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THE USE OF TRANSGENIC PLANTS FOR THE DEVELOPMENT OF SELECTED BIOPRODUCTS – ACHIEVEMENTS OF THE POLISH SCIENTISTS

Magdalena Zapalska, Krzysztof Kowalczyk
University of Life Sciences in Lublin

Abstract. Green biotechnology plays an important role in the modern agriculture. Recent progress in molecular biology and genetic engineering provides an opportunity of obtaining transgenic plants with improved characteristics, such as yield parameters, nutritional value, taste, biochemical composition, cold tolerance or pathogen resistance. Genetically modified plants can be used to produce a variety of recombinant proteins of biomedical or industrial significance, including enzymes, antigens, antibodies, hormones and secondary metabolites. Research on transgenic plants has been carried out in many countries. While there has been great development of green biotechnology worldwide, some significant achievements in this field can be contributed to Polish scientists. The paper presents research on genetically modified crops carried out in Polish scientific centers and its potential usage in different areas of man life.

Key words: transformation, genetic engineering, GM plants, green biotechnology, recombinant proteins

Green biotechnology plays an important role in the modern agriculture. All over the world biotechnological methods such as genetic engineering, micropropagation techniques or cell and tissue culture technologies are used in modern plant research and plant breeding. One of the applications of green biotechnology is developing plants with enhanced properties. However, creating new plant varieties by the means of transformation often meets with social concern. In many countries there is still an ongoing debate over the utilization of genetically modified organisms (GMOs). Some social groups, in particular those associated with different ecological organizations, consider the utilization of GMOs as unacceptable, especially in agricultural production. Other social

Corresponding author: Magdalena Zapalska, Institute of Plant Genetics, Breeding and Biotechnology, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland, e-mail: magdazapalska@poczta.fm

groups are of the opinion that widespread utilization of GMOs does not pose a hazard to man, on the contrary – it can benefit mankind [Kowalczyk and Gruszecka 2010]. It should be pointed out that the usage of GMOs is not only limited to agricultural production. Genetically modified organisms are of great importance in basic research, especially in the study of gene expression, determining the influence of the transgene on morphological features or metabolic pathways analysis. Moreover, these organisms are used to produce a variety of proteins and other substances of biomedical or industrial interest [Masuda and Kitabatake 2006, Aksamit-Stachurska et al. 2008, Czubacka and Doroszewska 2010, Gerszberg et al. 2012]. While there has been a great progress in the development of green biotechnology worldwide, some significant achievements in this field can be contributed to Polish scientists. The paper presents research carried out in the Polish scientific centers on genetically modified crops and its potential usage in different areas of man life.

Flax (*Linum usitatissimum* L.) is an important source of natural fibers and oil in over 30 countries of the world. Flax fibers are obtained in a long and difficult process called retting. Linen is a strong, biodegradable fabric which has low-production costs therefore it could replace petroleum-based synthetic polymers. Flax fibers, however, show low elasticity. For that reason the usage of linen fibers in textile industry has been so far limited [Wróbel-Kwiatkowska et al. 2009, Żuk et al. 2011]. Recently there has been an increase in the demand for natural fibers in Europe therefore various approaches has been applied by Polish scientists in order to improve flax fibers biochemical and mechanical parameters [Wróbel-Kwiatkowska et al. 2007a, 2007b], retting efficiency [Musialak et al. 2008] and resistance to *Fusarium* infection [Wróbel-Kwiatkowska et al. 2004, Lorenc-Kukuła et al. 2009, Boba et al. 2011].

Wróbel-Kwiatkowska et al. [2007b] obtained transgenic flax which accumulated poly-β-hydroxybutyrate (PHB) in its stem tissue. PHB is a bacterial biodegradable polymer displaying similar physical and chemical properties to polypropylene. Although the PHB itself is too fragile, weak and flexible for some applications, it may serve as a matrix reinforcing flax fibers. PHB is synthetized in a three-step enzymatic reaction conducted by β-ketothiolase (*phb A*), acetoacetyl-CoA reductase (*phb B*) and PHB synthase (*phb C*). A multigene construct containing *phb A, phb B* and *phb C* genes under the control of 14-3-3 promoter (isoform 16R) was inserted into the flax genome. PHB accumulation in transgenic plants resulted in improved mechanical properties (strength, Young's modulus and the energy for failure) of flax fibers. Moreover, an increase in cellulose content was detected which might have also contributed to the improvement in mechanical properties of the fibers. Stems of transgenic flax plants showed a reduction in lignin, pectin and hemicellulose levels which led to increased retting efficiency. Furthermore, transgenic plants had an increased phenolic acids level and showed higher resistance to *Fusarium*, which may have been caused by both, greater accumulation of phenolic acids and changes in the structure of the cell walls [Wróbel-Kwiatkowska et al. 2007b, 2009].

Further research on genetically engineered flax fibers enriched in PHB focused on its molecular structure and chemical composition. Infra-red spectroscopic analyses revealed that PHB was bound by hydrogen and covalent bonds to the highly ordered cellulose polymers in the fibers. The aggregation of platelets on composite materials containing transgenic flax fibers was also examined. On the contrary to the composite containing fibers from the control plants, the composite containing fibers from genetically engineered plants induced almost no platelet aggregation. Consequently, transgenic flax plant overexpressing PHB may become useful in the construction of biomedical devices that come in contact with blood [Szopa et al. 2009].

The objective of the study carried out by Lorenc-Kukuła et al. [2005a] was to generate flax plants with increased antioxidant properties. Flax oil, due to its composition, has a beneficial effect on human health. Linseed oil is the richest plant source of linoleic and linolenic polyunsaturated fatty acids (PUFA). PUFA are very susceptible to oxidation and rancidity, thus flax oil has a very short shelf life, even though it is supplemented with antioxidants such as vitamin A and E and stored in dark glass jars. In order to improve flax oil stability and increase antioxidants content transgenic plants with genes controlling the phenylpropanoid biosynthesis pathway were generated. In cited study transgenic flax plants simultaneously overexpressing chalcon synthase (CHS), chalcon isomerase (CHI) and dihydroflavonol reductase (DFR) genes from *Petunia hybrida* were engineered. Antioxidant capacity and compounds content were measured. In both seeds and green part extracts derived from transgenic plants antioxidant potential was significantly increased. Moreover, a modification of the fatty acids composition in seeds has been revealed. An increase of approximately 32% in monounsaturated fatty acids (MUFA) level associated with higher protection against free radicals was noted.

After succeeding in obtaining transgenic flax plants with increased antioxidant properties further research on its potential biomedical application has been conducted. A new dressing material (named FlaxAid) made of transgenic flax products was developed. In the study linen fabric moisturized with oil emulsion and seedcakes extract was used in the treatment therapy of human chronic skin ulceration. It was recently indicated that oxidative stress is an important factor in chronic wounds progression and pathogenesis since reactive oxygen species cause damage to various macromolecules and impair cellular mechanisms. The coordinative usage of the three components derived from transgenic flax plants resulted in generating new dressing material that contained broad spectrum of strong antioxidative compounds. The new bandage was used in a pilot study performed on 30 patients of Dermatology Department of the Wrocław Military Hospital who were diagnosed with chronic nonhealing venous ulcers. After 12-week study a rapid rate of healing was observed. A reduction in the wound exudes and wound size was reported, accordingly in 66% and 80% of the cases. In several cases the flax dressing therapy resulted in complete healing of the ulcers [Skórkowska-Telichowska et al. 2010].

The subject of antioxidant capacity manipulation was also investigated in transgenic *Solanum tuberosum* L. plants. Various approaches were used, among them overexpression of single genes involved in flavonoid biosynthesis pathway (either CHS, CHI or DFR) or expression of a multigene construct encoding all of the three genes. The goal of the study was to increase the level of antioxidants in potato plants and consequently obtain plants more resistant to abiotic and biotic stresses. Genetic manipulation of phenylpropanoid biosynthesis pathway resulted in significant increase in anthocyanins and phenolic acids content. However, a decrease in starch and glucose levels was also observed [Łukaszewicz et al. 2004]. In view of the fact that glycosylation improves stability of antioxidative compounds, transgenic potato plants overexpressing dihydroflavonol reductase (DFR) were subsequently super-transformed with the glycosyltransferase (UGT) cDNA. The engineered super-transformed plants showed increased concentration of flavonols and anthocyanins whereas tuber yield and starch content remained about the same as in the control plants [Aksamit-Stachurska et al. 2008].

Transgenic approach has been used in an attempt of improving cold tolerance of *Cucumis sativus* L. by the scientists from Polish Academy of Science and Warsaw Agricultural Uniwersity. Since dehydrins are suggested to be associated with chilling and freezing tolerance, genetically modified cucumber plants overexpressing SK_3-type DHN24 dehydrin from *Solanum sogarandinum* were engineered. In the study, no correlation between the concentration of DHN24 protein and chilling tolerance was detected. Nevertheless, all but one transgenic lines expressing DHN24 showed significantly increased chilling tolerance, and one transgenic line (TCH10) displayed improved freezing resistance. Although the molecular mechanism of dehydrin involvement in cold protection still remains unclear the reported results suggest that the overexpression of the DHN24 can be used to enhance low-temperature tolerance in cucumber seedlings [Yin et al. 2006].

Transgenic plants can be obtained not only by the introduction of new gene to the host's genome but also by silencing endogenous genes in order to block expression of undesirable gene products. RNAi-mediated silencing has been proven to be a powerful tool for determining gene function and obtaining plants with altered features [Gasparis et al. 2011].

In the study performed by Zalewski et al. [2010] transgenic barley (*Hordeum vulgare* L.) plants exhibiting silenced expression of *HvCKX1* were obtained. The cytokinin oxidase/dehydrogenase (CKX) enzyme is involved in the degradation of cytokinins, phytohormones regulating plant growth and development. In order to silence the expression of *HvCKX1* the RNAi cassette carrying fragment of the gene was constructed. Almost 80% of transformants showed a significant decrease in CKX enzyme activity. Moreover, lower CKX activity was accompanied by higher plant yield and root weight. Presented results indicate that the silencing of *CKX* genes may be a useful tool in obtaining plants with improved agronomic traits.

The RNAi-mediated silencing approach was also used in the study on *Pin* genes encoding puroindoline proteins. *Pin* genes play a significant role in determining grain texture phenotype. Silencing cassettes for *Pina* and *Pinb* genes were introduced into the genomes of two *Triticum aestivum* L. cultivars, Kontesa and Torka. The analyses revealed very low level or lack of expression of *Pina* and *Pinb* in the silenced lines. Low amounts or absence of puroindoline proteins were correlated with an increase in grain hardness [Gasparis et al. 2011].

Plant diseases cause significant losses in the quantity and quality of crops. The most effective method of reducing the effects of diseases is the introduction of cultivars with genetically determined resistance. The usage of resistant cultivars is the most effective, economical and environmentally safe approach in controlling plant diseases [Feuillet and Keller 1998, Navabi et al. 2004]. Traditional breeding methods such as selection, introduction of resistance genes from wild species and genes pyramiding do not always produce the desired results. Moreover, traditional breeding is time-consuming – it often takes many years to produce new crop variety [Kowalczyk 2004, Kowalczyk et al. 2009, Kowalczyk et al. 2011]. Genetic engineering, along with plant transformation techniques, allows to obtain plants with improved resistance to pathogens in a short time. Furthermore, the introduction of a single or few genes does not change the genetic background and does not contribute to the deterioration of the yield components and quality characteristics.

Two main pathogens of flax plants are *Fusarium oxysporum* and *Fusarium culmorum,* which can cause up to 80% loss in yield [Musialak et al. 2008]. Several approaches have been used so far in order to increase resistance of flax to fungal infection. The improved resistance to *F. culmorum* and *F. oxysporum* has been shown by flax plants overexpressing β-1,3-glucanase. The enzyme belongs to pathogenesis-related (PR) proteins and directly inhibits the growth of *Fusarium* mycelium [Wróbel-Kwiatkowska et al. 2004].

In a collaborative study conducted by researchers from Poland and Germany, transgenic carrots (*Daucus carota* L.) constitutively expressing microbial chitinase CHIT36 where generated. Endochitinase CHIT36 is a lytic enzyme secreted by *Trichoderma harzianum*. The enzyme exhibits strong antifungal activity since it degrades chitin, the main component of fungal cell walls. Resistance assays showed enhanced tolerance of all obtained transgenic carrots to *Alternaria radicina* and *Botrytis cinerea*. Transgenic plants exhibited less severe disease symptoms and slower disease progress [Barański et al. 2008].

By means of transformation, transgenic *Solanum lycopersicum* L. and *Nicotiana tabacum* L. plants resistant to Tomato spotted wilt virus (TSWV) were generated. Pathogen-derived resistance in transformed plants was obtained by the introduction of the nucleoprotein (N) gene from the Bulgarian isolate of TSWV to the host plants genomes. Transformed plants revealed different range of responses to TSWV inoculation. Most of the transformants showed either complete lack of virus invasion, mild local symptoms or delayed appearance of infection symptoms. Enhanced tolerance to TSWV was not correlated to nucleoprotein level, which suggests that the engineered resistance can be based on the post-transcriptional silencing mechanism [Federowicz et al. 2005].

Similar approach was used by Czubacka and Doroszewska [2010] to engineer transgenic tobacco plants resistant to Potato virus Y (PVY). The constructs used in transformation carried coat protein gene derived from Lettuce mosaic virus (LMV CP) and the replicase gene of PVY in sense and antisense orientation. The results of the study showed that the transgenic lines exhibiting high resistance to PVY were characterized by worse agronomic traits when compared to the transformants more susceptible to the virus infection.

A number of research describe positive correlation between level of antioxidants and resistance to pathogen infection [Gandikota et al. 2001, Niggeweg et al. 2004, Lorenc-Kukuła et al. 2005a, Treutter 2005, Boba et al. 2011]. Lorenc-Kukuła et al. [2009] investigated the effect of glycosylation of phenolic compounds on plant protection against fungal infection. Glycosylation leads to the stabilization of phenylpropanoids. The genetically engineered flax plants overexpressing glucosyltransferase gene (*SsGT1*) derived from *Solanum sogarandinum* were obtained. It has been shown that the accumulation of glucosyl derivatives of phenylpropanoids remarkably improved flax defense against *Fusarium* infection.

Transgenic potato plants overproducing the anthocyanin glycosyltransferase showed approximately 60% higher resistance to *Erwinia carotovora* subsp. *carotovora* than nontransformed plants [Lorenc-Kukuła et al. 2005b].

Molecular farming is one of the most dynamically developing sectors of green biotechnology. Genetically modified plants can be used as bioreactors producing recombinant proteins of pharmaceutical or industrial significance such as enzymes, antibodies, antigens, secondary metabolites or hormones. The plan expression system provides a possibility of producing large amounts of recombinant proteins by means of relatively low costs. Plant species most commonly used for molecular farming include *Zea mays*, *Solanum tuberosum*, *Oryza sativa*, *Nicotiana tabacum* and *Solanum lycopersicum* [Yusibov et al. 2011, Gerszberg et al. 2012].

Gerszberg et al. [2012] carried out research on transgenic potato plants expressing gene encoding staphylokinase (SAK) from *Staphylococcus aureus*. Staphylokinase is a thrombolytic factor (plasminogen activator) which plays role in dissolving a thrombocyte- and erythrocyte-rich clots, subsequently leading to restoration of proper blood circulation. Although Western blot analysis confirmed the presence of staphylokinase domain in six transformants, the protein activity was observed in only one of them. Nevertheless, the possibility of producing recombinant SAK protein in transgenic potato plants has been confirmed.

Interleukin 2 (IL-2) is a cytokine which participates in regulation of immune responses. It stimulates proliferation of T cells and activates various cells of immune system such as B cells, natural killer cells and macrophages. Interleukin 2 is used for the treatment of kidney cancer and skin melanoma. It is also being studied for immunotherapy of other cancers including leukemia, liver cancer, gastric cancers as well as HIV infection. Interleukin 2 has a short circulatory half-life therefore the scientists from Institute of Biochemistry and Biophysics of Polish Academy of Sciences in Warsaw focused their studies on obtaining recombinant human interleukin 2 (hIL-2) in fusion with proteinase inhibitors. Since plant-based expression system is considered to be safe, efficient and inexpensive, *Nicotiana tabacum* plants were used to produce recombinant protein. With the purpose of improving hIL-2 stability, expression cassettes containing additionally cDNA of two proteinase inhibitors (either *Cucurbita maxima* trypsin inhibitor I or silk proteinase inhibitor from *Galleria mellonella*) were designed. The level of recombinant protein was determined and the biological activities of both proteinase inhibitors as well as hIL-2 was confirmed. The study demonstrated the protective effect of both proteinase inhibitors against trypsin digestion. The possibility and usefulness of using protective agents in order to improve stability of recombinant human interleukin 2 has been shown [Redkiewicz et al. 2012].

In recent years, transgenic plants have been used to produce a variety of pathogen's antigens with the intention of developing and manufacturing recombinant vaccines. The idea of using plants for vaccine production appeared in the early nineties. Since then many potential plant-derived vaccines have been obtained [Ashraf et al. 2005, Yusibov et al. 2011]. Some of these vaccines have been tested in preclinical animal trials or have undergo early clinical trials. Among them are rabies vaccine produced in spinach

(*Spinacia oleracea* L.) [Yusibov et al. 2002], tobacco leaves [Ashraf et al. 2005] and carrots [Rojas-Anaya et al. 2009], Norwalk virus vaccine produced in potato tubers [Tacket et al. 2000] and tomato fruits [Zhang et al. 2006] and hepatitis B vaccine obtained in potato tubers [Kong et al. 2001, Thanavala et al. 2005] and lettuce (*Lactuca sativa* L.) [Kapusta et al. 1999, Kapusta et al. 2010, Pniewski et al. 2011]. Research on the latter one conducted by Kapusta et al. was firstly reported in 1999. In mentioned study the authors initially transformed lupin (*Lupinus luteus* L.) with the DNA fragment encoding hepatitis B virus (HBV) surface antigen (HBsAg). HBsAg is a viral envelope surface protein known of its highly immunogenic properties. Significant level of HBsAg-specific antibodies was found in mice that were fed with the transgenic lupin. Subsequently, transgenic lettuce plants expressing HBsAg predestined for human consumption were obtained. Lettuce was chosen for antigen production as it does not contain harmful substances (such as alkaloids), can be cultivated in various conditions and easily undergo lyophilization. Experiment carried out on human volunteers confirmed the possibility of immunization against hepatitis B virus via oral administration of transgenic lettuce leaves.

Further studies focused on dosage, timing of administration and antigen formulation of edible vaccine against HBV. It has been shown that relatively low doses (100 ng) of S-HBsAg assembled into virus-like particles (VLPs) administered in extended intervals between oral prime and boost (up to 60 days) induced efficient immunization. Next, a prototype oral vaccine formula was created. Edible vaccines ought to be simple to administer, therefore lettuce leaves expressing VLP-assembled S-HBsAg were lyophilized and converted into tablets. Although the freeze-drying process caused an 90% decrease of S-HBsAg VLPs content, the low dose of VLPs appeared to sufficiently induce immune response. Moreover, lyophilized tissue compressed into tablets preserved hepatitis B surface antigen content for at least one year of room temperature storage [Pniewski et al. 2011].

In order to increase vaccination efficacy anti-HBV vaccines containing multiple antigens have been introduced into immunization programs [Zuckerman et al. 2001, Rendi-Wagner et al. 2006, Zanetti et al. 2008]. Therefore the research has been carried out by Pniewski et al. [2012] on producing novel tri-component plant-derived vaccine against hepatitis B virus containing small surface HBV antigen (S-HBsAg) in conjunction with medium (M-HBsAg) and large (L-HBsAg) surface antigens of HBV. Transgenic tobacco and lettuce plants carrying M- or L-HBsAg genes were obtained. The antigens were expressed in leaves tissue at the level of $\mu g \times g^{-1}$ of fresh weight and were assembled into VLPs or analogous aggregates. The influence of lyophilization and storage temperature in the aspect of antigen stability was determined. The authors presume that combining three separate constituents (semi-products containing medium, large and previously obtained small HBV antigens) could led to creation of a novel plant-derived oral tri-component vaccine against hepatitis B.

The prevalence of obesity and diagnosed diabetes has led to an increase in the demand for low-caloric, non-carbohydrate sweeteners. Thaumatin is a sweet-tasting protein produced in the fruit of *Thaumatococcus daniellii* Benth, a West African perennial plant. Since it is approximately 100 000 times sweeter than sucrose on a molar basis it has been used as an intense sweetener and flavor enhancer [Masuda and Kitabatake

2006, Szwacka et al. 2012]. Recombinant thaumatin has been produced in several transgenic plants so far, including potato [Witty 1990], tomato [Bartoszewski et al. 2003], cucumber [Szwacka et al. 2002], strawberry (*Fragaria* × *ananassa* Duchesne) [Schestibratov and Dolgov 2005] and tobacco [Rajam et al. 2007, Pham et al. 2012].

Table 1. GM plants and results of transformation

Plant species	Indruduced gene	Transformation result	References
Linum usitatissimum	*phb A, phb B, phb C*	improved mechanical properties of flax fibers	Wróbel-Kwiatkowska et al. 2007b, 2009
Linum usitatissimum	*CHS, CHI , DFR*	increased antioxidants content	Lorenc-Kukuła et al. 2005a
Linum usitatissimum	*β-1,3-glucanase*	improved resistance to *Fusarium oxysporum* and *Fusarium culmorum*	Wróbel-Kwiatkowska et al. 2004
Linum usitatissimum	*SsGT1*	increased resistance to *Fusarium*	Lorenc-Kukuła et al. 2009
Solanum tuberosum	*CHS, CHI, DFR*	increased antioxidants content	Łukaszewicz et al. 2004
Solanum tuberosum	*5-UGT*	increased resistance to *Erwinia carotovora* subsp. *carotovora*	Lorenc-Kukuła et al. 2005b
Solanum tuberosum	*SAK*	staphylokinase overexpression	Gerszberg et al. 2012
Cucumis sativus	*DHN24*	increased chilling tolerance	Yin et al. 2006
Cucumis sativus	*thaumatin II*	thaumatin overexpression	Szwacka et al. 2002
Hordeum vulgare	*HvCKX1*	silencing of *HvCKX1* gene expression and higher plant yield and root weight	Zalewski et al. 2010
Triticum aestivum	*Pina, Pinb*	silencing of *Pina, Pinb* genes expression increase in grain hardness	Gasparis et al. 2011
Daucus carota	*CHIT36*	increased resistance to *Alternaria radicina* and *Botrytis cinerea*	Barański et al. 2008
Solanum lycopersicum, *Nicotiana tabacum*	nucleoprotein (N) gene from TSWV virus	increased resistance to TSWV	Federowicz et al. 2005
Nicotiana tabacum	LMV CP virus coat protein gene, replicase gene of PVY	increased resistance to PVY	Czubacka and Doroszewska 2010
Nicotiana tabacum	*hIL-2*	overexpression of recombinant human interleukin 2 (hIL-2)	Redkiewicz et al. 2012
Lactuca sativa	*HBsAg*	overexpression of HBsAg, edible vaccine against HBV	Kapusta et al. 1999, Pniewski et al. 2011, 2012

In the case of transgenic cucumber plants sensory evaluation for several cultivation cycles has been carried out. Conservation of the sweet-taste phenotype was confirmed. According to chemical and taste analyses recombinant protein was identical to native thaumatin. The concentration of sweet-tasting protein in fruit flesh varied from 4,1 $\mu g \times g^{-1}$ to 6,8 $\mu g \times g^{-1}$ of fresh weight. Sensory assessment showed that the presence of recombinant protein strengthened the sweet taste of transgenic cucumber fruits [Szwacka et al. 2012]. Moreover, transgenic fruits were characterized by higher concentration of aroma compounds when compared with the control [Zawirska-Wojtasiak et al. 2009]. Nutritional studies conducted by Kosieradzka et al. [2001] showed no negative effects of transgenic cucumbers on the health state of model animals.

Analyses of numerous genetically modified plants have significantly increased the knowledge and understanding of many physiological processes and molecular mechanisms. Some new conceptions explaining the excess light-induced immune defence phenomenon have been suggested. The obtained results indicate that excess light can be physiologically 'memorised' by plants and used for optimization of future light acclimatory and immune defense responses. This process, called cellular light memory, implies that plants can store information on the excess light incidents and different spectral composition of light and use it to improve its chances of survival [Szechyńska-Hebda et al. 2010, Karpiński et al. 2012].

All over the world scientists make use of the progress in molecular biology and engineer transgenic plants with improved characteristics. There are many purposes of generating genetically modified plants: improving yield parameters, nutritional value, taste, pathogen resistance. Vast number of these concepts have been examined by Polish researchers (tab. 1). Among many others, there are transgenic flax plants with improved mechanical parameters and increased antioxidant properties, cucumber with enhanced cold-tolerance, carrot with increased resistance to fungal infection and higher-yielding transgenic barley. It should be pointed out that green biotechnology in Poland does not only concentrate on the production of GMOs for agricultural purposes. Great achievements have been made in the field of molecular farming. Transgenic plants have been successfully used as bioreactors for the production of recombinant proteins of pharmaceutical significance such as staphylokinase and interleukin 2. Moreover, a prototype of an edible, plant-derived vaccine against HBV was created. In the view of the presented paper it should be stated that Polish scientists greatly contribute to the global development of green biotechnology, which offers solution to many problems of the contemporary world.

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WYKORZYSTANIE ROŚLIN TRANSGENICZNYCH DO OTRZYMYWANIA WYBRANYCH BIOPRODUKTÓW – OSIĄGNIĘCIA POLSKICH NAUKOWCÓW

Streszczenie. Zielona biotechnologia odgrywa ważną rolę we współczesnej gospodarce. Rozwój biologii molekularnej oraz inżynierii genetycznej pozwala na tworzenie roślin transgenicznych o ulepszonych cechach, takich jak plon, wartość odżywcza, smak, skład chemiczny, tolerancja na chłód czy odporność na patogeny. Rośliny genetycznie modyfikowane mogą być wykorzystane do produkcji białek rekombinowanych ważnych z punktu widzenia medycyny i przemysłu, jak na przykład enzymy, przeciwciała, hormony czy metabolity wtórne. Badania nad roślinami transgenicznymi przeprowadzane są w wielu krajach. Mając na uwadze ogólnoświatowy rozwój zielonej biotechnologii, nie należy zapominać o osiągnięciach Polskich naukowców. Praca prezentuje badania nad otrzymywaniem roślin genetycznie zmodyfikowanych, które wykonano w Polskich ośrodkach badawczych. Ponadto przedstawiono potencjalne możliwości zastosowania otrzymanych bioproduktów z tych roślin.

Słowa kluczowe: transformacja, inżynieria genetyczna, rośliny genetycznie modyfikowane, zielona biotechnologia, białka rekombinowane

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