DOI: 10.46793/SBT26.495N

QUALITY PARAMETERS AND POTENTIALS OF UTILIZATION OF DIFFERENT MAIZE HYBRIDS FOR FOOD AND FEED

Valentina Nikolić, Slađana Žilić, Marijana Simić, Milica Radosavljević, Milomir Filipović, Jelena Srdić

Abstract: Quality parameters of six maize hybrids created at the Maize Research Institute Zemun Polje were investigated in this study. Physical properties, kernel structure, and chemical composition of one yellow dent standard and five specialty maize hybrids of different grain color were analyzed. Whole-grain maize flour is naturally gluten-free which makes it suitable for persons suffering from celiac disease. Fiber, protein, and oil make maize grain an essential component for animal feed production. All maize hybrids showed favorable processing and nutritive characteristics which make them highly suitable for different uses.

Key words: maize hybrids, physical properties, chemical composition, food and feed

Introduction

Maize (*Zea mays* L.) is one of the most important crops and its production ranks as the third in the world after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) (Liu, 2020). It is one of the most diverse grain crops found in nature. Maize varieties can be classified, by characteristics of their kernel endosperm, into several main groups: flint, dent, floury, popping maize, sweet and waxy.

Maize grain, in average, consists of 71.3 % starch, 9.91 % protein, 4.45 % fat, 1.42 % ash, and 2.66 % crude fiber (Eckhoff, 2009). Depending on the genetic background that affects the color of the pericarp, aleurone, germ and endosperm, the color of maize grains can vary from white and yellow, through orange, red, burgundy, blue and purple to brown (Žilić, 2012).

Specialty maize hybrids, in comparison with standard genotypes, have properties that tend to improve the quality of finished products which makes them suitable for specific end uses. However, even though breeding of specialty hybrids improves some quality traits, these maize varieties often have lower yield than the standard maize hybrids. Therefore, the added value of specialty maize must surpass the yield reduction in order to be profitable (Scott, 2019).

The aim of this study was to determine quality parameters of one standard yellow dent hybrid and five specialty maize hybrids of different genetic

Maize Research Institute Zemun Polje, Slobodana Bajića 1, Belgrade-Zemun, Serbia (valentinas@mrizp.rs);

background in order to evaluate their end use value, primarily as ingredients of food and feed.

Material and methods

Six maize hybrids of different genetic background developed at the Maize Research Institute, Zemun Polje, were investigated in this study. The two-replicate trial was set up according to the randomized complete-block design at the experimental field located at the Maize Research Institute, Zemun Polje. The plot size was 21 m^2, while the sowing density was 60,000 plants ha^{-1}. Maize ears of each replicate were harvested in the full physiological maturity stage from the area of 7 m^2 (two inner rows). Whole grain maize flour was obtained by grinding on a laboratory mill for fine samples preparation (mesh 0.5 mm).

Standard laboratory methods applied for determining physical properties of maize ear and grain were described in detail in an article previously published by Radosavljević (2001). Dry matter content in the maize flour was determined by the standard drying method in an oven at 105 °C to constant mass. The protein content was determined by the Kjeldahl method as the total nitrogen multiplied by 6.25 (AOAC, 1990). Crude fiber content was determined by Weende method adjusted for Fibretec™ Systems, Foss, Denmark (Agricultural food products, 1993). The results are expressed in the percentages per dry matter (d.m.). All analyses were performed in two replicates, and the results are presented as means.

Statistical analysis was performed in Minitab19 Statistical Software using one-way ANOVA analysis of variance with Fisher's LSD (Least Significance Difference) test. Differences between the means with probability $p<0.05$ were accepted as statistically significant. Means that do not share a letter are significantly different.

Results and discussion

Results obtained by manual dissection of maize kernels showed that standard yellow dent hybrid had the largest endosperm content, the popcorn genotype had the highest pericarp share, followed by red dent, while white dent hybrid had the largest percent of germ (Table 1). The highest 1000-kernel mass was determined in red grain hybrid (364.08±5.52 g), and the lowest in popcorn hybrid (132.67±21.55 g) (Table 2). Higher 1000-kernel mass is a preferred wet-milling characteristic because it is associated with greater starch and protein yield and lesser yields of fiber (Milašinović, 2005). Yellow popcorn had the highest absolute density and milling response, due to the largest share of hard endoseprm in the kernel, while high-oil hybrid had the lowest milling response (Table 2). All the analyzed hybrids had test weights higher than 650.0 kg m^{-3}, required for animal feed according to Serbian regulations (Pravilnik o kvalitetu hrane za životinje, 2016), and 69.50 kg hl^{-1} (695.0 kg m^{-3}) required for US Grade No. 2 corn (Somavat, 2016), while in Serbia, there is no minimal request for this parameter for maize grain quality for human food consumption. Milling response and the share of hard and soft fractions of the endosperm are parameters of grain hardness which, observed from the aspect of the industrial application of maize, starch processing in particular, represent its most important physical properties. Water absorption index ranged from 0.216±0.01 (high-oil hybrid) to 0.270±0.05 (waxy hybrid). Water absorption index is a very important parameter for the wet milling of the maize grain because it influences the separation of the maize kernels into their basic components (starch, protein, oil, and fibers). During the steeping phase of the process, the morphological and biochemical changes that occur are responsible for all subsequent stages of the process and, therefore, for the final quality of the product (Botelho, 2013).

Tabela 1. Struktura zrna ZP hibrida kukuruza
Table 1. Structure of the ZP maize hybrids kernel

Hibrid *Hybrid*	Omotač (%) *Pericarp (%)*	Klica (%) *Germ (%)*	Endosperm (%) *Endosperm (%)*
Žuti zuban *Yellow dent*	5.30±0.20[c]	11.39±1.04[a]	83.31±1.05[a]
Beli zuban *White dent*	6.09±0.32[b]	12.88±0.42[a]	81.03±0.72[b]
Crveni zuban *Red dent*	6.64±0.40[b]	11.57±0.68[a]	81.79±0.60[a,b]
Žuti kokičar *Yellow popcorn*	9.33±0.34[a]	9.20±0.47[b]	81.46±0.40[b]
Uljani *High-oil*	6.10±0.52[b]	12.20±2.42[a]	81.70±1.91[a,b]
Voskovac *Waxy*	6.24±0.16	12.32±0.63[a]	81.48±0.50[b]

Starch, the most abundant storage polysaccharide in plants, is the predominant component of maize grain. Standard yellow dent hybrid had the largest starch content (71.17±1.54 %), the highest protein content was determined in popcorn hybrid (11.52±1.46 %), high-oil genotype had the highest oil content (7.21±0.10 %), while crude fibre and ash content did not vary significantly (Table 3). Popcorn hybrids generally have higher content of hard endosperm that surrounds a small amount of moist starch in the center. High-oil maize hybrids are excellent source of energy and essential fatty acids for human as well as animal nutrition due to the highly polyunsaturated, high linoleic content of oil. Waxy endosperm hybrids contain 100% amylopectin starch (branched molecular form), opposed to standard dent maize that has average ratio of 72 % amylopectin and 28 % amylose. This hybrid is very suitable for feed because studies have shown that steers gain more weight when fed waxy maize. This hybrid is also very sought for in the food industry as a thickener because of the stability of amylopectin starch (Scott, 2019).

Tabela 2. Fizička svojstva zrna ZP hibrida kukuruza
Table 2. Physical properties of ZP maize hybrids grain

Hibrid ***Hybrid***	**AM** ***1000-KM***	**HM** ***TM***	**G** ***AD***	**IF** ***FI***	**OM** ***MR***	**TF** ***HE***	**MF** ***SE***	**IAV** ***WAI***
Žuti zuban ***Yellow dent***	271.33± 51.12^{b,c}	780.12± 20.24^{b}	1.27± 0.04^{b}	45.81± 36.91^{a}	10.02± 1.60^{b}	62.62± 1.79^{b}	37.38± 1.79^{b}	0.241± 0.01^{a,b}
Beli zuban ***White dent***	292.91± 53.56^{b,c}	789.97± 20.34^{b}	1.26± 0.02^{b}	38.81± 24.64^{a}	10.78± 0.77^{b}	59.14± 0.53^{b,c}	40.86± 0.53^{a,b}	0.255± 0.02^{a,b}
Crveni zuban ***Red dent***	364.08± 5.52^{a}	780.32± 6.07^{b}	1.29± 0.01^{b}	23.00± 1.23^{a}	12.49± 1.71^{b}	54.61± 4.09^{c}	45.39± 4.09^{a}	0.230± 0.03^{a,b}
Žuti kokičar ***Yellow popcorn***	132.67± 21.55^{d}	891.16± 9.53^{a}	1.37± 0.01^{a}	34.03± 57.14^{a}	26.91± 9.05^{a}	76.82± 4.85^{a}	23.18± 4.85^{c}	0.236± 0.02^{a,b}
Uljani ***High-oil***	244.40± 31.70^{c}	761.43± 17.09^{b}	1.27± 0.02^{b}	16.43± 10.45^{a}	9.80± 0.35^{b}	61.17± 1.79^{b}	38.83± 1.79^{b}	0.216± 0.01^{b}
Voskovac ***Waxy***	317.25± 7.48^{a,b}	754.4± 41.2^{b}	1.26± 0.01^{b}	25.33± 12.30^{a}	10.57± 0.93^{b}	58.37± 3.18^{b,c}	41.63± 3.18^{a,b}	0.270± 0.05^{a}

***AM**–apsolutna masa, (g);
HM–hektolitarska masa, (kg·m^{-3});
G–gustina, (g·cm^{-3});
IF–indeks flotacije (%);
OM–otpornost na mlevenje, (s);
TF–tvrda frakcija endosperma, (%);
MF–meka frakcija endosperma, (%);
IAV– indeks apsorpcije vode.

1000- KM-*1000-kernel mass (g);*
TM-*test mass (kg·m^{3});*
AD- *Absolute density (g cm^{-3});*
FI-*flotation index (%);*
MR-*milling response (s);*
HE-*hard endosperm fraction (%);*
SE-*soft endosperm fraction (%);*
WAI-*water absorption index.*

Tabela 3. Hemijski sastav zrna ZP hibrida kukuruza
Table 3. Chemical composition of ZP maize hybrids grain

Hibrid *Hybrid*	Skrob (%) *Starch (%)*	Proteini (%) *Protein (%)*	Ulje (%) *Oil (%)*	Sirova celuloza (%) *Crude fiber (%)*	Pepeo (%) *Ash (%)*
Žuti zuban *Yellow dent*	71.17±1.54[a]	9.17±0.96[b]	5.85±0.38[b,c]	2.15±0.14[a]	1.25±0.19[a]
Beli zuban *White dent*	67.00±0.57[c]	9.03±0.62[b]	6.34±0.33[b]	2.36±0.16[a]	1.27±0.25[a]
Crveni zuban *Red dent*	70.12±0.55[a,b]	9.68±0.72[b]	5.32±0.11[c]	2.19±0.12[a]	1.36±0.13[a]
Žuti kokičar *Yellow popcorn*	64.63±0.55[d]	11.52±1.46[a]	5.29±0.54[c]	2.58±0.08[a]	1.33±0.23[a]
Uljani *High-oil*	68.77±1.53[b,c]	10.13±0.83[a,b]	7.21±0.10[a]	2.30±0.62[a]	1.27±0.06[a]
Voskovac *Waxy*	69.63±1.84[a,b]	10.10±0.67[a,b]	5.72±0.91[b,c]	2.23±0.10[a]	1.39±0.08[a]

The results obtained in this research are in accordance with findings of the studies previously conducted on ZP maize hybrids (Nikolić, 2020; Radosavljević, 2020; Milašinović-Šeremešić, 2019)

Conclusion

Maize hybrids investigated in this study had a wide range of quality traits regarding grain physical properties, structure and chemical composition. Significant differences between grain hardness, millability and contents of basic chemical components represent a starting point for various possibilities of their utilization in food and feed production particularly, as well as a large number of industrial applications. They can be used primarily for obtaining the gluten-free whole-grain maize flour for the production of functional food, as well as a valuable component of animal feed. These findings are implying that genetic variability of maize hybrids plays a key role in their further processing.

Acknowledgements

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

Agricultural food products (1993). Determination of crude fibre. General method NF-V03-040 (status: certified standard ref. ISO 5498), Assn. Fr. De Normalisation, Paris.

AOAC (1990). Association of Official Analytical Chemists, Official Methods of Analysis, ed. by Herlich K. AOAC, Arlington, VA. pp. 70–84.

Botelho F.M., Corrêa P.C., Martins M.A., Botelho S. de C.C., Horta de Oliveira G.H. (2013). Effects of the mechanical damage on the water absorption process by corn kernel. Food Science and Technology, Campinas, 33(2), 282-288.

Eckhoff S.R., Watson S.A. (2009). Chapter 9: Corn and sorghum starches: Production, Starch: Chemistry and Technology, third edition BeMiller J.N., Whistler R. L. (eds.), 373-439. Elsevier Inc.

Liu J., Fernie A.R., Yan J. (2020). The past, present, and future of maize improvement: Domestication, genomics, and functional genomic routes toward crop enhancement. Plant Comunications, 1(1), Article 10010, pp. 1-19.

Milašinović M (2005). Fizičke, hemijske i tehnološke karakteristike novih ZP hibrida kukuruza. Magistarski rad. Tehnološki fakultet, Novi Sad.

Milašinović Šeremešić M, Radosavljević M, Srdić J, Tomičić Z, Đuragić O (2019): Physical traits and nutritional quality of selected Serbian maize genotypes differing in kernel hardness and colour. Food and Feed Research, 46(1): 51-59.

Nikolić V., Božinović S., Vančetović J., Radosavljević M., Žilić S. (2020). Grain properties of yellow and red kernel hybrids from Serbia. Selekcija I semenarstvo, 26 (2), 7-14.

Pravilnik o kvalitetu hrane za životinje (2016). II Kvalitet hrane za životinje. Službeni glasnik RS, 4/2010 i 113/2012, 27/2014, 25/2015 i 39/2016.

Radosavljević M., Božović I., Bekrić V., Jovanović, R., Žilić S., Terzić D. (2001). Savremene metode određivanja kvaliteta i tehnološke vrednosti kukuruza. PTEP- Časopis za procesnu tehniku i energetiku u poljoprivredi, 5 (3), 85-88.

Radosavljević M., Milašinović-Šeremešić M., Terzić D., Jovanović Ž. Srdić, J. Nikolić V. (2020). Grain chemical composition of dents, popping maize and sweet maize genotypes. Journal on Processing and Energy in Agriculture, 24 (2), 77-80.

Scott P., Pratt R.C., Hoffman N., Montgomery R. (2019). Chapter 10 - Specialty Corns, Corn (Third Edition), Serna-Saldivar S.O. (ed.), 289-303, AACC International Press.

Somavat P., Li Q., Gonzalez de Mejia E., Liua W., Singh V. (2016). Coproduct yield comparisons of purple, blue and yellow dent corn for various milling processes. Industrial Crops and Products, 87, 266-272.

Žilić S., Serpen A., Akillioğlu G., Gökmen V., Vančetović J. (2012). Phenolic compounds, carotenoids, anthocyanins, and antioxidant capacity of colored maize (*Zea mays* L.) kernels. Journal of Agricultural and Food Chemistry, 60, 1224-1231.