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DRIED DISTILLERS' GRAINS WITH SOLUBLES (DDGS) PRODUCED FROM DIFFERENT MAIZE HYBRIDS AS ANIMAL FEED

SUVA DŽIBRA RAZLIČITIH HIBRIDA KUKURUZA KAO HRANIVO ZA ŽIVOTINJE

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ABSTRACT

This paper presents results of studies on qualities of maize dried distillers' grains with solubles (DDGS), as animal feed, which is a by-product from the process of maize grain-based bioethanol production. Twenty maize hybrids, developed at the Maize Research Institute, Zemun Polje, were used in this study. The moisture content in all DDGS samples was below 13% - the maximum value according to the Serbian Regulation. Furthermore, obtained results show that all observed DDGS samples had a high content of protein (29.58 - 36.08%), i.e. three-fold higher than in the initial raw material - maize grain. The digestibility of dry matter in samples of DDGS ranged from 74.09 (ZP Rumenka) to 82.41% (ZP 505). Based on obtained results, samples of DDGS were of high quality and therefore can be used as feed for the preparation of complete and concentrated feed.

Key words: *maize, dried distillers' grains with solubles (DDGS), animal feed, bioethanol.*

REZIME

Proizvodnjom bioetanola od zrna kukuruza dobija se sporedni proizvod poznat kao kukuruzna džibra. Na svaki litar bioetanola proizvedenog od zrna kukuruza nastaje oko 0,89 kg suve kukuruzne džibre. Ovaj sporedni proizvod industrije bioetanola predstavlja odličan izvor proteina i energije pa se zbog toga najčešće koristi kao komponenta smeša za ishranu domaćih životinja. Prihod od prodaje suve kukuruzne džibre mogao bi da ima pozitivan uticaj na ekonomsku isplativost proizvodnje bioetanola postupkom suvog mlevenja s obzirom da se ovim procesom jedna trećina kukuruznog zrna prevodi u suvu džibru. U ovom radu prikazani su rezultati ispitivanja kvaliteta suve kukuruzne džibre, kao hraniva za životinje. U istraživanju je korišćeno 20 hibrida kukuruza Instituta za kukuruz „Zemun Polje". Sadržaj suve materije kretao se od 90,47 (ZP Rumenka) do 91,87% (ZP 362), što ukazuje da je sadržaj vlage u svim uzorcima bio manji od 13%, maksimalne vrednosti prema Pravilniku o kvalitetu hrane za životinje. Rezultati su pokazali da su svi ispitani uzorci imali visok sadržaj proteina, između 29,58 (ZP 505) i 36,08% (ZP 611k). Pored toga uočeno je da je sadržaj proteina u suvoj džibri skoro utrostručen u odnosu na zrno kukuruza kao polaznu sirovinu. Svarljivost suve materije uzoraka suve kukuruzne džibre kretala se u rasponu od 74,09 (ZP Rumenka) do 82,41% (ZP 505). Na osnovu dobijenih rezultata ustanovljeno je da su uzorci suve džibre svih ispitivanih hibrida dobrog kvaliteta i mogu se koristiti kao hranivo za pripremu potpunih i koncentrovanih smeša za ishranu životinja.

Ključne reči: *kukuruz, suva kukuruzna džibra, hrana za životinje, bioetanol.*

INTRODUCTION

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. Maize grain consists of approximately 70% of starch, which makes it a very suitable feedstock for the bioethanol production *(Radosavljević et al., 2008)*. Renewability of maize and growing environmental pollution by oil products represent two principal reasons for maize becoming one of the major raw materials for the energy production *(Radosavljević et al., 2009)*. The production of bioethanol has been increasing over the years, and has reached the level of 85 billion litres in 2013. According to the Global Renewable Fuels Alliance (GRFA), this level of the bioethanol production was predicted to reduce GHG emissions by 100 million tonnes in 2013 *(Renewable Fuels Association - RFA, 2013)*.

Stillage, distillery wastewater from the bioethanol production process, is mostly used as feedstuff in dried (dried distillers' grains with solubles -DDGS) or wet form (wet distillers' grains - WDG) *(Mojović et al., 2012)*. A new concept of fermented liquid stillage has been recently introduced in animal diets. One of the examples of incorporating fermented stillage in animal feed is using dried residues of lactic acid fermentation on whole wasted bread as feedstuff *(Đukić-Vuković et al., 2013, 2013a)*. A recent increase in the biofuel production, particularly the dry grind maize-to-ethanol process, creates a sizable stockpile of its co-product in the form of dried distillers' grains with solubles (DDGS), which is made by blending wet distillers' grains (WDG) and syrup and drying the mix *(Liu et al., 2011)*. A gallon (3.78 l) of bioethanol produced from maize kernels generates about 3.36 kg DDGS *(Pimentel, 2003)*. The typical moisture content of the final product, DDGS, necessary to prevent microbial degradation and to maintain product stability, should range from 10% to 13%). Due to the high proportion of nutritional components, especially protein content, DDGS is sold as animal feed. Income from DDGS is important to the profitability of maize ethanol production by dry-grind process since one-third of maize is converted into DDGS in dry-grind processing *(Probst et al., 2013)*. The utilisation of DDGS to feed animals in Serbia could provide income generation in the amount of 14% of the

total revenue from the bioethanol production. Accordingly, there is a tendency in the world to increase the proportion of distillers' dried grains in the combination with other feeds and feedstuffs (complete, supplements) for different types and categories of domestic animals *(Semenčenko, 2013)*.

The majority of previously globally carried out studies on physical and chemical properties of maize distillers' dried grains have been performed on samples taken from plants for the commercial bioethanol production. This paper presents some of the results obtained in studies carried out at the Maize Research Institute, Zemun Polje under laboratory conditions of the production of bioethanol and distillers' dried grains of ZP maize hybrids.

MATERIAL AND METHOD

Samples of maize dried distillers' grains, a by-product of a laboratory process of producing alternative fuel - bioethanol were used in experiments. The starting raw material was grain, i.e. whole grain maize flour of 20 maize hybrids developed at the Maize Research Institute, Zemun Polje. These hybrids encompassed standard grain quality hybrids and specialty maize hybrids. Samples of dried distillers' grains were prepared by the procedure consisting of a separate two-step hydrolysis and fermentation of starch from samples of whole grain maize flour. The method is based on use of commercial enzymatic products Termamyl SC and SAN Extra L (Novozymes, Denmark) in the phases of maize starch hydrolysis and on the application of yeast *Saccharomyces cerevisiae* var. *ellipsoideus* during fermentation of hydrolysates after the procedure described by Semenčenko et al. (2013). Samples of total distillers' grains of selected ZP maize hybrids were dried in the ventilation dryer at the temperature of 60˚C for 48h. Dried samples were crushed in a mortar and subsequently ground in a laboratory mill with a rotating blade and a cooling chamber. The contents of dry matter and protein were determined by the standard laboratory method and the Kjeldahl method, respectively. The dry matter digestibility was determined by a method suggested by Aufréré (2006). The content of certain amino acids in dried distillers' grain samples was estimated by equations proposed by Fiene et al. (2006).

RESULTS AND DISCUSSION

Results obtained on quality of distillers' dried grains of ZP maize hybrids show that the dry matter content varied from 90.47 (ZP Rumenka) to 91.87% (ZP 362), meaning that the moisture content in all samples of distillers' dried grains was below 13%, which is the maximum value according to Serbian Regulation on Quality of Feedstuff (2010). According to the US Grain Council (2012), the recommended moisture content in distillers' dried grains amounts to 11%, which means that all observed samples of distillers' dried grains have met this criterion.

The protein content in the samples of distillers' dried grains varied from 29.5% (ZP 505) to 36.08% (ZP 611k), which is within recommended values (Pravilnik o kvalitetu hrane za životinje, Sl. Glasnik RS 4/2010, 113/2012, 27/2014). According to this Regulation, the minimum content in distillers' dried maize grains should be 25%. Based on the comparison of the protein content in the samples of dried distillers' grains with the protein content in the whole grain flour of maize hybrids (9.07% vs. 13.25%) it can be concluded that the protein content in the samples of dried distillers' grains increased more than double in comparison to the protein content in whole grains of corresponding maize hybrids as starting raw material (Figure 1).

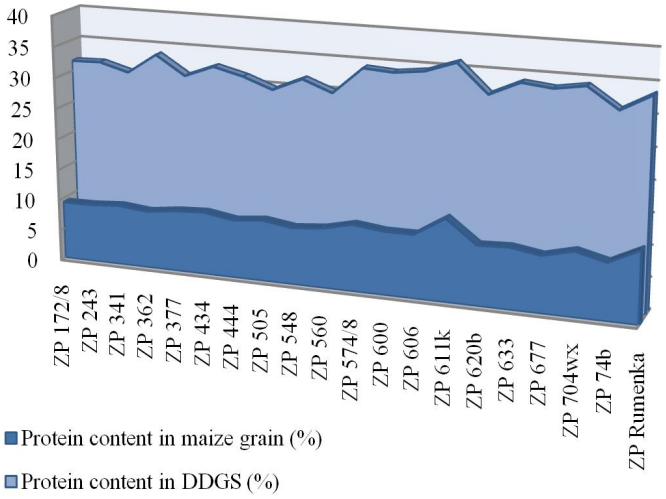

Fig. 1. Increase of protein content in DDGS compared to maize grain as a starting raw material

Generally, proteins of maize distillers' grains originate from two main sources: yeast and maize grain. During the growth, yeast ferments starch and produces a cell mass that mainly consists of proteins *(Belyea et al., 2004)*. Therefore, one part of proteins of maize distillers' grains originate from yeast. Since yeasts do not have proteolytic enzymes, they cannot degrade maize proteins, and thus maize grain proteins remain in maize distillers' grains, where they are enriched by yeast proteins.

The dry matter digestibility of samples of maize distillers' grains was determined by the pepsin-cellulase method and ranged from 74.09% (ZP Rumenka) to 82.41% (ZP 505) (Figure 2). A very high digestibility (81.88%) of dry matter of maize dried distillers' grains was recorded in the waxy maize hybrid ZP 704wx. Waxy maize hybrids contain approximately 100% amylopectin starch components, unlike dent maize hybrids in which the amylopectin to amylase ratio amounts to 72:28%. Some researches have determined that the use of waxy maize hybrids as a dent maize substitute had a positive effects in nutrition of dairy cows during the lactation period, as well as during the growth of cattle *(Akay et al., 2001)*. Other researchers concluded that it is better to use waxy maize than yellow-seeded dent maize in the diet of ruminants due to the high amylopectin digestibility in the rumen of ruminants *(Mohd et al., 1984)*. The good dry matter digestibility of the waxy maize hybrid ZP 704 wx can be contributed, to the greatest degree, to the high amylopectin digestibility.

All coefficients of dry matter digestibility of maize distillers' grains are higher than coefficients of dry matter digestibility of the whole maize plant. *Terzić et al. (2010)* have registered values of digestibility of dry matter of the whole maize plant ranging from 58.09 to 66.65%. Previously published data on digestibility of dry matter of maize grains of two ZP hybrids varied from 83.90 % for ZP 633 to 81.67 % for ZP Rumenka *(Radosavljević et al., 2010)*. A higher digestibility of dry matter of maize grain than maize dried distillers' grains can be explained by a lower content of cellulose and ashes and a higher content of easily digestible carbohydrates (mainly starch) in maize grain. The coefficient of correlation (r = - 0.15) indicates that the protein content does not have a significant effect on the dry matter digestibility *(Semenčenko, 2013)*.

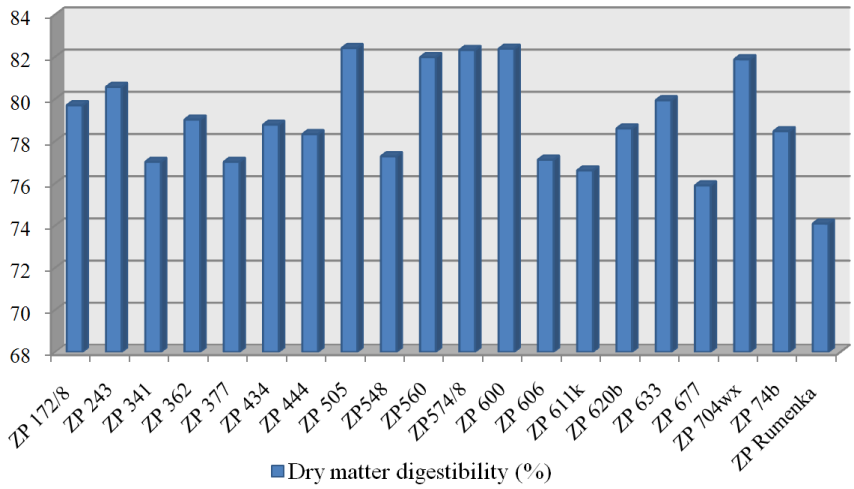

Fig. 2. Dry matter digestibility of investigated DDGS samples

Table 1 shows calculated values of the content of certain amino acids in maize dried distillers' grains.

Table 1. Content of certain amino acids in DDGS samples calculated according to equations proposed by Fiene et al. (2006)

Amino acid (%)	Genotype					
	ZP 434	ZP 611k	ZP 633	ZP 704wx	ZP 74b	ZP Rumenka
Arginine	1.37	1.52	1.42	1.44	1.31	1.41
Isoleucine	1.22	1.36	1.29	1.28	1.15	1.28
Leucine	3.88	4.31	4.09	4.03	3.64	4.01
Lysine	1.03	1.16	1.08	1.09	0.97	1.07
Methionine	0.67	0.74	0.70	0.69	0.63	0.70
Cystine	0.66	0.72	0.68	0.69	0.64	0.68
TSAA	1.32	1.44	1.36	1.37	1.26	1.35
Threonine	1.19	1.31	1.23	1.24	1.13	1.22
Tryptophan	0.25	0.28	0.26	0.27	0.24	0.26
Valine	1.62	1.78	1.69	1.68	1.53	1.68

TSAA -Total Sulphur Amino Acid

Spiehs et al. (2002) established a greater range of values of the arginine content (0.92-2.17 %), and a somewhat lower content of leucine (2.97-3.81%). According to the US Grain Council (2012) the contents of lysine, arginine, tryptophan and methionine of maize dried distillers' grains should range from 0.61% to 1.06%, 1.01 to 1.48%, 0.18 to 0.28% and 0.54 to 0.76%, respectively. The calculated values for amino acids, in the majority of cases, are in accordance with the average values given by the US Grain Council.

Data on the chemical composition, contents of digestible and metabolisable energy, as well as presence of certain substances in samples of dried distillers' grains of ZP maize hybrids, previously published by Semenčenko et al., (2013), also point to the high quality of this nutrient.

Spiehs et al. (2002) concluded that the chemical composition of maize dried distillers' grains varied not only in dependence on the type of raw material, fermentation procedures and technological processing, but it also varied from batch to batch within the same processing plant. Therefore, they recommended that a complete chemical analysis to check the content of maize dried distillers' grains that were added to feedstuffs should be performed at least once a year. Moreover, they concluded that maize dried distillers' grains were generally higher in crude fat, digestible and metabolisable energy, lysine, methionine and threonine levels than DDGS of other cereals, hence they would be better suited for use in diets of animals especially swine.

Numerous studies have been conducted on the effects of feeding DDGS to different categories of animals. *Niemiec et al. (2013)* reported that 15% addition of maize dried distillers' grains with solubles to feed mixtures for commercial flocks of laying hens was advisable. If maize DDGS addition exceeds 15%, a slight decrease in production results and deterioration in selected parameters of egg quality shall be expected. *Loar et al. (2010)* conducted a study in which they fed laying hens with varying levels of DDGS. The 16% DDGS treatment resulted in a significantly higher egg production than the 0, 8, and 24% treatments, whereas the 32% treatment was intermediate and was not significantly different from any other treatment. *Lumpkins et al. (2004)* concluded that high quality DDGS was an acceptable ingredient in broiler diets and recommended a 6% maximum dietary inclusion rate in the starter period and 12 to 15% DDGS in grower and finisher phases of broiler production. A study by Noll and Brannon (2005) showed that up to 20% DDGS could be included in turkey tom grower or finishing diets but when high protein levels were fed, diets containing 15% DDGS can improve growth performance. The use of maize distillers' dried grains in swine diet has been increasing. Many breeders add 20% DDGS into feed mixtures for all categories of swine. Although this percentage is recommended, some breeders add DDGS to grower and finisher diets of swine even in a higher percentage (up to 30%). Due to the risk that a higher share of maize distillers' dried grains in swine diet can adversely affect the quality (hardness) of bacon, this share should be limited to 20%, until negative effects are examined in detail. When formulating feed mixture with maize distillers' dried grains for different categories of swine, attention should be paid to meeting needs of digestible amino acids and absorbable phosphorus, as well as to the lysine to protein ratio. This ratio should not be lower than 2.80 in diets fed to swine *(Stein, 2007)*.

The participation of maize distillers' dried grains in all stages of fattening cattle can be 40% of the diet dry matter. Such a participation of maize distillers' dried grains in diets fed to fattening cattle results in a greater growth, better quality of meat and carcasses *(U.S. Grains Council, 2012)*. The best applications for using DDGS in beef cow diets are in situations when: 1) supplemental protein is needed (especially when feeding low quality forages) to replace maize gluten feed or soya bean meal, 2) a low starch, high fibre energy source is needed to replace maize gluten feed or soy hulls and 3) a source of supplemental fat is needed *(U.S. Grains Council, 2012)*.

CONCLUSION

Based on obtained results it can be concluded that samples of dried distillers' grains of all studied ZP maize hybrids can be characterised as very good. Values of observed parameters: moisture content, protein content and dry matter digestibility are in accordance with regulations on quality of feedstuffs. Therefore, dried distillers' grains obtained from ZP maize hybrid can be used as nutrients for the preparation of complete and complementary feed.

The dry matter content varied from 90.47 (ZP Rumenka) to 91.87% (ZP 362), pointing out that the moisture content in all samples was below 12%, which is the maximum value according to the *Serbian Regulation* (2014). A high protein content (29.58% in ZP 505 and 36.08% in ZP 611k) indicates a high nutritional and energy value of distillers' dried grains as feed. The protein percentage in maize distillers' dried grains was doubled in relation to the maize grain as a starting raw material. The di-

gestibility of dry matter of samples of maize distillers' dried grains ranged from 74.09% (ZP Rumenka) to 82.41% (ZP 505), i.e. it was higher than the digestibility of dry matter of the whole maize plant, pointing out to potentially positive effects of distillers' dried grains as feed.

Calculated values of contents of certain amino acids in the majority of cases agree with average values given in literature.

Obtained results point out to the fact that maize distillers' dried grains with solubles as a by-product of bioethanol cereal-based industry can positively affect the development of bioethanol production in our country, as well as it could be used as feedstuffs in diets of many domestic animals.

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