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COMPARISON OF SELECTED MAIZE HYBRIDS FOR FEED PRODUCTION

UPOREDNI PRIKAZ ODABRANIH HIBRIDA KUKURUZA ZA PROIZVODNJU HRANE ZA ŽIVOTINJE

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ABSTRACT

The objectives of this study were to investigate chemical composition and in vitro dry matter digestibility (IVDMD) as well as to determine correlations between some important quality parameters of the maize hybrids developed for silage preparation in order to evaluate their suitability for feed production.

The IVDMD coefficients of the whole plant ranged from 0.5667 to 0.6734 with the neutral detergent fibers digestibility (NDFD) varying from 166 to 322 g/kg. Regarding IVDMD, the hybrids ZP 427, ZP 648 and ZP 666 were superior to other investigated hybrids. Very significant positive correlation was found between IVDMD of the whole maize plant and NDFD (r=0.79); very significant negative correlation was determined between L/NDF of the whole maize plant and NDFD and IVDMD (r=-0.73, r=-0.91). Obtained results are of an exceptional importance for the breeding programs and selection of potentially most suitable hybrids for silage production.

***Key words:** maize hybrids, biomass, lignocellulose fibers, in vitro dry matter digestibility (IVDMD), animal feed.*

REZIME

Osnovni cilj istraživanja prikazanog u ovom radu bio je da se ispitaju hemijski sastav i in vitro svarljivost suve materije odabranih domaćih hibrida kukuruza različitog genetičkog porekla i grupa zrenja. Pored toga, cilj je bio i da se odrede korelacije između pojedinih značajnih parametara kvaliteta hibrida kukuruza selekcionisanih za pripremanje silaže, kako bi se odredila njihova podobnost za proizvodnju hrane za životinje. Svi ispitivani hibridi su komercijalni i njihova detaljna karakterizacija je neophodna za proširenje njihove upotrebe u proizvodnji hrane za životinje.

In vitro svarljivost suve materije određivana je enzimskom metodom prema Aufréré. Koeficijenti svarljivosti cele biljke kretali su se od 0,5667 do 0,6734, dok se svarljivost NDF-a (NDFD) kretala od 166 do 322 g/kg. Odnos ligninske frakcije i NDF-a cele biljke ispitivanih hibrida varirao je u rasponu od 30 do 39 g/kg. Na osnovu svarljivosti suve materije hibridi ZP 427, ZP 648 i ZP 666 su ocenjeni kao veoma pogodni za proizvodnju hrane za životinje. Utvrđene su značajne razlike u hemijskom sastavu i svarljivosti suve materije ispitivanih hibrida. Veoma značajna pozitivna korelacija određena je između svarljivosti suve materije cele biljke i NDFD (r=0,79); veoma značajna negativna korelacija između L/NDF cele biljke kukuruza i NDFD, odnosno svarljivosti suve materije (r=-0,73, r=-0,91).

Rezultati ovog istraživanja imaju veliki značaj za selekciju potencijalno najpogodnijih hibrida za proizvodnju silaže.

***Ključne reči:** hibridi kukuruza, biomasa, lignocelulozna vlakna, in vitro svarljivost suve materije, hrana za životinje.*

INTRODUCTION

Maize (*Zea mays* L.) has, after the most important cereals in the world – wheat and rice, many uses as food, feed and raw material for industrial processing. Due to its high nutritional value maize silage is widely used as roughage for feeding ruminant livestock (*Barros-Rios et al., 2012; Struik and Dolstra, 1991*).

In Serbia, maize is traditionally cultivated as a number one field crop. The main aim of modern maize breeding is the development of high yielding hybrids tolerant to drought and pests. However, maize is the most important forage plant due to its quality of biomass, suitability for silage and diversified utilization as feed maize. Nevertheless, importance of detailed hybrid characterization regarding composition and digestibility in improving maize hybrid properties for high-value feed formulation is currently on the rise.

In the period of 2009-2011 in Serbia maize was sown on 1,242,667 ha, that is on 37.7 % of total arable land. The average annual production of maize in Serbia for the mentioned period was 6.7 mil tons with the average yield of 5.43 t/ha. In production trials with 10 ZP maize hybrids conducted in 37 locations a higher average yield (of almost 8 t/ha) was recorded in Serbia in 2011. The aim of the study carried out by *Kresović et al. (2011)* was to create favorable conditions for the plant growth and development under which the genetic yield potential could be maximally exploited. In the trials under irrigation with the sowing densities ranging from 40,000 to 100,000 plants/ha in the period 2006-2009 these authors found that the average maize grain yields (four maize hybrids of different FAO maturity groups - ZP 341, ZP 434, ZP 684 and ZP 704) were in the range from 10.69 to 13.73 t/ha.

Starch in cereals is the most abundant energy source for domestic animals. It is the main carbohydrate constituent of maize kernel, makes two thirds of a maize kernel dry matter (DM) and is, therefore, the most important economic component of maize grain *(Radosavljević and Milašinović, 2008).*

The plant cell walls are the most abundant source of carbohydrates in nature and represent the primary energy source for ruminant animals. The maize cell walls are predominantly composed of polysaccharides – cellulose and hemicellulose, and a highly complex polymer lignin *(Lorenz, 2009).* Therefore, forage quality assays based on the analyses of cell wall, i.e. fibers present in forages are of major concern in ruminant nutrition. Renewability of maize as a raw material and growing environmental pollution by oil products represent two principal reasons for maize becoming one of the major feedstocks for the energy production *(Radosavljević et al., 2009).* Alternative fuel - bioethanol is mostly produced from starchy parts of the maize grain leaving significant amounts of valuable by-products such as distillers' dried grains with solubles (DDGS), which can be used as a substitute for traditional feedstuff *(Semenčenko et al., 2014).*

Many authors have reported that differences in the genetic background of maize hybrids affected their chemical composition, especially the acid detergent fibers (ADF), neutral detergent fibers (NDF), starch and protein content *(Thomson et al., 2001; Johnson et al., 2002; Watson, 2003; Fray et al., 2004).* Enzymatic digestibility of the maize plant is genetically determined and affects the quality and potential utilization of maize biomass *(Barros-Rios et al., 2012; Jung, 1997).* Percentages of crude fiber and fiber constituents: ADF, NDF and acid detergent lignin (ADL) of maize are closely associated with dry matter digestibility *(Kim et al., 1999).*

The main goal of this study was to investigate chemical composition and IVDMD of kernel and whole plant of the selected local maize hybrids of different genetic background and maturity groups most widely grown in Serbia. Furthermore, the aim was to determine the correlations between important quality parameters of the maize hybrids developed for silage preparation in order to evaluate their suitability for feed production.

MATERIAL AND METHOD

Six dent kernel maize hybrids with different genetic background and maturity groups (ZP 341, ZP 427, ZP 648, ZP 666, ZP 758, ZP 802) were tested in the field experiments conducted in 2012. The investigated maize hybrids are generally characterized by high yield potential. The two-replicate trail was set up according to the randomized complete-block design in the experimental plot of the Maize Research Institute, Zemun Polje. The experimental plot size amounted to 21 m^2, while plant density was 60,000 plants per hectare. The maize samples for the determination of the kernel chemical composition (contents of starch, protein, oil, crude fiber, ash, and amylase content in starch) were drawn at harvest maturity. The starch content was determined by the Ewers polarimetric method (ISO 10520, 1997). The protein content was estimated as the total nitrogen by the Kjeldahl method multiplied by 6.25, while the lipid concentration was determined according to the Soxhlet method (AOAC, 1990). The amylase content was determined by a rapid colorimetric method *(McGrance et al., 1998)*.

In addition, the following traits were assayed: lignocellulose fibers such as NDF, ADF, ADL, hemicelluloses and cellulose content, reducing sugars, sucrose and IVDMD of kernel and the whole maize plant. Plants of each replicate were harvested at the full waxy maturity stage from the area of 7m^2 (two inner rows). Samples of the whole maize plants were chopped and dried at 60 ^oC for 48 h and then ground in the mill with 1-mm sieves. The modified Van Soest detergent method was applied to determine lignocellulose fibers (NDF, ADF, ADL) *(Mertens, 1992)*. IVDMD of the whole maize plant based on enzymatic solubility (ES) was performed by the Aufréré method (2006). The NDFD was calculated by the equation reported by *Brenner et al. (2010)*: NDFD=100(ES-(100-NDF))/NDF); the L/NDF ratio of the kernel and the whole plant of the investigated maize hybrids was determined according to *Frey et al. (2004)*. The reducing sugars and sucrose contents were determined according to the Luff-Schoorl method (AOAC, 1995).

Data reported for the assayed parameters of the ZP hybrids were assessed by the analysis of variance (ANOVA) and the LSD multiple test was used for any significant differences at the P<0.05 level between the means. All the analyses were conducted using the statistical software package STATISTICA 8.1. (StatSoft Inc. USA).

RESULTS AND DISCUSSION

The effect of genotype on chemical composition of maize kernel is given in Table 1. The starch content ranged from 662.7 (ZP 341) to 705.5 g/kg DM (ZP 802), protein from 97.5 (ZP 802) to 106.5 g/kg DM (ZP 427), oil from 49.3 (ZP 758) to 72.9 g/kg DM (ZP 427), crude fiber from 18.9 (ZP 427) to 26.3 g/kg DM (ZP 666) and ash from 13.3 (ZP 802) to 15.0 g/kg DM (ZP 648).

The kernel samples were assayed for main starch constitutive components – amylose and amylopectin (data not shown). The content of amylose in these starches was characteristic for the normal maize starches (approximately 24 % of amylose and 76 % of amylopectin) and these results were in accordance with findings previously reported by *Milašinović et al. (2007)*.

Table 1. Kernel chemical composition of maize hybrids

Hybrid	Starch (%)	Protein (%)	Oil (%)	Crude fibers (%)	Ash (%)
ZP 341	66.27^c	10.60^a	6.39^b	2.17^{ab}	1.40^{bc}
ZP 427	66.60^c	10.65^a	7.29^a	1.89^b	1.47^{ab}
ZP 648	70.34^a	10.51^a	5.25^d	2.09^b	1.50^a
ZP 666	69.89^{ab}	10.53^a	5.86^c	2.63^a	1.41^{bc}
ZP 758	69.17^b	10.56^a	4.93^d	2.27^{ab}	1.44^{ab}
ZP 802	70.55^a	9.75^b	5.87^c	2.01^b	1.33^c
$LSD_{0.05}$	1.13	0.24	0.35	0.47	0.08

Means in the same column with different superscripts differ (p<0.05)

Fibers are valuable nutritional components of maize grain that affect its technological properties. The content of NDF, ADF, ADL, hemicelluloses and cellulose in kernel are presented in Table 2. The NDF, ADF, ADL, hemicellulose and cellulose contents in the maize kernel varied from 167.1 (ZP 648) to 233.6 g/kg DM (ZP 341), 21.3 (ZP 648) to 26.9 g/kg DM (ZP 666), 2.0 (ZP 758) to 3.6 g/kg DM (ZP 666), 145.8 (ZP 648) to 207.3 g/kg DM (ZP 341) and 18.7 (ZP 648) to 23.4 g/kg DM (ZP 666), respectively. Furthermore, the data in Table 3 show that the NDF, ADF, ADL, hemicelluloses and cellulose of the whole plant of the observed maize hybrids varied from 481.1 (ZP 666) to 568.9 g/kg DM (ZP 802), 222.3 (ZP 648) to 265.4 g/kg DM (ZP 802), 14.2 (ZP 666) to 22.1 g/kg DM (ZP 802), 246.3 (ZP 427) to 303.5 g/kg DM (ZP 802) and 207.8 (ZP 648) to 244.5 g/kg DM (ZP 341), respectively.

Table 2. Kernel lignocellulose fibers content of maize hybrids

Hybrid	NDF (%)	ADF (%)	ADL (%)	Hemicelluloses (%)	Cellulose (%)
ZP 341	23.36^a	2.63^{ab}	0.35^a	20.73^a	2.29^a
ZP 427	21.58^b	2.31^c	0.30^{ab}	19.27^b	2.01^a
ZP 648	16.71^e	2.13^c	0.26^{bc}	14.58^e	1.87^a
ZP 666	20.51^c	2.69^a	0.36^a	17.81^c	2.34^a
ZP 758	17.90^d	2.40^{bc}	0.20^c	15.50^d	2.20^a
ZP 802	17.17^{de}	2.27^c	0.23^{bc}	14.90^{de}	2.04^a
$LSD_{0.05}$	0.99	0.28	0.08	0.72	0.68

Means in the same column with different superscripts differ (p<0.05)

Table 3. Whole plant lignocellulose fibers content of maize hybrids

Hybrid	NDF (%)	ADF (%)	ADL (%)	Hemicelluloses (%)	Cellulose (%)
ZP 341	53.35[b]	26.32[a]	1.87[b]	27.03[b]	24.45[a]
ZP 427	48.07[d]	23.44[bc]	1.45[c]	24.63[d]	21.99[b]
ZP 648	48.14[d]	22.23[d]	1.45[c]	25.91[c]	20.78[d]
ZP 666	48.11[d]	22.67[cd]	1.42[c]	25.44[c]	21.25[cd]
ZP 758	49.21[c]	23.65[b]	1.93[b]	25.56[c]	21.32[bc]
ZP 802	56.89[a]	26.54[a]	2.21[a]	30.35[a]	24.33[a]
LSD $_{0.05}$	0.8	0.8	0.2	0.6	0.7

Means in the same column with different superscripts differ (p<0.05)

The content of non-fiber carbohydrates, reducing sugars and sucrose in the kernel and the whole plant of maize hybrids is presented in Table 4. The reducing sugars and sucrose contents in the kernel of observed maize hybrids ranged from 1.5 (ZP 758) to 5.8 g/kg DM (ZP 666) and from 19.6 (ZP 802) to 32.1 g/kg DM (ZP 648), while the corresponding values in the whole plant of the same maize hybrids ranged from 43.8 (ZP 666) to 71.9 g/kg DM (ZP 648) and from 9.7 (ZP 666) to 49.6 g/kg DM (ZP 802), respectively.

Table 4. Reducing sugars and sucrose content of maize hybrids

Hybrid	Kernel		Whole plant	
	Reducing sugars	Sucrose	Reducing sugars	Sucrose
ZP 341	0.19[cd]	2.90[a]	5.53[c]	3.14[b]
ZP 427	0.29[bc]	3.14[a]	5.63[c]	2.80[b]
ZP 648	0.34[b]	3.21[a]	7.19[a]	3.22[b]
ZP 666	0.58[a]	2.07[b]	4.38[e]	0.97[c]
ZP 758	0.15[d]	2.02[b]	5.08[d]	1.56[c]
ZP 802	0.34[b]	1.96[b]	6.48[b]	4.96[a]
LSD $_{0.05}$	0.12	0.66	0.34	0.84

Means in the same column with different superscripts differ (p<0.05)

The data presented in Tables 5 and 6 show the IVDMD, NDFD and the lignin to NDF ratio (L/NDF) of the kernel and the whole plant of the observed maize hybrids, respectively. The lignin to NDF ratio in the kernel ranged from 12 (ZP 758) to 18 g/kg (ZP 666). The IVDMD coefficients of the maize kernel ranged from 0.8821 (ZP 341) to 0.9314 (ZP 427) with the NDFD varying from 349 (ZP 802) to 682 g/kg (ZP 427) (Table 5). The lignin to NDF ratio (L/NDF) of whole plants ranged from 29 (ZP 666) to 39 g/kg (ZP 758 and ZP 802) and the IVDMD from 0.5667 (ZP 802) to 0.6734 (ZP 648), with the NDFD varying from 166 (ZP 758) to 322 g/kg (ZP 648) (Table 6).

Table 5. Kernel IVDMD of maize hybrids

Hybrid	Content ($g\ kg^{-1}$)		Dry matter digestibility (%)
	NDFD	L NDF^{-1}	
ZP 341	495[c]	15[c]	88.21[d]
ZP 427	682[a]	14[d]	93.14[a]
ZP 648	476[c]	16[b]	91.25[b]
ZP 666	592[b]	18[a]	91.63[b]
ZP 758	440[c]	12[e]	89.97[c]
ZP 802	349[d]	14[d]	88.81[d]
LSD $_{0.05}$	61	1	1.05

Means in the same column with different superscripts differ (p<0.05)

Table 6. Whole plant IVDMD of maize hybrids

Hybrid	Content ($g\ kg^{-1}$)		Dry matter digestibility (%)
	NDFD	L NDF^{-1}	
ZP 341	309[a]	35[ab]	63.12[c]
ZP 427	319[a]	31[bc]	67.28[a]
ZP 648	322[a]	30[c]	67.34[a]
ZP 666	273[b]	29[c]	65.00[b]
ZP 758	166[d]	39[a]	58.96[d]
ZP 802	238[c]	39[a]	56.67[e]
LSD $_{0.05}$	16	5	0.8

Means in the same column with different superscripts differ (p<0.05)

In addition, the correlations between the investigated parameters of the kernel and whole maize plant were statistically determined (Tables 7 and 8).

Table 7. Correlation coefficients between kernel IVDMD and lignocellulose fibers content of maize hybrids

	NDF	ADF	ADL	Hemice.	Cellul.	NDFD	L NDF^{-1}
Dry matter digestibility	0.03	-0.17	0.17	0.03	-0.28	0.80**	0.29
NDF		0.65*	0.79**	1.00**	0.55	0.62*	0.24
ADF			0.66*	0.59*	0.96**	0.27	0.33
ADL				0.77**	0.48	0.61*	0.77**
Hemice.					0.49	0.61*	0.22
Cellulose						0.12	0.15
NDFD							0.39

Table 8. Correlation coefficients between whole plant IVDMD and lignocellulose fibers content of maize hybrids

	ADF	ADL	Hemice.	Cellul.	NDFD	L NDF^{-1}	Dry matter digestibility
NDF	0.94**	0.86**	0.95**	0.91**	-0.18	0.67*	-0.74**
ADF		0.83**	0.77**	0.99**	-0.14	0.67*	-0.66*
ADL			0.80**	0.76**	0.58*	0.95**	-0.93**
Hemice.				0.73**	-0.21	0.60*	-0.73**
Cellul.					-0.04	0.58*	-0.58*
NDFD						-0.73**	0.79**
L NDF^{-1}							-0.91**

A very significant positive correlation was established between IVDMD coefficients of the kernel and NDFD (r=0.80), NDF and ADL with hemicelluloses (r=1.00 and r=0.77), as well as between ADF and cellulose (r=0.96) (Table 7). Furthermore, a highly significant negative correlation was observed between digestibility of the whole maize plant and NDF, ADL, hemicelluloses content and lignin to NDF ratio (r=-0.74, r=-0.93, r=-0.73, r=-0.91, respectively) and a significant negative correlation between the ADF and cellulose content and the IVDMD (r=-0.66 and -0.58, respectively) (Table 8). A very significant positive correlation was determined between NDF and ADF, ADL, hemicelluloses, cellulose, as well as among ADF and ADL, hemicelluloses and cellulose content. The NDFD was positively significantly correlated with ADL and ADL with hemicellulose and cellulose content (Table 8).

Among different types of maize, chemical composition of dent maize kernel was studied the most in the past. However, the objective of this study was to observe both kernel and whole plant chemical composition (starch, protein, oil, crude fibers and ash contents) of ZP maize hybrids of different maturity groups, various genetic bases and utilization purposes. Obtained results showed that six investigated ZP maize hybrids had very different kernel chemical composition, especially regarding starch, its major constituent. The amylose-amylopectin ratio is very important regarding starch digestibility *(Anker-Nilssen et al., 2006)*. The amylose content in starches isolated from six ZP maize hybrids was characteristic for normal maize starches (24-26 %). The results of amylose content are in accordance with those previously reported by *Radosavljević et al. (2000, 2010 and 2012)* on ZP maize hybrids.

Results obtained in this study indicate that the genotype parentage had affected kernel chemical properties of ZP hybrids. The hybrid ZP 802 with a genetic background different from the remaining hybrids had the highest starch content, the lowest protein and ash content. The lowest starch content was determined in two maize hybrids with the genetically similar background: ZP 341 and ZP 427. The hybrid ZP 666 had the highest and hybrid ZP 427 the lowest crude fiber content of maize kernel. The hybrid ZP 427 had the highest oil and protein content as well. The starch content was negatively correlated with NDF (r=-0.85), hemicellulose (r=-0.88) and oil content (r=-0.70). This finding is in agreement with findings of *Idikut et al. (2009)*.

Genetic variation in chemical composition and digestibility are of great importance to meet requirements for different end uses *(Rudi et al., 2006)*. The results obtained in this study indicate that there is a high variability in kernel chemical composition among the observed ZP maize hybrids which could provide great possibilities for their application in industrial processing. These findings are in agreement with those previously published by *Watson (2003); Milašinović et al. (2007); Srichuwong et al. (2010); Semenčenko et al. (2013)*.

In vitro NDF digestibility provides more accurate estimates of total digestible nutrients, net energy and feed intake potential. In general, increased NDF digestibility will result in higher digestible energy and forage intakes *(Lorenz, 2009)*.

Kernel NDFD of six ZP maize hybrids ranged from 349 to 682 g/kg. Very similar results were obtained for NDFD at 24 and 48h *in situ* incubation by *Nuez-Ortin (2010)*. The hybrid ZP 427 had the highest digestibility and the NDFD content and a low lignin to NDF ratio in the maize kernel. The lowest contents of all lignocelluloses fibers in the maize kernel and very high IVDMD were determined in hybrid ZP 648. The lowest digestibility and the highest contents of all lignocellulose fibers were determined in the hybrid ZP 341. The differences in the contents of NDF, ADF, ADL, hemicellulose, cellulose and IVDMD of the maize kernel among observed ZP hybrids were 66.5, 5.6, 1.6, 65.1, 4.2 and 43.4 g/kg DM, respectively.

Moreover, the differences in the contents of NDF, ADF, ADL, hemicellulose, cellulose and IVDMD of the whole maize plant among observed ZP hybrids were 88.2, 43.1, 7.6, 57.2, 33.5 and 106.4 g/kg, respectively. Obtained values for the content of lignocellulose fibers in the whole plant differed significantly among hybrids and were closely related to digestibility. The differences in the contents of lignocellulose fibers affected the differences in IVDMD. The hybrid ZP 802 had the highest content of NDF, ADF, ADL and hemicellulose and the lowest IVDMD coefficient (0.5667), while the hybrid ZP 648 had the lowest content of ADF and cellulose and the highest IVDMD coefficient (0.6734) of the whole plant for investigated hybrids. The same hybrid had the highest NDFD and the lowest lignin to NDF ratio of the whole maize plant as well. The contents of lignocellulose fibers such as NDF, ADF, hemicelluloses and cellulose, and the lignin to NDF ratio in the whole maize plant of the investigated ZP hybrids were higher in comparison to the maize kernel; however, the IVDMD coefficients and NDFD were lower. This can be attributed to the dominance of starch as the main chemical and easily digestible constituent of maize grain. The amount of starch in the plant of various forage species, as well as the characteristics of their cell wall components are well known to affect the variability of IVDMD among different genotypes *(Emile et al., 2007)*.

The results also show that reducing sugars in the whole maize plant were higher in comparison to the maize kernel. ZP 802 has the lowest, i.e. the highest sucrose content in the kernel, i.e. the whole plant, respectively and also high content of reducing sugars in both, kernel and whole plant.

According to the obtained results the hybrids ZP 427, ZP 648 and ZP 666 (Tables 5 and 6) were superior to other investigated hybrids regarding IVDMD and, therefore, rated as very suitable for feed production. The hybrids ZP 427 and ZP 648 share one common parent, while the hybrids ZP 648 and ZP 666 are genetically related. Even though genetically similar to ZP 427, ZP 341 had statistically lower IVDMD; however, it was still rated as good for feed preparation due to sufficiently high IVDMD of the kernel as well as the whole plant. The remaining two hybrids ZP 758 and ZP 802 were not suitable for the purpose regarding very low IVDMD. These hybrids have one common parent and the other parental components are very similar.

The correlation coefficients between the IVDMD and all other investigated parameters of the kernel and the whole maize plant were observed. A very significant positive correlation was found between digestibility of the whole maize hybrid plants and NDFD (r=0.79). A very significant negative correlation was also found between L/NDF of the whole maize hybrid plants and NDFD and IVDMD (r=-0.73, r=-0.91, respectively). Based on the similar results, *Riboulet et al. (2008)* concluded that a maize hybrid, intended for a high value animal feed, should have a low content in ADL/NDF (ADL-lignin NDF ratio, %), the first factor negatively influencing whole plant digestibility. Furthermore, a very significant positive correlation was also found among all assayed lignocellulose fibers components (r=0.94, r=0.86, r=0.83, r=0.95, r=0.77, r=0.80, r=0.91, r=0.99, r=0.76, r=0.73). The range of obtained values corresponds with those previously reported by *Terzić et al. (2010, 2012 and 2013)* and by other authors as well *(Riboulet et al., 2008; Barriere et al., 2003)*. High positive correlation between hemicelluloses and NDF (r=0.95) IVDMD could, as observed by *Riboulet et al. (2008)*, highlight the influence of cell wall carbohydrate type and organization on feeding value. Higher hemicelluloses to cellulose ratio could similarly correspond to differently organized cell walls with a correlative higher degradability. Such higher hemicelluloses to cellulose ratio could also correspond to different tissue organizations and respective importance, giving a higher whole plant digestibility *(Riboulet et al., 2008)*. The results of the study performed by *Tatili Seven et al. (2006)* also indicated the strong relationship between nutritional composition and feed digestibility. High correlations were determined by both enzyme and nylon bag techniques in the same study.

Understanding how maize plant cell wall constituents affect IVDMD is an important goal of future breeding research programs in order to improve forage utilization in animal feeding.

CONCLUSION

Significant differences regarding chemical composition and IVDMD were observed among the investigated maize hybrids.

Two maize hybrids with similar genetic background, ZP 341 and ZP 427, had high kernel protein and oil contents, NDF, ADL, hemicelluloses and low starch content. The hybrid ZP 802 had the highest starch, the lowest protein and low oil content in kernel.

The hybrids ZP 427, ZP 648 and ZP 666 were superior to other investigated hybrids regarding IVDMD and were, therefore, rated as very suitable for feed production. Furthermore, the hybrid ZP 341 had statistically lower IVDMD than the superior ones; however, it was still rated as good for feed preparation due to sufficiently high IVDMD of the kernel as well as of the whole plant. The remaining two hybrids ZP 758 and ZP 802 were not suitable for the purpose due to very low IVDMD.

A very significant positive correlation was determined between kernel IVDMD and NDFD as well as between ADL content and L/NDF (r=0.80; r=0.77, respectively).

A very significant negative correlation was found between L/NDF of the whole maize hybrid plants and NDFD and IVDMD (r=-0.73, r=-0.91, respectively). All the investigated fiber components, except cellulose, were very negatively correlated to whole maize plant IVDMD.

The results obtained in this study indicate that genetic differences developed through decades of maize hybrids breeding programs can lead to providing farmers and industry with genotypes of good quality, desirable traits, and acceptable yield under extensive conditions and at a lower cost. However, variability of quality parameters of the maize genotypes under different environmental conditions and soil, manure and pest control should be further investigated in future studies.

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REFERENCES

Anker-Nilssen, K., Færgestad, E.M., Sahlstrøm, S., Uhlen, A.K. (2006). Interaction between barley cultivars and growth temperature on starch degradation properties measured *in vitro*. Anim. Feed Sci. Technol. 130, 3-22.

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

AOAC, Association of Official Analytical Chemists (1995). Official Methods of Analysis of AOAC International, AOAC International, Washington, USA, Secs. 942.15.

Aufréré, J., (2006). Prevision de la digestibilite des fourages et aliments concentres et composes des herbivores par une methode enzymatique pepsine-cellulase. AQ 353, pp. 1-6.

Barriere, Y., Guillet, C., Goffner, D., Pichon, M. (2003). Genetic variation and breeding strategies for improved cell wall digestibility in annual forage crops. A review. Anim. Res. 52, 193-228.

Barros-Rios, J., Santiago, R., Malvar, R.A., Jung, H-J.G. (2012). Chemical composition and cell wall polysacharide degradability of pith and rind tissues from mature maize internodes. Anim. Feed Sci. Technol. 172, 226-236.

Brenner, E.A., Zein, I., Chen, Y., Andersen, J.R., Wenyel, G., Ouyunova, M., Eder, J., Darnhofer, B., Frei, U., Barriere, Y., Lubberstedt, T. (2010). Polymorphisms in O-methyltransferase genes are associated with stover cell wall digestibility in European maize (*Zea mays* L.). BMC Plant Biol. 10, 27. doi:10.1186/1471-2229-10-27.

Emile, J. C., Jobim, C. C., Surault, F., Barrière, Y. (2007). Genetic variations in the digestibility in sheep of selected whole-crop cereals used as silages. Animal 1, 1122-1125.

Frey, T.J., Coors, J.G., Shaver, R.D., Lauer, J.G., Eilert, D.T., Flannery, P.J. (2004). Selection for silage quality in the Wisconsin quality synthetic and related maize populations. Crop Sci. 44, 1200-1208.

Idikut, L., Atalay, A.I., Kara, S.N., Kamalak, A. (2009). Effect of hybrid on starch, protein and yields of maize grain. J. Anim. Vet. Adv. 8, 1945-1947.

Internatinal Standard ISO 10520, 1997. Determination of starch content – Ewers polarometric method.

Johnson, L.M., Harrison, J.H., Davidson, D., Robutti, J.L., Swift, M., Mahanna, W.C., Shinners, K. (2002). Corn silage management. I Effects of hybrid, maturity and mechanical processing on chemical and physical characteristic. J. Dairy Sci. 85, 833-853.

Jung, H-J. G. (1997). Analysis of forage and cell walls in ruminant nutrition. Conference: New Developments in Forage Science Contributing to Enhanced Fiber Utilization by Ruminants. J. Nutr. (supplement*)*, pp. 810S-813S.

Kim, J.D., Kwon, C.H., Kim, D.A. (2001). Yield and quality of silage corn as affected by hybrid maturity, planting date and harvest stage. Asian-Aust. J. Anim. Sci. 14, 1705-1711.

Kresović, Branka, Dragičević, Vesna, Simić, Milena, Tarapanova A. (2011). The responses of maize genotypes to growth conditions. Genetika 43, 655 -666.

Lorenz, A.J. (2009). Characterization, inheritance, and covariation of maize (*Zea Mays* L.) traits relevant to cellulosic biofuels production. UMI, ProQuest LLC, Ann Arbor, MI, pp. 1-178.

McGrance, S.J., Cornell, H.J., Rix, C.J. (1998). A simple and rapid colorimetric method for the determination of amylose in starch products. Starch 50, 158-163.

Mertens, D.R. (1992). Critical conditions in determining detergent fibers. In: Forage Analysis Workshop, Proceedings, NFTA Forage Testing Assoc. Denver, CO. Natl. Forage Testing Assoc. Omaha, NE, pp. C1-C8.

Milašinović, Marija, Radosavljević, Milica, Dokić, Ljubica, Jakovljević, J. (2007). Wet milling properties of ZP maize hybrids. Maydica 52, 289-292.

Nuez-Ortin, W.G. (2010). Variation and availability of nutrients in co-products from bio-ethanol production fed to ruminants. MS. Thesis, Department of Animal and Poultry Science, University of Sascatchewan, Saskatoon, Canada.

Radosavljević, Milica, Mojović, Ljiljana, Rakin, Marica, Milašinović, Marija (2009) ZP maize hybrids as a raw material for the bioethanol production. Journal on Processing and Energy in Agriculture (former PTEP), 13 (1), 45-49.

Radosavljević, Milica, Milašinović, Marija (2008). ZP maize hybrids as a raw material in the starch production. Journal on Processing and Energy in Agriculture (former PTEP), 12 (4), 191-195.

Radosavljević, Milica, Terzić, Dušanka, Milašinović-Šeremešić, Marija, Pajić, Zorica, Todorović, G. (2013). A comparison of maize hybrids for yield, carbohydrates and *in vitro* digestibility. 8th International Conference of the Chemical Societies of the South - East European Countries – ICOSECS 8, Belgrade, Serbia, June 27-29, 2013, Book of Abstracts, CD-ROM, pp. 255.

Radosavljević, Milica, Bekrić, V., Božović, Irina, Jakovljević, J. (2000). Physical and chemical properties of various corn genotipes as a criterion of technological quality. XVIII International Conference on Maize and Sorghum Genetics and Breeding at the End of the 20th Century, Beograd, June 4-9, 2000, pp. 23 (invited lecture). Genetika 32, 319-329.

Radosavljević, Milica, Bekrić, V., Milašinović, Marija, Pajić, Zorica, Filipović, M., Todorović, G. (2010). Genetic variability as background for the achievements and prospects of the maize utilisation development. Genetika 42, 119-135.

Radosavljević, Milica, Milašinović-Šeremešić, Marija, Terzić, Dušanka, Todorović, G., Pajić, Zorica, Filipović, M., Kaitović, Ž., Mladenović Drinić, Snežana (2012). Effects of hybrid on maize grain and plant carbohydrates. Genetika 44, 649-659.

Riboulet, C., Lefevre, B., Denoub, D., Barriere, Y. (2008). Genetic variation in maize wall for lignin content, lignin structure, *p*-hydroxycinnamic acid content, and digestibility in set of 19 lines at silage maturity. Maydica 53, 11-19.

Rudi, H., Uhlen, A.K., Harstad, O.M., Munck, L. (2006). Genetic variability in cereal carbohydrate compositions and potentials for improving nutritional value. Anim. Feed Sci. Technol. 130, 55-65.

Semenčenko, Valentina, Mojović, Ljiljana, Djukić-Vuković, Aleksandra, Radosavljević, Milica, Terzić, Dušanka, Milašinović-Šeremešić, Marija (2013). Suitability of some selected maize hybrids from Serbia for bioethanol and dried distillers' grains with solubles (DDGS) production. J. Sci. Food Agric. 93, 811-818.

Semenčenko, Valentina, Radosavljević, Milica, Terzić, Dušanka, Milašinović-Šeremešić, Marija Mojović, Ljiljana (2014). Dried distillers' grains with solubles (DDGS) produced from different maize hybrids as animal feed. Journal on Processing and Energy in Agriculture, 18 (2), 80-83.

Srichuwong, S., Guteša, Jelena, Blanco, M., Duvick, S.A., Gardner, C., Jane, J. (2010). Caracterization of corn grains for dry-grind ethanol production. J. ASTM Int. 7, 434-449.

Statistical Yearbook of the Republic of Serbia (2012). Stastistical Office of the republic of Serbia, Belgrade, pp. 206-208.

Struik, P.C., Dolstra, O. (1991). Some remarks on session III on nutritive value of forage maize. In: Hinterholzer, J. (Ed.), Proceedings of the 15th Congress of the Maize and Sorghum Section of EUCARPIA. Baden (near Vienna), pp. 333–336.

Tatili Seven, P., Cerci, I.H. (2006). Relationship between nutrient composition and feed digestibility determined by enzyme and nylon beg *(in situ)* techniques in feed sources. Bulg. J. Vet. Med. 9, 107-113.

Terzić, Dušanka, Radosavljević, Milica, Milašinović Šeremešić, Marija, Pajić, Zorica, Todorović, G. (2013). Lignocellulose fibres and resistant starch of maize hybrids. The First International Symposium on Agriculture Engineering - ISAE 2013, Belgrade, Serbia, October 4-6, 2013. Proceedings, CD-ROM, pp. IV49-IV57.

Terzić, Dušanka, Radosavljević, Milica, Žilić, Slađana, Milašinović, Marija, Semenčenko, Valentina (2010). Quality parameters of ZP hybrids biomass. XII International Symposium on Forage Crops of Republic of Serbia "Forage Crops basis of the Sustainable Animal Husbandry Development", Kruševac, 26-28.05.2010. Biotechnology in Animal Husbandry (spec. issue), pp. 491-496.

Terzić, Dušanka, Milašinović-Šeremešić, Marija, Radosavljević, Milica, Filipović, M. (2012). Fibers, cell wall content, and in vitro digestibility of different maize hybrids. 6th Central European Congress on Food, Novi Sad 23-26.05.2012. Proceedings, pp. 1630-1634.

Thomas, E.D., Mandebvu, P., Ballard, C.S., Sniffen, C.J., Carter, M.P., Beck, J. (2001). Comparison of corn silage hybrids for yield, nutrient composition, in vitro digestibility, and milk yield by dairy cows. J. Dairy Sci. 84, 2217-2226.

Watson, S.A. (2003). Description, development, structure, and composition of the corn kernel. In: White, P.J., Johnson, L.A. (eds.), Corn Chemistry and Technology, American Association of Cereal Chemists, Inc., St. Paul, MN, USA, pp. 69-106.

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