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THE UTILISABLE VALUE OF THE MAIZE PLANT (BIOMASS) FOR SILAGE

UPOTREBNA VREDNOST KUKURUZNE BILJKE (BIOMASE) ZA SILAŽU

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ABSTRACT

According to the estimation of leading experts, the maize utilisation for the production of silage from the whole plant, wet ear and wet grain should be one of the most important forms of its application in animal nutrition. Maize a major forage crop, because the highest accumulation of solar energy per area unit is accomplished by maize production and ensiling. At the Maize Research Institute, Zemun Polje, selection, testing and evaluation of silage maize.

The aim of this study was to draw attention to this extremely significant field of science and studies on the utilisation of the whole maize plant (biomass) in feeding of domestic animals, primarily ruminants. This paper presents and discusses previous results and achievements of long-term scientific researches on the improvement of maize plant utilisation in making good-quality silage not only in our country but also in the world.

Key words: *maize, silage, lignocellulose fibres, digestibility.*

REZIME

Prema procenama vodećih stručnjaka korišćenje kukuruza za proizvodnju silaže od cele biljke, vlažnog klipa i vlažnog zrna trebalo bi da bude jedan od značajnijih oblika njegove primene u ishrani životinja. Kukuruz je najvažnija krmna biljka jer se njenom proizvodnjom i siliranjem postiže najviša akumulacija sunčeve energije po jedinici površine. U Institutu za kukuruz „Zemun Polje“ paralelno sa ispitivanjem i ocenom kvaliteta hibrida kukuruza namenjenih proizvodnji zrna vrši se selekcija, ispitivanje i ocena i silažnih formi kukuruza, odnosno upotrebne vrednosti i kvaliteta kukuruzne biljke za ishranu životinja. Kao rezultat ovog naučnoistraživačkog rada poslednjih nekoliko decenija selekcionisani su hibridi kukuruza koji su na osnovu ispitivanih parametara kvaliteta za silažne forme kukuruza visokog kvalitete. Karakteriše ih: visok prinos ukupne suve i ukupne svarljive suve materije po hektaru, visoko učešće suve materije klipa u ukupnom prinosu suve materije i visoka svarljivost suve materije cele biljke kukuruza.

Cilj ovog rada bio je da se skrene pažnja na ovu izuzetno značajnu oblast nauke i istraživanja upotrebe cele kukuruzne biljke (biomase) u ishrani domaćih životinja, prvenstveno preživara. Prikazani su i diskutovani dosadašnji rezultati i dostignuća višegodišnjeg naučnoistraživačkog rada na unapređenju korišćenja kukuruzne biljke za spremanje kvalitetne silaže u našoj zemlji kao i u svetu. Opisan je kukuruz kao sirovina za proizvodnju i spremanje silaže od cele kukuruzne biljke kao kvalitetne kabaste hrane za ishranu domaćih životinja.

Ključne reči: *kukuruz, silaža, lignocelulozna vlakna, svarljivost.*

INTRODUCTION

According to the areas of cultivation and produced quantities, maize is a major field crop in Serbia. The greatest part of maize produced in both, our country and the world, is used as processed or unprocessed product in domestic animal feeding. Silage is one of the most important forms of maize utilisation (*Pejić, 1994*). The development of new silage maize hybrids and studies on the effect of silage on animal feeding have been increasingly gaining in importance world-wide (*Coors and Lauer, 2001*). Many agroeconomic factors contribute to the fact that maize is a forage crop with no competitors in a large number of countries in the world. Among numerous factors, the following ones are the most important: possibility of obtaining high and stable yields by selection of hybrids greatly adaptable to specific conditions of each region, quality of maize biomass with a great proportion of fermentable carbohydrates and costs, i.e. the price of nutritive units achieved per hectare, are usually significantly lower than costs of achieved nutritive units of other crops (*Bekrić, 1997*).

A great importance is given to maize production for ensilage and the use of silage for animal feeding not only in all European countries but in other countries around the world. In Serbia, out of total areas (1.24 million ha) sown with mercantile maize, approximately 5 % are used for silage. Furthermore, the Maize Research Institute, Zemun Polje is the only institution in our country in which studies with the aim to improve maize utilisation have been conducted for more than half a century (*Pejić, 1994; Bekrić, 1997; Terzić, 2006; Terzić et al., 2014*).

It is known that out of the total potential value of a feed, the nutritive value is related to only one its part, that is, to the part that is reabsorbed in the digestive tract and is used in the animal organism. In order to determine the nutritive value of some feed the chemical analyses are applied and they result in data on elementary properties of the nutritive matter content. These analyses of the chemical composition provide data for defying forage, i.e. the whole maize plant as a specific source of nutrient substances, which represents a base for balancing rations for certain types and category of domestic animals. Moreover, having information on the total chemical composition of forage (maize plant) is not sufficient for a successful estimation of general useful efficiency of forage. In order to estimate the nutritional value of forage, i.e. maize plant, it is necessary to know the final result of utilisation of nutrients by domestic animals. For this purpose, nutrient digestibility of maize plants is tested and according to obtained results, efficiency of utilisation of nutrients, i.e. maize plants, is gained. The application of a digestibility coefficient in the evaluation of silage forms of maize hybrids signifies the more accurate parameter of hybrid quality than the standard analyses of the basic chemical composition, and therefore the comparative assessment of hybrids on the basis of digestibility is more unbiassed and

reliable. Tests of *in vitro* digestibility of the whole plant and morphological fraction of the maize hybrid plant are of particular importance as there are major differences in digestibility, because digestibility of cellulose plant parts depends on genetic background. As digestibility is independent of energy density, its testing is gaining importance in nutrition of domestic animals (*Pejić, 1994, Institut za kukuruz "Zemun Polje"-juče, danas, sutra, 2015*).

The aim of this study was to present and discuss previous results and achievements of long-term scientific researches on the improvement of maize plant utilisation in making good-quality silage not only in our country but also in the world. Maize was described as a raw material for production and making of silage from the whole maize plant as quality forge for feeding domestic animals.

MATERIAL AND METHOD

Maize plant silage: Silage is a product of controlled fermentation under controlled conditions without the presence of air i.e. oxygen. Under such conditions undesirable microflora ceases to be active and beneficial microflora begins to be active - activity of anaerobic bacteria of lactic acid fermentation. These bacteria decompose easily decomposable carbohydrates (glucose, fructose, sucrose) by their ferments (enzymes) and produce lactic acid as a natural preservative. The selected ZP maize hybrids with different genetic background and maturity groups were tested as a raw material for production and making of silage from the whole maize plant (*Terzić, 2006; Terzić et al., 2013, Terzić et al., 2014; Semenčenko et al., 2014*).

Criteria for the evaluation of maize silage hybrids: Silage is usually produced from the whole maize plant, although it can be produced from wet ear or wet grain. The following parameters are the most important for quality of silage forms of maize hybrids: the total dry matter yield (t ha^{-1}) ranges from 12 t ha^{-1} to 25 t ha^{-1} and the yield of the total digestible dry matter (t ha^{-1}), yield structure, i.e. a participation of ear dry matter in the total yield of dry matter (40-60 %), chemical composition, content of lignocellulosic fibres, dry matter digestibility and NDF digestibility of the whole maize plant. Methods applied in order to determine the whole maize plant quality as a raw material for silage production were described in the previously published paper (*Radosavljević et al., 2015*).

RESULTS AND DISCUSSION

Dry matter yield of the whole maize plant

Depending on genetic yielding capacity (yield potential) and agroecological conditions silage maize yields vary from 12 tonnes to 25 tonnes of the total dry matter per hectare at physiological maturity necessary for ensiling with a dry matter content of 35-42 %.

The quality of maize silage primarily depends on the quality of biomass for ensiling and the consistent application of technical and technological standards during ensiling. Results on the evaluation of silage mass of certain maize hybrids show that there are differences even among standard grain hybrids of the same FAO maturity groups when they are used as silage plants. Some of the hybrids have certain advantages in relation to other hybrids. These advantages are manifested in a more favorable possibility of combining a high dry matter yield of the whole plant with a high percentage of the share of dry matter yield of a ear in order to simultaneously achieve a satisfactory relationship of moisture and dry matter at the harvest time of the plants for silage.Yields of silage mass of hybrids depend on the same factors as the yields of hybrid for dry grain production, hence they very signficantly vary over years. Drought is the most common limiting factor for yield. The analysis of the data show two great variations in yields of the total dry matter of maize biomass of the observed same hybrids over years. The deviation of the maximum from the minimum yields of the total dry matter ranged from 7.8 t ha^{-1} for the hybrid ZP 377 to 13.2 t ha^{-1} for the hybrid ZP 667. The lowest, i.e. highest percentage deviation in dry matter yield was detected in the hybrid ZP 588 (39.42 %), i.e. ZP 667 (55.00 %), respectively. Such a high deviation in yields of the total dry matter of maize biomass of observed hybrids was affected by extremely dry 2012. year. The differences between the maximum and the minimum yield of the total dry matter of maize biomass for 2010. and 2011. years, considered the standard years, varied from 1.49 % in the hybrid ZP 444 to 15.45 % in the hybrid ZP 555 (*Institut za kukuruz "Zemun Polje"-juče, danas, sutra, 2015*).

A certain regularity of dry matter yield increase with the increase of the FAO maturity group was observed, with the yield in the FAO 700 higher by 10 t ha^{-1} than in the FAO 200. Greater sowing densities of early maturity hybrids did not compensate the difference in yields between hybrids of early and late FAO maturity groups. Results obtained on yields of digestible dry matter of the whole plants of observed ZP maize hybrids of different FAO maturity groups ranged from 8.9 t ha^{-1} to 16.5 t ha^{-1} (*Pejić, 1994*).

Yield structure of the maize plant (Participation of dry matter of the ear and the plant without year in the total yield of dry matter)

The yield structure of the maize plant is a percentage share of the ear dry matter and the dry matter of the whole plant without ear (stover) in the total yield of the whole plant dry matter and significantly affects quality and a nutritive value of biomass and thereby silage. The nutritive value of biomass, including maize plant silage, primarily depends on the percentage share of ear dry matter, as the most quality part of the maize plant, in the total dry matter yield. This percentage ranges from 40 % to 60 %.

The yield of the whole plant dry matter of ZP maize hybrids at the stage of physiological maturity for silage, with the dry matter content of 33.82 % - 43.37 %, varied from 14.9 t ha^{-1} to 25.7 t ha^{-1}. The yield of the digestible dry matter of the whole plant of observed ZP maize hybrids ranged from 8.9 t ha^{-1} to 16.5 t ha^{-1}. The share of ear dry matter in the total dry matter yield varied from 45.02 % to 54.95 %. The difference in the yield of the whole plant dry matter in the observed ZP maize hybrids amounted to 10.8 t ha^{-1}, digestible dry matter was 7.6 t ha^{-1}, while the difference in the share of ear dry matter in the total dry matter yield of the whole plant amounted to 9.9 % (*Institut za kukuruz "Zemun Polje"-juče, danas, sutra, 2015)*.

Chemical composition and content of lignocellulosic fibres in maize plant

According to its chemical composition maize plant is chiefly carbohydrate nutrient and is poor in proteins and mineral matters. Carbohydrates and proteins are two most important components of the maize plant chemical composition. All carbohydrates in maize plant can be grouped into structural (in plant cell walls) and non-structural carbohydrates (present in the content of the plant cell). Furthermore, all structural carbohydrates are classified into three groups: NDF (Neutral Detergent Fibres), composed of hemicellulose, cellulose and lignin, ADF (Acid Detergent Fibres) composed of cellulose and lignin, and ADL (Acid Detergent Lignin), which is pure lignin. On the other hand, non-structural carbohydrates or NFC (Non-fibre Carbohydrates) are composed of starch, sugar and pectin.

Depending on the content of lignocellulosic fibres in the maize plant, a typical chemical composition was as follows: crude proteins varied from 8.3 % to 9.3 %, crude fats varied from 2.7 % to 3.2 %, ash varied from 4.1 % to 6.2 %, NFC varied from 27 % to 48 %, starch varied from 15.0 % to 31.0 %, NDF varied from 36.0 % to 54.0 %, ADF varied from 21.0 % to 33.0 % and ADL varied from 1.57 % to 2.94 %.

The content of proteins, crude fat, ash, NFC, NDF, ADF and ADL of the whole plant of observed ZP maize hybrids (ZP 161, ZP 388, ZP 434, ZP 555, ZP 677 and ZP 704) at the physiological maturity for ensiling, with the dry matter content of 32.40 % - 38.23 %, ranged from 7.70 % to 9.94 %, 3.52 % to 4.42 %, 2.85 % to 3.59 %, 60.93 % to 66.23 %, 33.20 % to 41.22 %, 42.57 % to 50.84 %, 19.32 % to 25.74 % and from 1.63 % to 2.51 %, respectively (*Institut za kukuruz "Zemun Polje"-juče, danas, sutra, 2015*). These results are in agreement with results previously obtained by *Martin et al., 2008 and Mertens, 1992*. with the exception of insignificantly higher values of crude fats and lower ash that were recorded in the ZP maize hybrids.

In recent times, the standard chemical composition of nutrients has not been considered sufficient to define nutritive values of a nutrient. In order to more precisely define the nutritive value of fibrous feeds, data on lignocellulosic fibre fractions are necessary: NDF - Neutral Detergent Fibres, ADF - Acid Detergent Fibres, ADL - Acid Detergent Lignin (lignin insoluble in 72 % sulphuric acid), hemicellulose and cellulose, as well as dry matter digestibility. The precise defying of quality of ZP maize hybrid biomass is very important for the evaluation of their suitability for ensiling and animal feed (*Terzić, 2006*). Furthermore, obtained results should help breeders in selection of particular inbreds when developing silage hybrids that could enter national and international markets (*Terzić et al., 2010; Terzić et al., 2012 a,b,c*). Bearing all this in mind, it is necessary to analyse the content of lignocellulosic fibres, dry matter digestibility and NDF, as well as the relationship of lignocellulosic fibres of the whole maize plant as primary quality parameters for biomass silage.

The studies on the content of lignocellulosic fibres (NDF, ADF, ADL, hemicellulose and cellulose) of maize hybrids have been performed at the Maize Research Institute, Zemun Polje since the end of the 1970^{s} by the application of the modified Van Soest acid detergent fibre method (*Mertens, 1992*). Since digestibility of fibrous feeds are closely related with the morphological structure of plants, the results of digestibility of maize plants and their parts is conditioned by the content of crude fibre fractions: NDF, ADF and ADL. It is known that the content and the ratio of these fibres determine the level of consumption and digestibility of silage, i.e. determine the nutritive value of fibrous feeds, which directly affect production performances of dairy cows.

In general, the content of lignocellulose fibres (NDF, ADF and ADL) increases in plants as they mature. Unlike other forage crops, maize is a plant in which the crude cellulose content decreases with maturity, while the nutritive value increases because grain dry matter increases in the total yield of the whole plant dry matter. Contents of proteins and ash decrease in maize plants from milk stage to waxy ripeness, while contents of crude fats, NFC and NFE increase. Changes occurring in contents of nitrogen free extracts, crude fat and crude cellulose have a special effect on the increase of the energy value of maize plants over stages of maturity.

The basic and most often used parameter of the structure of cell walls is the content of NDF including hemicellulose, cellulose and lignin (ADL). Hemicellulose and cellulose are structural carbohydrates that can be decomposed by enzymes of rumen microflora. Ruminants digest these structural carbohydrates slower than non-structural carbohydrates, such as starch, sugars that are contained within the plant cell. Lignin, located in the wall structure of plant cells, reduces digestibility of hemicellulose and cellulose by enzymes of rumen microflora. Unlike NDF, ADF (cellulose, lignin - ADL) does not encompass the hemicellulose content, and therefore it does not represent the content of total lignocellulosic fibres in the plant cell, i.e. in fibrous feeds. In recent times, leading laboratories in the world in addition to the content of lignocellulosic fractions, have initiated studies on NDF digestibility that have been used as a quality parameter of fibrous feeds. The lower NDF digestibility is, the lower dry matter digestibility is and therefore the energy value of fibrous feed is lower, hence production performance of animals is lower (production of meat, milk).

Recent results obtained in the Maize Research Institute, Zemun Polje for the contents of lignocellulose fibres and their mutual ratio of eight silage maize hybrids and ZP maize hybrids of various genetic bases and different maturity groups showed that the contents of NDF, ADF, ADL, hemicellulose and cellulose of the whole plant of observed silage maize hybrids ranged from 44.54 % to 55.93 %; 22.12 % to 28.26 %, 1.76 % to 2.77 %, 24.41 % to 27.67 % and from 18.36 % to 25.63 %, respectively. Differences in contents of NDF, ADF, ADL, hemicellulose and cellulose between observed silage hybrids amounted to 11.39 %, 8.14 %, 1.01 %, 3.26 % and 7.27 %, respectively (*Terzić et al., 2014*).

According to *Semenčenko et al., 2014* the content of lignocellulosic fibres ranged from 49.26 % to 56.76 % (NDF), 22.75 % to 28.43 % (ADF), 1.61 % to 2.45 % (ADL), 25.77 % to 28.33 % (hemicellulose) and from 21.14 % to 26.21 % (cellulose). Differences in contents of these fibres in observed ZP maize hybrids of different genetic bases and various FAO maturity groups were less pronounced than those detected in silage maize hybrids. However, these differences were statistically significant and affected dry matter digestibility of observed hybrids. The lowest contents of NDF, ADF and ADL were determined in the maize hybrid ZP 434 that is a dent with a hard endosperm. Obtained results are in accordance with results more recently published by foreign authors who had recorded higher contents of NDF, ADF and ADL in morphological parts, but also in the whole plant of dent maize in relation to hard forms of dent maize (*Ferreira et al., 2013 and 2014; Khan et al., 2015*).

Results presented by *Terzić et al., 2014* show that ratios of contents of lignocellulosic fibres (L/NDF, ADF/NDF, Hemicellulose/NDF, Cellulose/NDF, Cellulose/ Hemicellulose) of eight observed silage hybrids ranged from 3.48 % - 5.30 %, 45.15 % - 49.84 %, 49.49 % - 54.85 %, 41.20 % - 45.81 % and 75.17 % - 92.59 %, respectively. The corresponding values for the observed ZP maize hybrids are presented by *Semenčenko et al., 2014*.

Differences in ratios of certain lignocellulose fibres of the whole plants of observed ZP maize hybrids, calculated on the basis of their contents, were statistically significant. These differences between certain parameters also affected the total dry mater digestibility of the whole plant. Since digestibility of fibrous feeds is closely linked to morphological structure of plants, the results of digestibility of the maize plant and its parts are conditioned by the content of fractions of lignocellulosic fibres and their interrelationships.

Maize plant digestibility (Dry matter digestibility (DMD) and NDF digestibility (NDFD) of the whole maize plant)

The studies of dry matter digestibility of the whole maize plants are specially emphasised within the scope of activities of

the Maize Research Institute, Zemun Polje. Studies on *in vitro* digestibility of the whole plant and morphological fractions (leaf, stalk, husk, cob, grain) of maize hybrids after methods of *Tilly and Terry* (*1963*) were introduced at the end of the 1980^{s}. Since 2008. year , a new enzymatic method for the determination of dry matter digestibility has been applied in these studies. This mehtod has been broadly used in western European countries such as Belgium, France (INRA), Germany and the UK. Since then, the *in vitro* method has been used in studies of maize hybrids digestibility (*Aufréré, 2006*). The introduction of this method reduced the duration of the analysis from 96 to 48 hours, thus providing the testing of a greater number of samples in the series. The application scope of this new enzymatic method in the assessment of dry and organic matter digestibility is broad and encompasses: different fibrous feeds (green matter of the whole maize plant and its morphological parts, grasses, legumes, grass and clover mixtures, pure clover, lush meadow vegetation, straw and ammonia treated straw) and concentrated feed and their mixtures (concentrates). In addition, this method can be applied to both, raw and processed feed such as dried and conserved feed (hay, silage). Generally, enzymatic methods for the digestibility determination have been introduced as a replacement of chemical and biological methods that require fistulated animals for taking ruminal fluid.

In recent times, besides the content of lignocellulosic fractions, NDF digestibility, as a quality parameter of fibrous feeds, has been gaining importance. Although NDF and ADF are good indicators of the plant fibre content in fibrous feeds, they do not show the degree of digestibility of these fibres. The NDF digestibility (NDFD) provides more precise data on the content of total nutrients (TDN), net energy content (NE) and a potential intake of fibrous feeds by animals. Generally, the increased NDF digestibility results in greater digestibile energy and greater intake of fibrous feeds. Significant differences in dry matter digestibility and NDF digestibility of the whole plants were obtained in studies on the chemical composition of standard grain hybrids (*Terzić et al., 2014*). The dry matter digestibility and NDF digestibility of the whole plant of observed silage maize hybrids ranged from 57.02 % to 66.16 % and from 23.15 % to 29.26 %, respectively, while differences in dry matter digestibility and differences in NDF digestibility amounted to 9.14 % and 6.11 %, respectively (*Terzić et al., 2014*).

Teh results of digestibility of both dry matter and NDF of the whole plant of nine ZP maize hybrids of various genetic background and different FAO maturity groups that the NDF digestibility varied from 19.37 % (ZP 505) to 31.86 % (ZP 560), while the dry matter digestibility in observed ZP maize hybrids ranged from 59.67 % (ZP 677) to 65.53 % (ZP 434). Differences in NDF digestibility affected dry matter digestibility of the whole plant (*Semenčenko et al., 2014*). According to studies carried out by some foreign authors, diary caws in lactations fed on fibrous feeds consumed greater amounts of dry matter and produced more milk if they were fed with fibrous feeds that contained more digestible NDF (*Bertoia and Aulicino, 2014*; *Thomas et al., 2001*).

Considering the crucial effect and the great importance of observed parameters of maize yield and biomass quality on the estimation of hybrid fitness for silage, the intercorrelation between parameters was determined.

Results of statistically obtained coefficients of correlation of dry matter digestibility and NDF digestibility with the content and the ratio of lognocellulosic fibres of nine selected ZP maize hybrids are presented by *Semenčenko et al., 2014*. A significant positive correlation was determined between the NDF digestibility and the hemicellulose content (r = 0.55).

Furthermore, a very significant positive correlation was determined between the NDF digestibility and the *in vitro* dry matter digestibility of the whole maize plant (r=0.66). Very significant negative correlations were recorded between the *in vitro* digestibility of the whole maize plant and the ADF content (r=-0.61); ADF/NDF (r=0,-0.73); hemicellulose/NDF (r=-0.65) and hemicellulose/cellulose (r=0.69). Significant negative correlations were detected between the *in vitro* digestibility of the whole maize plant dry matter and the NDF content (r=-0.50), ADL content (r=-0.58) and cellulose content (r=-0.58). Moreover, the correlations between ADL and NDF and between ADL and ADF were also significantly negative amounting to r=-0.58 and r=-0.51, respectively. These results are in accordance with our previously published results (*Radosavljević et al., 2012, Radosavljević et al., 2015; Barriere et al., 2009*), as well as with results gained by foreign authors who had determined a negative correlation between the digestibility of organic matter (dry matter-ash content) and NDF and between ADF and hemicellulose, as well as a significant negative correlation between organic matter digestibility and NDF content in organic matter. Very significant positive correlations between digestibility of the whole maize plant and cellulose/NDF (r=-0.73) as well as hemicellulose/cellulose (r=-0.69). Biomass of observed maize hybrids was estimated as high quality feed, and therefore it can be used for feeding ruminants depending on the type, category and needs of animals.

CONCLUSION

According to observed quality parameters for silage maize forms, the maize hybrids selected at the Maize Research Institute, Zemun Polje are considered hybrids of high quality. They are characterised by: high yields of the total dry and total digestible dry matter per hectare, high participation of ear dry matter in the total dry matter yield and high digestibility of the whole maize plant.

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