed with various doses of NK603 modified maize, grown with or in absence of exposure to Roundup herbicide, using food free of GMO but containing water with the addition of varying amounts of Roundup, or using food free of GMO or the herbicide (control). The results of the two-year experiment suggested manifestation of disturbances in the function of liver and kidneys, a higher mortality of animals, and manifestation of palpable tumours in the experimental groups (particularly those exposed to Roundup), compared to the control. Female rats manifested an increased sensitivity to the food containing toxic compounds. It was suggested that this was linked to, among others, a lowered content of isoflavonoid antioxidants: ferulic acid, reduced by 16–30% and caffeic acid, reduced by 21–53% in NK603 maize, which reflected an overexpression of 5-enolpyruvylshikimate-3-phosphate synthase (EPSP) gene, originating from *Agrobacterium tumefaciens* – and permitting the plant to be resistant to Roundup [57]. A modulating effect of the above-mentioned isoflavonoids was demonstrated on estrogen receptors and, therefore, their chemopreventive and anti-inflammatory effects [57, 58].

The analyses by Pusztai are also worth attention. He detected that lectin, the agglutinin synthesised by GM potatoes, was toxic for the growth and development of mammals. A diet consisting of genetically modified potatoes containing a lectin, synthetized as a product of the expression of a gene selected from *Galanthus nivalis*, negatively affected the alimentary tract in rodents [4, 23, 45]. Following exposure of rats to the diet, the unfavourable effects were identified, which included disturbed cell division, particularly in the gastric mucosa. The arising abnormalities were suggested to be linked not only with the presence of the transgene, but also with other elements of the genetic construction, and with the process of transformation of genetic information. It should also be added that the described experiments involved small numbers of animals, and the duration of studies reached just 10 days (Tab. 2) [4, 45, 50, 59]. In quoting the above data, it becomes indispensable to mention the need for a detailed examination of transgenic food before it is introduced into the food markets.

Table 2. Negative results of consuming genetically modified food.

FOOD	NEGATIVE RESULTS OF TRANSGENESIS PROCESS
Star Link Maize	Risk of food allergy
Soybean enriched in methionine (gene isolated from Brazil nut)	Risk of food allergy
Milk from genetically modified cows	Increase of IGF-1* concentration in serum, positively correlated with breast, lung and colon cancer
Maize MON810	Harmful influence for cells of pancreas, intestines, liver and kidney of rodents
Potato (with lectin)	Immunity handicap Incorrect mitosis of cells and tissues

* IGF – 1 - insulin-resembling growth factor-1
Source: own modifications based on [4, 7, 9, 10, 44, 45, 50, 52, 59].

The practical use of genetic engineering techniques allows the formation of organisms with new traits, which in favourable conditions may pass from laboratories and food factories to environment. The uncontrollable spread of GM plants induces anxiety among ecologists due to the risk of a disturbed biological equilibrium in ecosystems. Toxins produced by modified plants and secreted throughout their vegetation period, may manifest ability to become accumulated in individual organs of the plants, and may cause some pests to become resistant to the harmful substance. In effect, instead of a reduction in the required doses of insecticides, it may prove necessary to increase the doses of pesticides, thus nullifying the effect of the conducted manipulations [7, 9, 10, 60].

A similar problem is posed by the fear of development of 'super weeds' resistant to herbicides. An assumption of the performed transgenesis process was that the introduced new gene will provide the plant with protection against herbicides. Following such a procedure, only a single type of herbicide could be used in small doses. However, through the unwanted hybridization of transgenic plants with weeds, one cannot exclude the formation of new species, insensitive to the herbicides targeted at them. Moreover, the new plants resistant to anti-weed agents will require the use of higher amounts of herbicide to destroy them, which results in contamination of water and soil and which may negatively affect the health of consumers [7, 20, 21, 44].

Development of resistance to antibiotics. A subsequent significant aspect posed by the opponents of GMO involves the risk of development of resistance to antibiotics, understood as a risk of transferring genes of resistance to antibiotics to genetically modified organisms. At the early stage of the transgenesis process, bacteria are frequently used, similar to bacterial genes resistant to therapeutic antibiotics, playing in parallel the role of markers or elements allowing to distinguish transformed cells from cells which did not accept the coding alleles. The common application of therapeutic agents as modifying agents poses the danger of transferring genes of resistance to the bacterial microflora of human and animal alimentary tracts – both the physiological and pathogenic microflora. In consequence, pathogens inducing various diseases may develop a stable lack of sensitivity to specific antibiotics, with resulting lowered efficacy or total loss of effectiveness of respective treatment. Thus, in order to avoid negative health effects, avoidance of using antibiotics as markers is recommended [7, 9, 44, 49, 61]. In order to avoid the negative health effects, avoidance is also recommended of using antibiotics as markers to the advantage of specific marker genes, such as nptII, which pose no risk to humans or animals [62].

SUMMARY

The study presents possible directions in which genetic modifications can be used, stressing the advantages and risks resulting from the consumption of transgenic food. The respective cultivation and production of modified products involve lower production costs and provide higher nutritive value of the obtained food products. The advantages resulting from the use of GMO result in increased profit for producers, provide therapeutic products, and increased variability of the obtained products and products with desirable organoleptic and utility traits [7, 21, 34, 46, 63]. Safety in the use of genetically modified food became higher due to incessant monitoring and testing GMO, required for admission to the trade market, even if GMO forms only a component of food [19, 20, 29]. Consumption of genetically modified food entails risk of undesirable effects, similar to the consumption of traditional food. The difference is in the fact of forming new experimental arrangements and the relatively short duration of using transgenesis products. The main apprehension of GMO opponents is focused on the health of consumers. It is speculated that genetically modified food is responsible for the development of food allergies, resistance to antibiotics and synthesis of toxic substances. The appearance of risks associated with a broad use of GMO provides the basis for criticism from the side of biotechnology opponents. However, to date, it has not been clarified if the harmful effects result from products of genetic modifications or from the transgenesis process, affected by, among others, circumstances of the conducted manipulations [7, 20, 28, 46]. To date, no completely negative effects of transgenic food on the human body or its complete harmlessness could have been documented. Increasing amounts of GMO-containing assortments are introduced to the trade market and the consumers themselves must decide whether or not to consume transgenic food, which should be appropriately labelled and supplied with reliable information on the conducted modifications [13, 28, 63].

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