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GENETIC VARIABILITY AS BACKGROUND FOR THE ACHIEVEMENTS AND PROSPECTS OF THE MAIZE UTILISATION DEVELOPMENT

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Maize is one of the most important crops, and as such, one of the most significant naturally renewable carbohydrate raw materials of energy and numerous very different products. The dominance and superiority of maize are primarily caused by the extremely wide, very diversified and enormous possibilities of its utilisation.

Previous accomplishments are presented and prospective developments of the maize chemistry and technology, i.e. maize utilisation in our country and worldwide were discussed in the present study. The

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objective of this study was to advert to this section of science that is full of real and great challenges. Changes in the maize production and utilisation are described. Some very important questions were asked, such as: what is it that makes maize such a valuable, naturally renewable raw material, how and why do we sow maize and harvest energy and products?

Key words: Maize, grain, utilisation, products

INTRODUCTION

Maize is a very diverse and one of the most important natural, biodegradable and renewable raw materials. According to FAO data, maize was sown on 157 million hectares in 2007 (http://www.fao.org). The total maize production in the world in 2007 amounted to 766 million tonnes of grain. The global maize production in 2007 in comparison to the production in 1900 increased by 7.6 times. In the recent times, the average global yield per hectare has approached the level of five tonnes of grain, while the most developed agricultures have reached the levels of 7-8 tonnes per hectare. The greatest maize producer, the United States of America (USA) with a share of 40% in the total world production, in 2004, reached the national record of 10.06 tonnes of dry grain per hectare on the area of 30 million hectares. Also in Serbia, maize is a traditionally national field crop number one. During the last two decades, maize has been grown in our country on areas of approximately 1.2 million hectares. The obtained average annual production was approximately 5.7 million tonnes of grain.

The dominance and superiority of maize are primarily caused by the extremely wide, very diversified and enormous possibilities of its utilisation. Today, maize-based products touch human lives all over the planet: there are thousands of food products, personal hygiene and health care products, household products and all possible industrial goods and commodities. Beside the fact that maize has become an important part of our everyday life, health food, sustainable development, it has also become an unavoidable factor of the global economy (CORN ANNUAL, 2007). Therefore, studies on the possibility of maize utilisation in our country require full attention. The Maize Research Institute, Zemun Polje, is the sole scientific institution in our country whose overall work has been aimed at the improvement of maize utilisation for the last several decades. These studies were directed to the development of a new assortment of biologically valuable food and ecologically safe products. The application of contemporary processing technologies provided the production of new and unique highly valuable food: whole and micronised whole flour of red-, yellow- and white-seeded maize, bread, the concentrate for the bread production, corn bread and instant corn bread with biologically valuable components of red- and yellow-seeded maize (RADOSAVLJEVIĆ, 2005b and RADOSAVLJEVIĆ, 2008). Furthermore, the original technology of maize cob processing was developed (RADOSAVLJEVIĆ, 2005a). Different ligno-cellulose-granulates were obtain for the use in various branches of industry, agriculture and environmental protection. Co-workers of the Department of Technology Research has published abut 400 papers and brief communications, several studies, elaborates and books, and were awarded numerous prizes and awards. The published papers present in details results obtained by a long-term scientific and research work on the improvement of maize utilisation (RADOSAVLJEVIĆ et al. 2005, RADOSAVLJEVIĆ, 2006, DRINIĆ and RADOSAVLJEVIĆ 2007, RADOSAVLJEVIĆ and MILAŠINOVIĆ, 2008b).

The objective of the present study was to show previous accomplishments and to discuss progress in the further development of maize utilisation in both, our country and the world.

CHANGES IN MAIZE PRODUCTION AND UTILISATION

In 2007 in comparison to 2000, the harvested areas under maize in the world were greater by 14%, the production scope was increased by 26%, the utilisation in nutrition of domestic animals was increased by 16%, while industrial processing was greater by 55%. In relation to the production scope in 1900, the production was three-fold greater after 60 years, while it was 7.6-fold greater in 2007.

Table 1 Global maize production and utilisation (http://www.fao.org)

	1960-1961	1999-2000	2007-2008
Harvested areas (1000 ha)	102,179	139,006	156,958
Stock (1000 t)	50,159	196,808	107,250
Production (1000 t)	199,957	607,630	766,234
Total supply (1000 t)	268,557	838,458	965,910
Export (1000 t)	14,022	76,751	94,110
Livestock feeding (1000 t)	131,412	422,949	491,048
Industrial processing (1000 t)	62,896	180,356	278,862
Total consumption (1000 t)	194,508	608,255	769,910
Average yield (t/ha)	1.95	4.31	4.80

Many studies show that the maize production increase is mostly contributed by: the development of technology and seed production industry, the increase of efficiency of cropping practices, innovations in the development of a wide scope of food and technical maize-based products, especially innovations in the bioethanol production and the increase of its utilisation as an alternative motor fuel. The average global yield has been recently approaching the level of five tonnes of grain per hectare, while the most developed agricultures have already reached the levels of 7-8 tonnes per hectare. The greatest maize producer, the United States of America (USA) with a share of 40% in the total world production, in 2004, reached the national record of 10.06 tonnes of dry grain per hectare on the area of 30 million hectares.

The National Corn Growers Association (NCGA) (http://www.ncga.com) has predicted the national average of 12 tonnes of dry grain per hectare in 2015-16. It was assumed that this increase would result from an increased genetic yielding potential of hybrids, improved cropping practices and biotechnological innovations.

The Republic of Serbia is one of more important maize producers not only in Europe but in the world, too. According to FAO data, Serbia ranked 21st by sown areas and 16th by the total maize grain production. Maize was grown on areas of approximately 1,340,000 hectares in Serbia in the 1985-2005 period, while the annual production amounted to 5,560,000 tonnes. In comparison to 1945, the maize production in 2005 was 2.5-fold greater, while the average yield was 2.8-fold higher (Statistical Yearbook of the Republic of Serbia, 2005). Table 2 shows the maize production and utilisation in Serbia during the last decade.

Table 2 Maize production and utilisation in the Republic of Serbia http://webrzs.statserb.sr.gov.yu/axd/index.php)

Year	Harvested areas, ha	Total yield, t	Yield per ha, kg	Consumption in industry, t	Import, t	Export, t
1997	1270607	6626795	5215	450883	11228,527	119264,493
1998	1255433	4953408	3945	483152	152,197	462942,233
1999	1263020	6126428	4850	393611	0,837	254521,165
2000	1202944	2937537	2441	375189	4,090	195047,711
2001	1216607	5910485	4858	336842	210994,292	10465,893
2002	1196353	5586426	4669	365123	464,192	335572,044
2003	1199871	3817338	3181	347227	563,621	165552,726
2004	1199921	6569414	5474	296183	9454,468	190514,104
2005	1220174	7085666	5807	320422	1545,214	813139,135
2006	1169976	6016765	5142	420408	1545,225	1350512,266
2007	1201832	3904825	3249	415899	-	-

During the last decade, maize has been grown in our country on areas of approximately 1.2 million hectares. The obtained average annual production was approximately 5.4 million tonnes of grain.

MAIZE AS A RAW MATERIAL - MAIZE GRAIN QUALITY

One of the most important questions that can be asked from the aspects of the maize production and utilisation is: what is it that makes maize so valuable naturally renewable raw material? And the answer is very simple. Everything starts with a small mature maize kernel. The kernel is composed of three basic parts: pericarp (coat), germ and endosperm. Based on the morphological structure, i.e. kernel and endosperm structure there are five major types of maize: dent, flint, floury, popping and sweet maize. Yellow-seeded dent maize is mostly commercially grown in both, our country and the world. Results obtained in many studies on the kernel structure show that well mature kernels of standard dent maize are composed of: coat (6-7%), germ (10-12%) and endosperm (approximately 80%) (BEKRIĆ, 1997).

Observing from the practical application point of view, the chemical composition of the maize kernel is its most important trait, for both those using it in industry and those using it as food and feed. Among the different types of maize, the chemical composition of the dent maize kernel was studied the most in the past (WHITE and JOHNSON, 2003).

The next, also very important question for the maize utilisation is: what is maize kernel quality? Maize quality is interpreted and defined differently in the scientific literature. Which is the best and the most proper of them all? The newest concept of the developed market implies the identification of the most important ways of utilisation, as well as, requirements of each single use in relation to the most significant kernel properties. Therefore, maize quality signifies different elements for different users, i.e. consumers. Generally, there are three main groups of kernel quality factors: disadvantages (foreign materials, damages, heat damages, toxic substances), transport and storage conditions (humidity variation, insect attack, malfunction, warming up) and utilisation requirements (composition: proteins, starch, oil, etc., millability, hardness) (ECKHOFF and PAULSEN, 1996).

The quality determination of maize intended for a further utilisation plays a significant role in its purchasing, control of processing, and especially in studies carried out with the aim to improve its utilisation. Beside general requirements related to kernel health and purity, each group of processors has its own specific requirements related to quality.

The optimum maize utilisation means compliance of kernel properties with the requirements of each single use. Therefore, maize quality has a different meaning for different users that is consumers. For instance, the best results in animal nutrition were gained by the use of maize with high contents of proteins and oil, as well as, a low content of fibres. Maize with soft, floury endosperm is suitable for wet milling as it steeps easier and for a shorter period of time, which later on provides a better separation of starch and gluten. The starch content is the most important criterion for the maize-based alcohol production. This content should be above 70% in order to produce 37-40 litres of ethanol out of 100 kg of maize. Semi-flint maize with a high protein content and if possible with a white cob is recommended for products made by alkali cooking. Based on the estimation of leading world experts within this field, compliance of kernel properties with utilisation requirements can result in a greater maize value.

Quality of maize as a raw material for industrial processing and livestock feed is determined by the Standard JUS E.B3. 516/1. According to this Standard maize quality is determined by: contents and types of admixtures, moisture content, test weight, maize quality class, sensory properties, presence of pests, presence of microorganisms, presence of residues of plant protecting agents. Based on this Standard maize is classified into five classes in which the total amount of admixtures has not be higher than: 4%, 7%, 11%, 15% and 18% for the first, second, third, fourth and fifth class, respectively. According to the Standard, the optimum maize kernel moisture content should not be higher than 14%. Besides this Standard, there are some other regulations that directly or indirectly define maze quality: Regulations on quality of cereals, livestock feed and aliment (BEKRIĆ, 1997, RADOSAVLJEVIĆ *et al*, 2001).

Chemical and physical properties of several hundred ZP hybrids have been analysed within the long-term studies on maize grain quality at the Maize Research Institute, Zemun Polje. Based on obtained results, a great number of scientific papers was published (BEKRIĆ, 1997, RADOSAVLJEVIĆ *et al*, 2001b, RADOSAVLJEVIĆ *et al* 2001c, RADOSAVLJEVIĆ *et al* 2002a, RADOSAVLJEVIĆ *et al* 2002b, MILAŠINOVIĆ *et al,* 2003, RADOSAVLJEVIĆ *et al* 2006, PAJIĆ *et al* 2006, MILAŠINOVIĆ 2007a, MILAŠINOVIĆ 2007b). The parameters of kernel quality, i.e. results obtained on chemical composition, physical and milling properties of the most widely grown ZP maize hybrids are presented and discussed in this study. Kernel quality of 18 hybrids of different FAO maturity groups (FAO 300-800) and different types of endosperm was observed: nine of these 18 hybrids were standard dents (ZP 360, ZP 434, ZP 480, ZP 511, ZP 677, ZP 680, ZP 684, ZP 737 and ZP 808), two were high-oil hybrids (ZP 702u and ZP 703u), one waxy hybrid (ZP 704wx), two hybrids with white endosperm (300b and ZP 551b), three semi-flints (ZP 633, ZP 735 and ZP 750) and one popping maize hybrid (ZP 611k). Gained results are presented in Table 3.

The basic kernel chemical composition of observed hybrids ranged as follows: contents of starch from 67.5 to 74.3%, proteins from 8.3 to 13.7%, oil from 4.1 to 8.0% (hybrid ZP 702u), fibres from 1.9 to 2.9% and ash from 1.1 to 1.5%. The test weight ranged from 816.4 kg m^{-3} (ZP 611k) to 950.0 kgm^{-3} 358.4 g (ZP 680). The 1000-kernel weight and density ranged from 175.6 g and 1.21 g cm^{-3}, respectively in hybrids ZP 360 and ZP 300b to 358.4g and 1.38 gcm^{-3}, respectively in hybrid 611k. The flotation index, as a very important parameter of hardness, ranged from 0% in ZP 735 to 68% in ZP 808. A milling response ranged from 7 s (ZP 704wx) to 25.8 s (ZP 750), while a portion of hard, i.e. soft endosperm fraction ranged from 54.3, i.e. 45.7%, respectively, in ZP 808, to 71.3, i.e. 28.7%, respectively, in ZP 611k. The water absorption index widely ranged from 0.180 (ZP 360) to 0.284 (ZP 704wx). Results obtained on the kernel structure show that a portion of kernel parts ranged as follows: 77.3-83.7% (endosperm), 10.4-16.4% (germ) and 5.1-8.6% (pericarp).

Yield, starch recovery and purity, i.e. the protein content in isolated starch, are the most important parameters for the evaluation of wet milling properties of maize hybrid grain. It was determined that ZP hybrids with a higher starch content, a lower 1000-kernel weight and a lower kernel density and a greater portion of soft endosperm fraction had greater starch yields in wet milling. The protein content in starches isolated from selected ZP hybrids was very low (<0.3%), what points out to high quality, i.e. purity of isolated starches. Based on the amylase content, isolated starches can be classified into two groups: normal starches with about 24% of amylose (17 out of 18 observed ZP hybrids) and waxy maize starches with about 1% of amylose (ZP 704wx).

Table 3 Chemical composition, physical and milling properties of kernels of ZP maize hybrids (Radosavljević et al. 2005, Milašinović 2005, Radosavljević and Milašinović, 2008a)

Properties	Average	Minimum	Maximum
Starch (%)	71.2	67.5	74.3
Proteins (%)	11.1	8.3	13.7
Oil (%)	5.7	4.3	7.6
Fibres (%)	2.4	1.9	2.9
Ash (%)	1.3	1.1	1.5
Test weight (g L^{-1})	848.1	816.4	950.0
1000-kernel weight (g)	306.0	175.6	358.4
Density (g cm^{-3})	1.28	1.21	1.38
Flotation index (%)	27.8	0	68
Water absorption index	0.214	0.180	0.284
Milling response (s)	18.4	7	25.8
Portion of soft fraction (%)	37.6	28.7	45.7
Portion of hard fraction (%)	62.4	54.3	71.3
Endosperm content (%)	80.8	77.3	83.7
Germ content (%)	13.0	10.4	16.4
Pericarp content (%)	6.2	5.1	8.6
Starch yield (%)	64.7	58.8	69.0
Gluten yield (%)	8.5	5.3	13.5
Germ yield (%)	7.9	7.2	8.3
Bran yield (%)	8.3	7.4	9.0
Starch recovery (%)	89.4	83.7	94.0
Protein content in isolated starch (%)	0.21	0.11	0.29
Amylose content (%)	22.7	1.0	26.0

Gained results show a wide variability of observed parameters, what provides exceptionally great and diverse possibilities of the application of ZP hybrids in industrial processing.

MAIZE-BASED PRODUCTS

According to one study, there were 1160 maize-based products out of 12 thousands products that could be bought in supermarkets (BEKRIĆ, 1997). Today, some web-sites offer the data that 2500 maize-based products out of 10 thousands products could be found in mega-markets. The number of important individual or group maize-based products number is not definite (BEKRIĆ and RADOSAVLJEVIĆ, 2008, http://www.ontariocorn.org).

Starch macro molecules under actions of acids, bases, enzymes, temperatures and pressure has flexibility due to which new possibilities for maize utilizations are provided (RADOSAVLJEVIĆ, 2003, RADOSAVLJEVIĆ 2007, RADOSAVLJEVIĆ and BEKRIĆ, 2008). Observing maize processing, the USA, as a dominant producer and processor of maize, are the first example of a strong development of industrial maize processing. However, other countries have also initiated an intense development: China, as a second maize producer in the world, can be considered a second example. The company Dachang was established in 1997. A total of three million tonnes of maize are annually processed in this company. Beside conventionally processed products, such as starch, gluten, oil, maize sweeteners, it is very interesting to mention that 300,000 tonnes of 40 types of amino acids are synthesised there. These amino acids are used in biochemical and pharmaceutical industry. Technological processes are fully automated and computerised. Products are exported in 60 countries all over the world.

In recent times, two fields of processing have been attracting a special attention. The first is already mentioned - the use of maize for bioethanol refinement. The second field is the use of maize for polylactic acid (PLA) refinement. PLA is used for the production of a great number of organic textile goods or as a biodegradable plastic.

BIOETHANOL

The scope of the world bioethanol production amounted to 13.489 billion gallons in 2006, and in comparison to the production in 2004 (10.770 billion gallons) it was higher by 25%. The USA, Brazil, China and India participate in the scope of the world production in the amount of 36%, 33%, 7.5% and 3.4%, respectively. These four countries produce 80% of the total bioethanol produced in the world. It should be also mentioned that Brazil mainly produces bioethanol from sugar cane, while the USA produce it from maize (Annual World Ethanol Production by Country, http://www.ethanolrfa.org/industry/statistics/).

Bioethanol that is ethyl alcohol or ethanol or "fire water" has been known to people for thousands of years. It was discovered as a motor fuel just a hundred years ago, when the first automobile made by Henry Ford used alcohol as a fuel, while R. Diesel used peanut oil for the same purpose. However, both manufacturers discovered soon enough that crude oil, occurring naturally beneath the earth's surface, if refined, provided much better upward pressure per litre than plant fuel and at the same time it was not expensive (BORN, 2007). Since then, ethanol as a motor fuel has been disregarded, except in case of wars and crises on the crude oil market, especially in 1973 when OPEC laid an embargo on petrol. There were estimations that if the price of crude oil overpassed the level of 27$ per barrel ethanol synthesised from plants would be commercially competitive. Today, a price of a crude oil barrel at stock markets is higher than 100$. During the first years of the 21st century, the world was confronted with great emissions of carbon dioxide due to combustion of fossil fuels, then with climatic changes, wars and high demands for motor fuels that took us back to ethanol as a motor fuel. Ethanol replaced methyl-tetra-butyl in petrol in order to reduce the emission of carbon dioxide.

Although bioethanol could be synthesised from many plants, sugar cane and maize came out as the most suitable raw material. According to data of the Renewable Fuels Association (RFA), 141 factories with the total capacity of 12.9 billions of gallons, produced ethanol from maize in the USA in February, 2008.

Taking into consideration that a bushel (25.4 kg) of maize grain can produce 10.4 litres of pure ethanol (conversion factor of 2.75), these capacities need 119 million tonnes of maize grain or 30% of the American national production and reserves. In spite of the stated development, ethanol is mostly used as an addition to petrol. There are only 1,200 E85 fuel stations in the US maize belt that sell E85 fuel (85% ethanol and 15% petrol). This fuel can be used only by specially redesigned engines. Although the distance that can be driven with one litre of ethanol is shorter by 30% than the distance if petrol is used, the costs are equal as ethanol in this region is cheaper than petrol.

There are two ways, i.e. procedures of getting ethanol from maize. The first procedure is wet milling of maize grain that produces starch, gluten, bran, germ and steeping water. Starch is then hydrolysed into sugars, which are fermented into ethanol by the use of yeast. Approximately 40% of ethanol is made by this procedure in the USA. The second procedure is dry milling of maize grain. Ground maize grain is mixed with water, warmed up to a certain temperature, then enzymes are added and they convert starch into sugars, which ferment into ethanol as in the first procedure. In both procedures, ethanol is separated from water by distillation. Each tonne of maize dry milled and prepared by this procedure produces approximately 360 litres of ethanol, 320 kg of dry distilled grain that are used as important animal feed. Extensive studies on nutritive and biological values of this product were carried out. New technologies for product enrichment were developed in order to compensate lower supplies of maize for animal husbandry as it is used to produce ethanol, on one the hand, and on the other hand, in order to lower ethanol production costs.

Brazil is ranking the first in the production of ethanol from sugar cane. In 2005, 3.96 billion litres of ethanol were produced in Brazil. Parameters of production costs of ethanol from sugar cane differ from the costs of the ethanol production from maize (BEKRIĆ and RADOSAVLJEVIĆ, 2008). In contrast to maize whose starch has to be transformed into sugars by the use of enzymes, and then to be fermented into ethanol, sugar cane stalks contain 20% of fermentable sugars, hence they can be fermented into ethanol immediately upon harvest. On the other hand, seven to nine tonnes of ethanol are obtained from a hectare of sugar cane, which is two-fold higher than from maize grown on the area of the same size. Besides, sugar cane plantations can be harvested seven times before a new crop is established; then eight units of ethanol is obtained from one unit of used energy and at last, ethanol obtained from sugar cane has a significantly lower emission that creates the greenhouse effect.

So far, farmers and agricultural mega-corporations benefit from the production of ethanol from maize that is supported by tax and tariff subsidies. However, as maize is a basic link in the food production, a high demand for maize affects the price increase that is approaching five dollars per bushel as it has never been. A well-known Noam Chomsky wrote exactly the same apropos great demonstrations in Mexico caused by the skyrocketing cost (about 50%) of tortillas, the staple food for Mexican workers and the poor. Starving the poor is a consequence of the US stampede to maize-based ethanol (CHOMSKY, 2008).

Biofuel or food? Proponents of the staple plant-based production of biofuels are strongly opposed by many scientific authorities within technology, ecology, sociology and other scientific fields (BEKRIĆ and RADOSAVLJEVIĆ, 2008). The following arguments are most often pointed out:

- Ethanol is useful for farmers and big corporations but without greater effects on the ecological protection;
- Great amounts of herbicides and nitrogen and other fertilisers are used for maize cultivation; also fossil fuels are used for the application of cropping practices and harvest. The production of a certain amount of maize-based ethanol requires the equal amount of fossil fuels;
- The increased demand for maize will result in ploughing up unused areas, which will lead to a greater carbon release due to the decay of organic matters;
- The ethanol production by wet milling of maize gives a third of ethanol, third of distilled grain and a third of carbon dioxide, which is considered the dark side of this process as ethanol is intended for the carbon dioxide reduction. A very important question arises: what should be done with carbon dioxide?
- As a potential benefit from ethanol is great, the abrupt development can endanger food supply;
- The only way to use advantages of biofuels without the reduction of food sources is to exclude food sources from the process and to produce biofules from plant by-products, harvest residues that are mainly burnt;
- The development of better ways of the decomposition of cellulose by genetic manipulation of microbes and enzymes from entrails of termites that naturally break down cellulose;
- Some algae also have a great potential for the biofuel production. The Green Fuel company from Arizona has already gained experimental results, hence the greatest attention is paid to the production cost reduction.

MAIZE-BASED BIODEGRADABLE PLASTICS AND TEXTILE FIBRES

Besides bioethanol, in the recent times, a newly developed material, a maize-based polylactic acid (PLA) has been attracting a great attention. This very important polymer derived from maize grain by biotechnological processes of separation, hydrolysis, fermentation and polymerisation, can be modified for different applications: the production of yarn that is textile fibres and the production of biodegradable plastic packing material, medical and many other usages. The revolutionary Ingeo™ fibre (it means formed from lava/magma) has been made in the Ingeo™ company that was established by the corporation Cargill Dow in which PLA and its fibre were tested and derived. This fibre has many specific properties. In contrast to synthetic fibres and fabrics, maize-based fibre does not absorb oil, its production emits 50% less gases than the production of polyesters and it consumes 50% less energy. Also, this fibre is a renewable material and as such can be recycled and used afterwards. T-shirts, socks, shirts and other PLA fibre-based products show a high porosity for respiration, do not absorb a lot of water, have a high resistance to ultra-violet radiation, a low index of refraction; the products are not easily flammable and susceptible to smoke; they have a small specific weight in relation to other fibres; they do not emit pollutants into the environment; when coloured they do not require strong and harmful chemicals. The biotechnological process, as already described above, consists of starch separation and its hydrolysis to sugars, then fermentation of derived sugars into lactic acid that is purified and polymerised by enzymes, so that small opal or white PLA granules or pellets are derived and then used for the production of fibres, yarn, plastic dishes and various packing materials. In January 2005, 85 companies in the world used the Ingeo^{TM} fibre for the production of different goods. The Blair factory from Nebraska annually processes 140,000 tonnes of PLA out of which a half is used for the textile fibres production, while the other half is used for the production of biodegradable plastic. A special team of researchers of the University of Nebraska - Lincoln, works on the further improvement of PLA performances and studies the possibility of deriving a textile fibre from maize husk whose quality will range between quality of cotton and flax.

ZP MAIZE-BASED PRODUCTS

The achievements in maize breeding provide a significant extension of assortments of highly-valuable food and ecologically safe products by specific purpose growing of hybrids of special and unique grain traits. The *Federal Institute for Plant and Animal Genetic Resources* released 535 ZP maize hybrids (470 hybrids of a standard chemical composition and 65 hybrids of specific grain traits) developed at the Maize Research Institute, Zemun Polje. Twenty eight, eleven, five, eight, two, three, seven and one out of the total number of hybrids were: sweet (*su*), popping (k), lysine (o_2), oil (u), waxy (*wx*), flint (t), white- (b) and red-seeded maize, respectively.

Although maize grain is characterised by a high nutritive value, its presence in food is low. Nutritionists support a greater participation of whole grain of different cereals in food, as in such a way all necessary vitamins, minerals and alimentary fibres - deficit substances - are ingested into the body. Whole maize flour from the nutritive aspect is a concentrated source of energy, essential fatty and amino acids, proteins, vitamins A, B and E complex, β-carotene, mineral matters, first of all K and Mg. Several different milling products of high nutritive and biological values were developed at the Maize Research Institute, Zemun Polje. These products can be used as individual components or as a complete semi-ready maize-based food, (Radosavljević et al 2002c). These products encompass three types of ZP whole fresh maize grain flour and three types of whole micronised flour made from yellow-, red- and white-seeded maize, (RADOSAVLJEVIĆ *et al*, 2006). The use of micronised maize, especially the whole grain of selected ZP maize genotypes is the essential specificity of these ZP products. Hence, the stated products contain all valuable constituents of the maize germ, especially essential polyunsaturated fatty acids and other grain constituents that contribute to different compositions of amino acids, minerals and the increased fibre content of components that positively affect human health. Furthermore, the products of red-seeded maize are characterised by a presence of a red colour of the pericarp due to the presence of anthocyanin, while yellow-seeded maize-based products have a very appealing yellow colour due to the presence of β-carotenes, important natural antioxidants. These products are made of whole grain of specially selected ZP maize genotypes: red-seeded maize - ZP Rumenka, yellow- seeded maize - ZP 633 and white-seeded maize - ZP 300b. These products contain all important valuable constituents of maize grain and they are unique on the domestic market and present a good basis for spreading numerous high-quality backing products. Not only that the ZP technology of the micronised flour production is unique, but it provides certain technological advancements in the production of maize bread and bakery products. The technology of micronisation is a contemporary technological procedure of grain thermal processing at high temperatures for a short period of time by which grain traits are modified and its digestibility is improved. Red whole maize flour has improved nutritive traits due to greater contents of proteins, anthcyanin and insoluble fibres. Yellow whole maize flour has enhanced nutritive traits due to greater contents of proteins, carotenes, high-quality oil and insoluble fibres, while white whole maize flour has improved nutritive traits due to greater contents of proteins, high-quality oil and insoluble fibres.

Starting up from the gained scientific and research results, potential possibilities, conditions and demands on the market, and in accordance with nutrition recommendations for ever greater participation of whole cereal grain in food, the production of highly-valuable food by the use of ZP hybrids of specific traits as a raw material for making many products has been organised. First of all, there is ZP bread with biologically valuable components of red- and yellow-seeded maize, (RADOSAVLJEVIĆ *et al* 2003, RADOSAVLJEVIĆ *et al* 2004). ZP bread is made of micronised maize and whole grain of specially selected ZP genotypes. Therefore, ZP bread contains all valuable constituents of maize germ, especially essential polyunsaturated fatty acids and other grain constituents that contribute to different compositions of amino acids, minerals and the increased fibre content of components that positively affect human health. Besides, bread with the supplement of micronised grain of red-seeded maize is characterised by a presence of a red colour of the pericarp due to the presence of anthocyanin, while bread with the supplement of yellow-seeded maize has a very appealing yellow colour due to the presence of β-carotenes, important natural antioxidants. Micronised flour contributes to a prolonged bread freshness, hence, it provides a longer duration of products (the five-day self-life). A specific palatable taste gives bread particular properties. Bread with 20% of micronised maize contains all biologically valuable components of grain, and its sensory properties are similar to products made from white flour. Maize bread is insufficiently present on the market, first of all, due to its sensory properties and fast loss of freshness. Soon, ZP Super Smile - a concentrate for the bread production with all valuable contents of maize grain will be found on our market, (RADOSAVLJEVIĆ, 2005b). The basis for the production of this concentrate, as well as, of bread is whole flour made of micronised maize of red-, i.e. yellow-seeded ZP genotypes. These products are not only unique on the domestic market, but are also characterised by the improved content of necessary nutritive components (proteins, oils, carbon hydrate, fibres, vitamins, anthocyanins, i.e. β-carotene and minerals). The newest ZP products of highly-valuable food, ZP corn bread and instant corn bread with all biologically valuable constituents of maize, have properties of traditional, i.e. national food (RADOSAVLJEVIĆ, 2008). Sensory properties of these products are also very similar to traditional, i.e. national and well known kind of products of these biologically highly-valuable maize-based food.

All ZP products of highly-valuable maize-based food are functional food as their regular consumption can provide certain health advantages and they can affect the prevention of some contemporary diseases. Produced ZP products of biologically valuable food have been tested at the Laboratory for Technology Research of the Maize Research Institute, Zemun Polje, and at the accredited laboratory of the Faculty of Technology, University of Novi Sad. They are declared in accordance with validated Regulations on the quality of cereals, milling and bakery products, pasta and quick frozen dough (OFFICIAL GAZETTE OF SFRY issues 37/88 and 23/91 and Official Gazette of FRY issue 24/94) and are packed in a packing material of a very attractive design that provides the maintenance of the high quality of the product. All ZP products made within the programme of biologically valuable food were awarded six golden medals and a certificate with a special acknowledgment for the programme of biologically valuable food at the 71st International Agricultural Fair held in Novi Sad in 2004. Both types of ZP bread were awarded golden and silver medals at the 40th International Autumn Fair in Novi Sad in 2003.

Besides products of biologically valuable food, new technical products CELGRAN® A, B and C, i.e. lignocellulose granules of different particle sizes, different chemical compositions and different physical and chemical properties that determine their utilisation, were produced by the original ZP technological processing of cobs (BOŽOVIĆ *et al* 2003, BOŽOVIĆ *et al* 2004, RADOSAVLJEVIĆ, 2005a). These products are intended for the metal industry for drying, polishing and degreasing and could be directly applied in the environmental protection. They are mainly intended for the domestic market as a replacement for expensive imported products. The lignocellulose complex symbolises the most important component of the chemical composition of these products. The cellulose content ranges from 36.4% in the smallest fraction C to 41.5% in the largest fraction A. The lignocellulose content ranges within similar interval around 40% in dependence on the fraction. All three fractions have a great potential to absorb water and oil. Depending on the particle size, the fractions can absorb over three times the weight of oil in regard to their own weight. All observed fractions of the CELGRAN® products provide efficient and easy oil removal from water surfaces. The CELGRAN® products, as well as, ZP flour with biologically valuable constituents of red-, yellow- and white-seeded maize were awarded at the exhibition "Invention-Belgrade 2003" by the Belgrade Association of Inventors and Authors of Technical Improvements.

CONCLUSION

Genetic variability of maize provides technical processing with a large scope of the most diverse qualitative traits that can be optimally used for different productions and purposes, on the one hand, while on the other hand, they could be a reliable indicator to researches-breeders regarding the objectives of studying within this field.

Several laboratories in the world develop processes of separation of substances from maize by biorefinement and then modify them into constitutive blocks for control and prevention of viral diseases, AIDS, then hepatitis and prevention of urinary tract infections. L-arabinose, one of more developed sugars, is studied as a constitutive block, i.e. the ingredient for the medicines against hepatitis. It is interesting to mention that Powell described in the Star Tribune, April, 2005, healing and lucrative components of maize for which pharmaceutical companies claimed that they had been highly valuable in both, healing and prices (the price of L-ribose and Levoglucosenone is 350 $ and 6,000 $ per pound, respectively).

Maize separation by biorefinement and enzymatic modifications provides making new products of functional food that have healing performances and help in treatments of coronary disease, osteoporosis and other degenerate diseases. Some futurist researchers published in daily newspapers that new materials strong as steel, lighter than fibreglass, would be in near future produced from maize, wheat and flax seed by NANO-BIOCOMPOSITION. These materials will be used for auto bodies, airplane wings, helmets, artificial heart valves, and other important goods.

A fact that there is no end of the development of maize-based products imposes as a conclusion. Also, it seems that wonders of maize, as well as, possibilities of its utilisation will never end. Therefore, contemporary agronomy should provide maize as a very important raw material.

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GENETIČKA VARIJABILNOST KAO OSNOVA ZA DOSTIGNUĆA I PERSPEKTIVE RAZVOJA KORIŠĆENJA KUKURUZA

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I z v o d

Kukuruz je je jedna od najznačajnijih gajenih biljaka i kao takav ujedno i jedna od najznačajnijih prirodno obnovljivih ugljenohidratnih sirovina energije i jako velikog broja veoma različitih proizvoda. Dominacija i superiorni položaj kukuruza uslovljeni su izuzetno širokim, veoma raznovrsnim i ogromnim mogućnostima njegovog korišćenja.

U ovom radu su prikazana dosadašnja dostignuća i diskutovane su perspektive budućeg razvoja hemije i tehnologije kukuruza, odnosno korišćenja kukuruza u našoj zemlji i u svetu. Cilj rada je bio da skrene pažnja na ovaj sektor nauke koji je pun pravih i velikih izazova. Opisane su promene u proizvodnji i korišćenju kukuruza. Postavljena su i neka od veoma važnih pitanja kao na primer: šta je to što čini kukuruz toliko i tako vrednom prirodnoobnovljivom sirovinom, šta je to kvalitet zrna kukuruza, kako i zašto sejemo kukuruz a žanjemo energiju i proizvode?

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