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GRAIN CHEMICAL COMPOSITION OF DENTS, POPPING MAIZE AND SWEET MAIZE GENOTYPES

HEMIJSKI SASTAV ZRNA GENOTIPOVA KUKURUZA ZUBANA, KOKIČARA I ŠEĆERCA

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ABSTRACT

Maize is one of the most important field crops both in the world and in our country. All commercially grown maize hybrids can be classified into one of five elementary types: dent, flint, floury, popping and sweet maize. The objectives of this study were to characterize the grain chemical compositions of yellow-seeded and white-seeded maize dents, popping maize and sweet maize genotypes. The results show that grains contents of starch, protein, oil, crude fibre, and ash of four selected maize genotypes ranged in the intervals: 53.54-68.13%; 9.19-13.00%; 4.35-5.39%; 2.13-3.93% and 1.28-2.85%, respectively. The amylose to amylopectin ratio varied from 21:79 to 28:72, which is a principal property of normal maize starch. The content of lignocellulosic fibres: NDF, ADF, ADL, hemicellulose and cellulose ranged from 11.31-15.27%; 2.51-3.54%, 0.24-0.52%, 8.10-12.68% and 2.14-3.02%, respectively. The solubility index of albumin, globulin, zein and glutelin ranged from 9.46-29.42%, 5.64-13.13%, 21.11-28.10% and 18.81-23.69%, respectively.

Keywords*: maize, grain, chemical composition*

REZIME

Kukuruz je jedna od najznačajnijih ratarskih biljka u našoj zemlji i u svetu. Na osnovu strukture zrna i sastava endosperma svi komercijalno gajeni hibridi kukuruza mogu se svrstati u jedan od pet osnovnih tipova: zubani, tvrdunci, brašnasti, kokičari i šećerci. Hemijski sastav kukuruznog zrna predstavlja njegovo najbitnije svojstvo. U ovom radu su prikazani rezultati ispitivanja hemijskog sastava zrna različitih genotipova kukuruza (zuban žutog i belog zrna, kokičari i šećerci). Hemijski sastav zrna odabranih genotipova kukuruza ispitivan je određivanjem sardžaja skroba, amiloze i amilopektina, lignoceluloznih vlakana (NDF - vlakna nerastvorna u neutralnom deterdžentu, ADF - vlakna nerastvorna u kiselom deterdžentu, ADL - lignin nerastvorljiv u 72% rastvoru sumporne kiseline, celuloza i hemiceluloza), proteina i proteinskih frakcija (% rastvorljivih proteina i indeks rastvorljivosti albumina, globulina, zeina, glutelina), ulja, sirove celuloze i pepela. Određivan je i sadržaj nestrukturalnih ugljenih hidrata (NFC–non fiber carbohydrate) i bezazotnih ekstraktivnih materija (BEM).

Rezultati ispitivanja hemijskog sastava zrna odabranih genotipova kukuruza zubana, kokičara i šećerca su pokazali da su se sadržaji skroba, proteina, ulja, sirove celuloze i pepela kretali u sledećim intervalima: 53,54-68,13%; 9,19-13,00%; 4,35-5,39%; 2,13-3,93% i 1,28-2,85%. Odnos amiloze i amilopektina skroba ispitivanih genotipova bio je u rasponu od 21:79 do 28:72, što je glavno svojstvo normalnog kukuruznog skroba. Sadržaj lignoceluloznih vlakana: NDF, ADF, ADL, hemiceluloze i celuloze bio je u rasponima od 11,31-15,27%; 2,51-3,54%, 0,24-0,52%, 8,10-12,68% i 2,14-3,02%. Sadržaj NFC kretao se od 67,16-73,97% i BEM od 74,83-83,05%. Indeks rastvorljivosti albumina je bio od 9,46-29,42%, globulina 5,64-13,13%, zeina 21,11-28,10% i glutelina 18,81-23,60%.

Ključne reči*: kukuruz, zrno, hemijski sastav*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important field crops both in our country and in the world. Maize grain represents a well-organized entity consisting of the three essential parts: pericarp or a coat (5.3%), endosperm (82.8%) and the germ/embryo (11.9%) (*Bekrić, 1997; Watson, 2003*). Based on the grain structure and the endosperm composition, all commercially grown maize hybrids can be classified into one of five basic types: dent, flint, floury, popping and sweet maize hybrids. The chemical composition of maize grain is its most important trait both in the selection and breeding of new maize hybrids and in the improvement of its practical application in industrial processing and in human and animal nutrition (*Watson, 2003; Radosavljević et al., 2015; Milašinović-Šeremešić et al., 2018*). The largest percentage of the produced maize in our country, as well as in the world, is traditionally used in the nutrition of domestic animals. Furthermore, maize is a very important cereal used in the food industry in the process of wet (starch processing) and dry milling (mill processing). The following products are made in the process of maize wet milling: starch, gluten, bran, germ and corn steep liquor (CSL). The primary products of dry maize milling are semolina and flour. The main products of wet and dry maize milling are used to produce a whole range of different food products, while their by-products are used in animal nutrition (*Nuss and Tanumihardjo, 2010*). Maize grain, as well as the grain of other cereals, contains the following most important chemical components: starch (61-78%), non-starch polysaccharides (about 10%), proteins (6-12%) and fats (3-6%) (*Sinha et al., 2011*). Due to the large and wide application of maize grain in various food products, the grain is an important source of these macronutrients. In the past few decades, many studies were carried out with the aim to improve the nutritional value of maize for food and feed (*Ai and Jane, 2016*). Therefore, the objective of the present study was to observe the chemical composition of different genotypes: yellow-seeded and white-seeded maize dents, popping maize and sweet maize.

MATERIAL AND METHOD

Four different maize genotypes (yellow-seeded and white-seeded maize dents, popping maize and sweet maize) were analyzed in the study. The sweet maize was harvested at the milk stage of maturity which is optimal for the technological quality of the specialty genotype. Other maize samples were harvested at the stage of physiological maturity which is the final stage in the maize growth process (maximum kernel dry weight has accumulated). The grain chemical composition of selected maize genotypes was observed by the determination of contents of starch, amylase and amylopectin, lignocellulose fibres (NDF - neutral detergent fibres, ADF - acid detergent fibres, ADL - acid detergent lignin, cellulose and hemicellulose), proteins and protein fractions (% of soluble proteins and the solubility index of albumin, globulin, zein and glutelin), oil, crude fibre and ash. Furthermore, the content of non-fibre carbohydrates (NFC) and nitrogen-free extracts (NFE) was determined. All methods applied in this study are described in detail in previously published papers (*Semenčenko 2013; Radosavljević et al., 2015*).

All results of chemical quality parameters presented in this paper are the average of a two-year research (2016, 2017).

RESULTS AND DISCUSSION

Table 1 shows the chemical composition of different maize genotypes (yellow-seeded and white-seeded maize dents, popping maize and sweet maize).

Obtained results show that contents of starch, protein, oil, crude fibres and ash in grain of observed maize genotypes ranged from 53.54 (sweet maize) to 68.13% (yellow dent); 9.19 (white dent) to 13.00% (sweet maize); 4.35 (white dent) to 5.39% (sweet maize); 2.13(white dent) to 3.93% (sweet maize) and from 1.28 (white dent) to 2.85% (sweet maize), respectively. The contents of NFC and NFE varied from 67.16 (sweet maize) to 73.97% (white dent) and from 74.83 (sweet maize) to 83.05% (white dent), respectively (Table 1). The highest content of grain starch was in the genotypes of yellow and white dent maize (68.13 and 68.11%), while the lowest starch content in grain was in the genotype of sweet maize (53.54%), which also had the highest content of protein (13.00%), oil (5.39%), crude cellulose (3.93%) and ash (2.85%). Besides the genotype of sweet maize had the lowest content of NFE (74.83%) and NFC (67.16%) in the grain. The white dent maize genotype had the highest content of NFE (83.05%) and NFC (73.76%) and the lowest content of protein (9.19%), oil (4.35%), crude cellulose (2.13%) and ash (1.28%) in the grain. Results presented in Table 1 are following previously published results (*Watson*, 2003; *Ai and Jane, 2016*; *Milašinović-Šeremešić et al., 2018 and 2019).*

Figure 1 shows the content of amylose and amylopectin in grain starch of different maize genotypes (yellow-seeded and white-seeded dents, popping maize and sweet maize).

The content of amylose and amylopectin, i.e. their ratio in grain starch of observed genotypes varied from 21:79 (sweet maize) to 28:72 (popping maize). The popping maize had the highest content of amylose (28%) which can be attributed to the kernel hardness (a high proportion of hard endosperm fraction) as well as specific genetics. Based on such obtained amylose to amylopectin ratios, starches of observed maize genotypes can be classified as normal maize starches (*Jane, 2009; Milašinović-Šeremešić et al., 2012*).

Table 1. Chemical composition of different maize genotypes

Genotype	Content (%)						
	NFE	NFC	Starch	Proteins	Oil	Crude fibres	Ash
Yellow-seeded dent	81.73	69.07	68.13	9.84	4.46	2.61	1.36
White-seeded dent	83.05	73.79	68.11	9.19	4.35	2.13	1.28
Popping maize	79.72	70.73	65.77	11.43	5.13	2.32	1.40
Sweet maize	74.83	67.16	53.54	13.00	5.39	3.93	2.85
Average	**79.83**	**70.19**	**63.89**	**10.87**	**4.83**	**2.75**	**1.72**
SD	**3.61**	**2.81**	**6.99**	**1.71**	**0.51**	**0.81**	**0.75**

NFE – nitrogen-free extracts; NFC - non-fibre carbohydrate

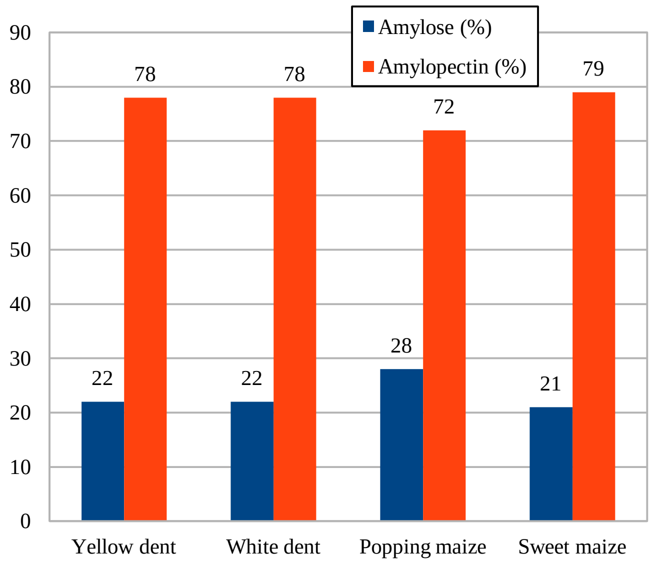

Fig. 1. Content of amylose and amylopectin in grain starch of different maize genotypes

In addition to the analyses of basic chemical composition, determinations of nutritional quality parameters such as the content of lignocellulosic fibres (NDF, ADF, ADL, hemicellulose and cellulose) and the protein fractions content (solubility and the solubility index of albumins, globulins, zein and glutelins) of selected maize genotypes also were done in this study. Lignocellulosic fibres are very valuable nutritional components of maize grain that affect grain nutritional and technological quality. Cellulose and hemicellulose are principal non-starch polysaccharides present in maize grain, especially in maize bran (*Watson, 2003).* The contents of NDF, ADF, ADL, hemicellulose and cellulose of grain of various maize genotypes (yellow- and white-seeded dents, popping maize and sweet maize) are presented in Table 2.

Table 2. Content of lignocellulosic fibres of grains of different maize genotypes

Genotype	Content (%)				
	NDF	ADF	ADL	Hemicellulose	Cellulose
Yellow-seeded dent	15.27	2.59	0.24	12.68	2.35
White-seeded dent	11.36	2.51	0.37	8.88	2.14
Popping maize	11.31	2.62	0.47	8.69	2.15
Sweet maize	11.61	3.54	0.52	8.10	3.02
Average	**12.39**	**2.82**	**0.40**	**9.59**	**2.42**
SD	**1.93**	**0.49**	**0.12**	**2.09**	**0.41**

NDF - neutral detergent fibres; ADF - acid detergent fibres; ADL - acid detergent lignin

The content of NDF, ADF, ADL, hemicellulose and cellulose of grain of observed maize genotypes ranged from 11.31 (popping maize) to 15.27% (yellow dent), 2.51(white dent) to 3.54% (sweet maize), 0.24 (yellow dent) to 0.52% (sweet maize), 8.10 (sweet maize) to 12.68% (yellow dent) and from 2.14 (white dent) to 3.02% (sweet maize), respectively (Table 2). The highest content of NDF (15.27%) and hemicellulose (12.68%) was detected in the grain of the yellow-seeded dent genotype. On the other hand, the highest contents of ADF (3.54%), ADL (0.52%) and cellulose (3.02%) was determined in the grain of the sweet maize genotype. At the same time, the results showed that the lowest content of grain lignocellulosic fibres NDF (11.31%), ADF (2.51%), ADL (0.24%), hemicellulose (8.10%) and cellulose (2.14%) was present in the genotypes of popping, white dent, yellow dent, sweet and white dent maize, respectively. Similar results have been obtained in previous studies (*Radosavljević et al., 2012; Milašinović-Šeremešić et al., 2017).*

Maize grain contains from 6% to 12% of proteins that are mainly located in the endosperm (70-79% of total grain proteins) and the germ (18-28% of total grain proteins) (*Watson, 2003).* Although maize is an important raw material for human and animal nutrition, maize grain proteins are deficient in the content of lysine, which is one of the essential and limiting amino acids in protein synthesis. The results of analyzing the protein content in grain of different maize genotypes (yellow-seeded and white-seeded dents, popping maize and sweet maize) are shown in Table 3.

The protein content of grain of four different maize genotypes is presented by the following parameters: solubility and the solubility index of proteins. Solubility of albumins, globulins, zein and glutelins ranged from 1.12 (popping maize) to 3.37% (sweet maize), 0.65 (sweet maize) to 1.27% (yellow and white dent), 2.43 (sweet maize) to 3.04% (yellow dent) and from 2.04 (yellow dent) to 2.80% (popping maize), respectively. Furthermore, the solubility index varied from 9.46 (popping maize) to 29.42% (sweet maize), 5.64 (sweet maize) to 13.13% (white dent), 21.11 (sweet maize) to 28.10% (yellow dent) and from 18.81 (yellow dent) to 23,60% (popping maize) in albumins, globulins, zein and glutelins, respectively. The results showed that the highest indexes of solubility of albumin, globulin, zein and glutelin were found in the genotypes of sweet (29.42%), white dent (13.13%), yellow dent (28.10%) and popping (23.60%) maize. However, the lowest solubility indices of albumin, globulin, zein, and glutelin were found in popping (9.46%), sweet (5.64%), sweet (21.11%) and yellow dent (18.81%) maize genotypes, respectively.

Table 3. Protein content in grain of different maize genotypes

Genotype	Albumins (%)		Globulins (%)		Zein (%)		Glutelins (%)	
	SP	SI	SP	SI	SP	SI	SP	SI
Yellow-seeded dent	1.42	13.13	1.27	11.74	3.04	28.10	2.04	18.81
White-seeded dent	1.51	15.62	1.27	13.13	2.45	25.34	2.08	21.51
Popping maize	1.12	9.46	0.85	7.15	2.66	22.46	2.80	23.60
Sweet maize	3.37	29.42	0.65	5.64	2.43	21.11	2.26	19.77
Average	**1.86**	**16.91**	**1.01**	**9.42**	**2.65**	**24.25**	**2.30**	**20.92**
SD	**1.02**	**8.72**	**0.31**	**3.59**	**0.28**	**3.11**	**0.35**	**2.11**

SP – soluble proteins; SI – solubility index

Due to its specific genetics and the harvesting stage, the kernel of sweet maize genotype had significantly different chemical composition (low starch content and high protein, fiber and ash contents) and very different nutritional quality parameters (high contents of ADF, ADL and cellulose and low content of hemicellulose, a high index of solubility of albumin and low solubility of globulin and zein) compared to other maize genotypes.

The results presented in this study could be useful for the improvement of maize utilization and the development of new maize-based products. In addition to this, they could be guidelines for maize breeders in the further research and development of new maize hybrids with desired properties for specific purposes.

CONCLUSION

The chemical composition of the four selected maize genotypes varied as shown by their proximate analyses.

Results obtained on grain basic chemical composition of the selected yellow-seeded and white-seeded maize dents, popping maize and sweet maize show that the contents of starch, protein, oil, crude fibres, and ash varied among tested genotypes. The highest content of grain starch was in the genotypes of yellow and white dent maize (68.13 and 68.11%), while the lowest starch content in grain was in the genotype of sweet maize (53.54%), which also had the highest content of protein (13.00%), oil (5.39%), crude cellulose (3.93%) and ash (2.85%). The ratio of amylose to amylopectin of all tested genotypes varied from 21:79 (sweet maize) to 28:78 (popping maize), which is a principal property of normal maize starch. Similarly, the nutritional quality parameters such as the content of lignocellulosic fibres (NDF, ADF, ADL, hemicellulose and cellulose) and the solubility index of albumin, globulin, zein and glutelin of observed maize genotypes were in a broad range as well.Thus, based on gained results, maize genotypes developed at the Maize Research Institute, Zemun Polje, can be classified as hybrids of high grain quality and as such are highly valuable naturally renewable raw materials for production and energy.

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