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Review paper
Pregledni znanstveni prispevek

POSSIBILITIES AND DILEMMAS OF USING TRANSGENIC FOOD IN HUMAN NUTRITION

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ABSTRACT

Expanded needs for food resulted in search of new prospects for higher food production and better quality. Gene technology means a quicker way to reach these objectives than the traditional selection of animals and plants do. Gene transfer enables the transfer of genes among not related organisms, which might cause ethic problems. In Europe the opposition to transgenic food is stronger than in the United States. Even that there are many antagonists to transgenic food, there are about 35 mills. ha sown by transgenic plants, primarily by soya following by maize, potatoes and cotton. Gene transfer in animals has still been used for research purposes only; hence, a wide use of meat of transgenic animals or other food products will not emerge in the next few years. Gene technology enables the increase of production in plants, as well as the rise of resistance to pests, viruses, frost, etc. Gene transfer is used to modify the physical and chemical composition and nutritional value of food (more unsaturated fatty acids, transfer of sunflower proteins into maize, etc.). Over 50 transgenic plants are used worldwide, 21 of them in the United States and 9 in the European Union, but in EU, only a few of them are used in agriculture. Gene transfer in animals will play a part in boundless possibilities of improvement the qualitative and quantitative traits. The yield, carcass composition and meat characteristics, the use of nutritive substances, and resistance to diseases can be improved. On the other hand, negative effects of gene technology on animals, human, and environment should be considered. Genetically modified food should be marked so that a consumer could freely decide whether to use it or not. Gene technology cannot solve all the problems of world nutrition but let this revolutionary method be legally applied.

Key words: human nutrition / genetically modified food / biotechnology / GMO

MOŽNOSTI IN DILEME UPORABE TRANSGENE HRANE V HUMANI PREHRANI

IZVLEČEK

Vse večje potrebe po hrani narekujejo iskanje novih možnosti za večjo proizvodnjo in boljšo kakovost hrane. Genska tehnologija prinaša hitrejšo pot za doseganje teh ciljev od klasične selekcije, tako pri hrani rastlinskega kot živalskega izvora. Z genskim transferjem lahko prenašamo gene med nesorodnimi organizmi, kar pa je etično sporno. Evropsko prebivalstvo ima veliko bolj odklonilno stališče do transgene hrane od ameriškega. Čeprav je veliko nasprotnikov transgene hrane , je danes na svetu posejanih že 35 milijonov ha s transgenimi rastlinami, od teh je največ soje, koruze, krompirja in bombaža. Genski transfer pri živalih je še vedno omejen na raziskave, zato še nekaj let ni pričakovati široke uporabe mesa ali druge hrane transgenih živali. Genska tehnologija omogoča pri rastlinah povečan pridelek, izboljša kakovost, poveča odpornost proti virusnim in glivičnim boleznim in škodljivcem, poveča odpornost na pozebo itd. Z genskim transferjem lahko spreminjamo fizikalno – kemično sestavo in prehransko vrednost hrane (več nenasičenih maščobnih kislin, prenos beljakovin sončnic v koruzo, itd.).V svetu se uporablja prek 50 transgenih rastlin, v ZDA 21 in v EU 9, vendar je v EU dovoljena le uporaba nekaterih transgenih rastlin v kmetijstvu. Neomejene možnosti se obetajo z genskim transferjem živali pri izboljšanju kvalitativnih in kvantitativnih lastnostih. Izboljšamo lahko prirast, sestavo trupov in mesa, izkoriščanje hranilnih snovi, povečamo odpornost na bolezni itd. Niso pa izključeni tudi vsi negativni učinki na živali, ljudi pa tudi na okolje. Gensko spremenjena hrana mora biti označena, tako da se lahko porabnik po lastni presoji odloči za ali proti njej. Genska tehnologija ne more rešiti vseh problemov svetovne prehrane, vendar naj se to revolucionarno metodo v zakonitih okvirih s pridom uporablja.

Ključne besede: prehrana ljudi / genetsko spremenjena živila / biotehnologija / GSO

INTRODUCTION

The usage of gene technology in food production has become interesting due to increased needs of food as well as its improved quality. With the application of gene technology to plants and animals the above goals can be achieved more quickly than by traditional selection. Gene technology can transfer isolated genes among unrelated organisms, which traditional selection cannot (Jany, 1996, 1999a). Consequently ethical dilemmas are opened concerning the eventual negative effects of production of genetically modified food. The negative consequences can affect the health, environment, aetiology, society and ethics (Ruttloff *et al*., 1997).

In Europe more restrictions are set to the production and use of genetically modified foods than in the United States (Van Dokkum, 2000). In the European Union the agricultural production looks forward to be sustainable. Ried (1996, 1999) reported that most of the Europeans opposed genetically modified food. In a survey in England and in Poland, 37% people did not object such food and only 17% in Austria, while the Americans generally did not mind if the food contained genetically modified components. It is expected that in EU less restrictions will remain for the use of gene technology if it proves to be harmless.

Gene technology has developed parallel to decoding animal and plant genomes, enabling the insertion or exchange of one or more genes with the foreign ones (Kappes, 1999). Cundiff *et al*. (1993) mentioned the economic limit of usage of gene technology. It is justified if at least 10% better quality as well as quantity is achieved, and it is not important which portion of the genome has been modified. The transgenic effect ranges between 10 and 20% in the economically important traits. In spite of many opponents to the transgenic food it has been found out that 35 mil. ha of agricultural lands are sown by transgenic plants, primarily by soya, maize, potatoes and cotton. Most of the plants are grown in the USA, Canada and China.

PRODUCTION TECHNOLOGY OF TRANSGENIC ORGANISMS

Several methods of production of genetically modified organisms (GMO) are known. The foreign gene that has been inserted into the cell of a microorganism, a plant or an animal is called a transgene. It is integrated into the genome of the recipients which are called transgenics. The transgenes are genes with known traits or mutated variants of known genes. In most cases also marker genes are used because of identification of transgenic organism. The integration of transgene into the cell is carried out by different methods:

– transduction with the use of bacteriophages,
– transgene injection using pronuclear microinjection
– transfer using modified viruses and plasmids
– electroporation method by which higher permeability of cell membrane is achieved.

For transfer of foreign gene also artificial chromosomes or fragments of chromosomes can be used. Transgenes can be transferred into the egg-cell by spermatozoa containing fragments of chromosomes (Ruttloff *et al*., 1997). The percentage of successful gene transfer in animals is still very low, 0.7 in cattle, 0.9 in pigs and 2.5% in mice.

Developed world, having material and intellectual capacities, leads the studies on transgenic technology for production increase and improved food quality. In fact, there is not only enough but even too much food in the developed world. However, developing countries that need this technology to exceed the food shortage cannot afford it (Sleicher and Images, 2000, Smolin and Grosvenor, 2000). Hence, gene technology is not a remedy to prevent the world from starvation. Transgenic seeds that developed countries can provide to developing countries to diminish the rate of malnutrition seems to be the best idea of gene engineering.

Consumers all over the EU require special labels for genetically modified foods so that they can decide according to their conviction. Besides many good effects, the transgenic plants can have numerous negative consequences. Transgenic plants that are resistant to pests will cause higher resistance in pests; consequently stronger herbicides and insecticides should be used in future. Transgenic food can cause certain allergies. The Western Europe had already been confronted with the BSE and dioxin in food; therefore the consumers' opposition to transgenic food is understandable and justified.

APPLICATION OF TRANSGENIC PLANTS IN HUMAN NUTRITION

Transgenic plants have been known for more than two decades. They were applied first in United States, following by Europe and in China. Man has used and selected plants and animals for centuries. Nowadays some economically important traits using the gene technology in the field of production, processing and control of food can be modified and improved.

Genetically modified foods are classified into three categories according to their usage and legal regulations (Jany, 1999b).

1. Food is genetically modified (potato, tomato, soya, maize, sunflowers, rice, pumpkins, melons, rape, etc.)
2. Food contains components of genetically modified plants (starch, oil, sugar, amino-acids, vitamins, etc.)
3. Food contains genetically modified organisms (yoghurt contains transgenic micro-organisms).

Gene technology enables higher yields in plants, resistance to pests and frost, as well as mechanical properties of fruits, etc. We can also modify physical and chemical composition in order to improve nutritional and physiological value of foods. Transgenic plants also enable production of more healthy food (more unsaturated fatty acids, transfer of proteins from legumes into wheat, increased content of essential amino acids, transfer of proteins form sunflowers into maize, etc.). Dangers of heart diseases, allergies are diminished and malignancy prevented (Elmadfa and Leitzmann, 1998).

There are more than 50 transgenic plants in the world, 21 of them are used in the USA. In the EU only a small number of transgenic plants is allowed, but only maize is widely produced. Transgenic soya, maize and rape for processing can be imported. Other transgenic plants can be grown only under strict control. When no negative effects can be detected, the application procedure for placing into the market can be started.

TRANSGENIC ANIMALS AND HUMAN NUTRITION

Important advancement in production and processing of transgenic plants has encouraged studies in animals (Berkowitz, 1993). Gene technology will stimulate the development of animal production beyond present limits. Like in plants, micrinjection and similar techniques are used to inject foreign gene (DNA) into the nucleus of fertilised egg-cell in animals. When egg is developed to blastula it is transferred to the uterus of an animal where transgenic organism develops. Genetic linkage maps for cattle, pigs and sheep elucidating chromosomal regions for economically important traits will considerably contribute to better quality and amounts of meat (Kappes, 1999).

Gene technology is prosperous in farm animal production and in improvement of quality and quantity traits (Falkner *et al*., 1997, Bonneau and Laarveld, 1999; Prieto *et al*., 1999). Gene technology stimulates the yields, higher nutrient consumption, and animal welfare. These traits can be improved directly by gene transfer or using growth hormones, vaccines, antibodies, immunity stimulants and anti-allergy DNA produced by genetic engineering. Gene transfer is expected to improve those production traits in animals that are poorly inherited (low heritability rate, h^2), for example number of weaned piglets per sow.

Mason *et al*. (1996) reported that transgenic plants that produced vaccines, which animals consumed with forage, were produced. The gene for resistance enables breeding of animals resistant to diseases. Vaccine for immune castration of animals, which is painless in male animals and diminishes aggressiveness while female animals are free of negative effects of oestrus, positively affects the economically important trait carcass composition (Remy *et al*., 1996). The possibilities of biotechnological interventions are numerous but the application depends on economic, social and cultural conditions.

Transgenic technique can improve the carcass traits and meat quality. The percentage of meat in carcass increases, taste and water binding improve, diminishes the percentage of fat and improves the fatty acid composition of meat (more non-saturated fatty acids, Prieto *et al*., 1999).

Milk has been modified with transgenes and in most cases without any harm to transgenic animals. Proteins that are used in pharmaceutical industry were obtained from milk of transgenic animals, like human antitripsin in sheep, plasminogene activator in goat and human protein C in pig.

Transgenic milk can be used:
- as food for wide use,
- as raw materials for milk products,
- as food for infants,
- as source of biologically active substances for pharmaceutical industry.

The proteins that resemble human protein the most and that are the most searched products from transgenic milk have been studied by several scientists. Even non-protein compounds of human milk, like oligosaccharides, are highly appreciated in milk of transgenic animals. Mammary gland produces milk proteins and lactose under the influence of hormones during late pregnancy and lactation period. Caseins and lactoglobulines are synthesized only during lactation period. Genes from mentioned compounds are used for transgenic milk production that is used for cheese production and for substitute to human milk for infant nutrition. Most of the experiments were carried on in mice; hence the results are not yet to be applied to nutrition. In large animals only lactoferrins were obtained. All experiments to obtain milk that would resemble human milk for infant nutrition have not been successful and we cannot expect desired results in four years times.

Prieto *et al*. (1999) reported on wide use of bovine growth hormone (somatotropin) in cattle to increase production of milk and meat. In Europe this hormone should not be used due to some negative effects in trial animals (trial mice grew larger than the control ones and they died earlier because of liver and kidney collapse), but possible harmful effects on human health have not been studied yet.

Solomon *et al*. (1994) predicted the possibilities of production of ideal pork with ultra low fat content and favourable fatty acids composition with transgenic pigs, which the bovine growth hormone gene had implied. In comparison to the control group the carcasses of transgenic pigs contained 85% less fat, 85% less saturated fatty acids, 91% less mono unsaturated and 66% less polyunsaturated fatty acids at 92 kg of body mass. The cholesterol content did not significantly differ.

Webb and Rotwell (1990) predicted less soft and exudative meat with identification of halothan gene that is responsible for malignant hyperthermia syndrome. The gene transfer will enable the choice of sex. Bishop (1995) reported that with determination of *SRY* gene region transgenic bull that has only male offspring could be obtained.

The most successful implication of gene transfer was achieved in salmon in Norway. Transgenic salmons grew 20 to 40% faster than their native peers. But in an accident in Norway sharks bit the net and transgenic salmons swam to the open see where crossing with native salmons began. This may cause the loss of native salmon population and destruction of ecological system.

SAFETY CONSIDERATIONS OF GMO IN FOOD

Jonas *et al*. (2001) discussed weather the consumption of DNA in approved novel foods and novel foods ingredients can be regarded as safe as consumption of DNA in existing form. All DNA, including DNA from GMOs are composed of the same 4 nucleotides. Genetic modification results in the re-assortment of sequences of nucleotides leaving their chemical structures unchanged. Therefore, DNA from GMOs is chemically equivalent to any other DNA. The only uniqueness is restricted to differences in the DNA sequence, which occurs also in natural variations. The present use of recombinant techniques in the food chain does not introduce changes in the chemical characteristics of the DNA. There is no difference in the susceptibility of recombinant DNA and other DNA to degradation by chemical or enzymatic hydrolysis. There are no indications that ingested DNA has allergenic or other immunogenic properties that would be of relevance for consumption of food derived from GMOs. Uptake, integration and expression of any residual extracellular DNA fragments from foods by microorganisms of the gastrointestinal trait can not be excluded. Each of these circumstances is a rare event and would have happen sequentially. *In vivo* uptake of DNA fragments by mammalian cells after oral administration has been observed. There are effective mechanisms to avoid genomic insertion of foreign DNA. There is no evidence that DNA from dietary sources has ever been incorporated into the mammalian genome. Flachowsky and Aulrich (2002) studied the animal nutrition with GMOs. Their conclusions are similar as they from Jonas *et al.* (2001). They didn’t find differences in physiological and nutritive values in food of animal’s products when the animals are feed with GM plants.

LEGISLATION AND LABELLING OF TRANSGENIC FOOD IN THE EUROPEAN UNION (EU)

Foods from GMO have already appeared at European market. Hence some methods of identification of these foods have been developed (Greiner *et al*., 1997; Jany, 1996, Basu *et al.* 1993). Beer, soya oil, tomatoes and it products, potato, maize, and some spices are on the market. Gene transfer has started many contradictory and emotional discussions especially on the German spoken market. Some sound requirements on adequate labelling of the genetically transformed food in EU have been passed so that consumers can choose according to their believes (religious, ethic, medical). Therefore EU introduced new system of NOVEL-FOOD classification on May 17 1997 (Jany, 1996; Marshal, 1995). NOVEL-FOOD has been classified into two groups:

1. Foods that are genetically modified organisms or that contain genetically modified organisms (tomato, yoghurt),

2. Foods that are produced from genetically modified organisms (oil produced from herbicide resistant soya, enzymes, vitamins).

NOVEL-FOOD classification does not enquire any special requirements, it is just a wide assortment of various foods and supplements. The products should be consistently labelled; they should not misguide the consumers and should enable the verification of data. Also other foods that enter the EU market should be properly labelled, for example genetransfer free. The consumer should be informed about the food. New products appear every day, so the legislation is not final. The level of 0.9% of GMO contamination has been set as a threshold for labelling of genetically modified food. All current and future products should be irreproachable to health, environment, ethics and society. In the latest EU legislation EU No. 1829/2003 and 1830/2003 genetically modified food is taken from the Novel-Food Classification. It is classified, together with the feedstuffs made from the genetically modified organisms, as genetically modified products, which have to be declared (Jany, 2004).

CONCLUSIONS

The latest development of biotechnology, particularly molecular biology, genetic engineering and transgenic technology has a very large number of potential applications in food production, including micro-organisms, plants and animals. Transgenesis is much more difficult to apply to farm animals than to plants or micro-organisms.

Gene technology in microorganisms and plants has been widely used for a while, especially in United States and China, but it is applied in animals only for research and scientific purposes. It is not expected that products from transgenic animals will be used in human nutrition in few years time.

The useful biotechnology also meets resistance from general public that perceives some risks for the animals, for human safety and for the environment. The general acceptance of biotechnology may depend on a clear communication, explaining the balance between the advantages and disadvantages of a given application. The public needs to be educated on the reality of biotechnology and be informed about the positive and negative aspects of any given application of biotechnology. On that basis, people can make an educated choice on whether or not they can accept it.

The positive effects of gene technology in medicine, agriculture, and in ecology are numerous. In medicine biotechnological methods are applied in diagnosis, therapy and prevention. In agriculture, the application of gene technology assists to higher production and more quality products; losses caused by pests are diminished, yield is increased, diseases are fewer and milk and meat are of better quality. The safety considerations of DNA in food are positive. DNA from genetically modified food can not incorporate into mammalian genome (Jonas *et al.*, 2001). The effects of transgenesis brings some negative effects like higher resistance of pests to herbicides and insecticides, appearance of virulent micro-organisms, some toxic substances (solanine in potatoes), and allergens in transgenic plants, environmental unbalance and so far.

Despite some negative effects of gene technology, it will develop under the supervision of independent commissions in order to prevent any harmful consequence anywhere (ethics, environment, society, medicine). Gene technology cannot solve all the problems of world’s nutrition but this revolutionary method should be used to advantage of human kind and complex ecosystems.

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