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INFLUENCE OF COMPRESSION DEGREE AND INOCULATION ON CHEMICAL COMPOSITION AND SILAGE QUALITY OF DIFFERENT MAIZE HYBRIDS

SUMMARY

The experiment was set up as three-factorial trial according to statistical model 2×2×2 (2^k), where A was the factor of maize hybrid (A_1 = hybrid FAO maturity group 4 and A_2 = hybrid FAO maturity group 7), factor B was the degree of compression of silage mass (B_1 = 700 gdm^{-3}, B_2 = 550 gdm^{-3}) and C was the inoculation of the silage material (C_1 =without inoculants; C_2 = with inoculants). Ensiling was performed in the experimental containers with a volume of 60 dm^3. Experimental containers were opened after 56 days and the representative samples were used to determine the main parameters of the chemical composition and the silage quality.

The chemical analysis in the silages of more compressed material (700 gdm^{-3}) showed the reduction of ammonia nitrogen and acetic acid, and increment of lactic acid ($P < 0.05$). Inoculation of silage material has not significantly improved the basic parameters of silage quality (relative ratio of lactic, acetic and butyric acids), but a significant decrease of pH values ($P < 0.05$) was determined. The influence of selected hybrids of silage corn was not significant for most parameters of chemical composition, except for the content of crude fiber and mineral matter.

Based on the research conducted, it can be concluded that the compression degree was the most important measure in the technology of silage making. The adequate compression shortens the duration of the aerobic phase and limits the activity of proteolytic enzymes. In practice, maximum attention should be paid to the factors which, directly or indirectly, the compression degree of ensiling material depends on: the degree of maturity, chop length, choice of the object for silage and/or choosing machines for compression. Factor of inoculation (inoculants based on homo fermentative bacteria of lactic acid) is of a little importance to the corn silage practice. Selection of hybrids factor was not significant for the most important parameter of chemical composition but can be assumed (based on the literature review) that is primarily significant for the total dry matter yield, especially in interaction with the factor of sowing density.

Keywords: corn, silage, hybrid, compression degree, inoculation, chemical composition, quality

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INTRODUCTION

In countries with intensive livestock production, preserved voluminous feed (hay and silage), in combination with concentrates, is used throughout the year (Đorđević et al., 2010), which ensures a stable milk production and stable milk quality. Nowadays, the effects of weather conditions on quality of hay and high variability of the chemical composition have resulted in the minimum use of hay, which is needed for normalization of the rumination process, and the maximum use of silage (Stojanovic et al., 2012).

Whole-plant corn silage is one of the most important energy sources in the diet of dairy cows, as these plant species give high yields of green mass, have a relatively high energy content of dry matter characterized by high palatability and represent an indispensable component for the preparation of fully mixed meals (Forouzmand et al., 2005). For decades, commercial corn hybrids have been selected, mainly, according to the grain yield and resistance to certain diseases, while the nutritional value has been relatively neglected (Bagg, 2000). However, there are significant differences in nutritive value between silages produced from different corn hybrids, which came out from different digestibility of nutrients. Nutritive value of corn silage is determined by hybrid, level of maturity and dry matter digestibility (Kamalak et al., 2003; John et al., 2005; Jalilvand et al., 2008). In previous decades, brown-midrib hybrids (mb3) were very common due to significantly lower share of lignin and therefore increased *in vitro* NDF digestibility fiber (Oba and Allen, 1999). However, these hybrids are not suitable for commercial production since they have low yield of grain and biomass for ensiling. In recent years, the ensiling of leafy maize hybrids has been studied a lot. Large amounts of leaves, higher grain moisture content and softer kernel texture are the main characteristics of these hybrids. Dwyer et al. (1998) stated that approximately 16% of North American corn silage production is from leafy hybrids. Modern maize hybrids have such habitus that allows them to be grown in more dense rows, which allows higher yield (Subedi et al., 2006). Increase of crop density in process of growing the silage maize is justified only from aspect of yield increase per acre, only if nutritional value of produced silage is not changed (Budakli et al., 2010). In order to increase nutritive value of maize silage various other hybrids are produced such as high-oil (Weiss and Wyatt, 2000), waxy (Akay and Jackson, 2001) and others.

In recent years, the corn silage has been increasingly prepared and used in the cattle diets in Montenegro. In some parts of Montenegro silage maize is grown at an altitude of 700 meters. Accordingly, the selection of hybrids and FAO maturity group is of great importance in order to obtain satisfactory yield of biomass in the optimal stage of maturity even in a shorter growing season. In addition, the maximum compaction of biomass and fermentation stimulation is very important parameters for the silage quality and usability. The ensiling practice requires very simple, cheap and effective procedures. In line with this, the aim of this experiment was to investigate the effect of two degrees of compression and inoculation on chemical composition and quality parameters of different corn hybrids.

MATERIAL AND METHODS

The experiment was set up as three-factorial trial according to statistical model 2×2×2 (2^k), where A was the factor of maize hybrid (A_1 = hybrid FAO maturity group 4 and A_2 = hybrid FAO maturity group 700), factor B was the degree of compression of silage mass (B_1 = 700 gdm^{-3}, B_2 = 550 gdm^{-3}) and C was the inoculation of the silage material (C_1 =without inoculants; C_2 = with inoculants).

Selection of the above hybrids was made due to differences in the growing season length, which might be important for conditions in Montenegro, and different altitudes where corn silage is grown. The ensiling was conducted in the stage of wax maturity of grain. The shoppedhybrids biomass was treated with an inoculant based on homofermentative lactic acids in order to enhance fermentation. According to producer`s specification, the inoculant contained microencapsuled bacteria *Lactobacillus plantarum* (min. 1.0×10^{11} CFU), *Lactobacillus acidophilus* (min. 1.0×10^{11} CFU), *Streptococcus faecium* (min. 1.0×10^{11} CFU) and *Pediococcus acidilactici* (min. 1.0×10^{11} CFU). The quantity of inoculant used according to the producer`s recommendation was 2.5 gt^{-1}. The biomasses were ensiled (compressed) in the plastic experimental containers with volume of 60 dm^3, with two degrees of compression. The degree of compaction of 700 gdm^{-3} is specific for optimum compressed silage, while the degree of compaction of 550 gdm^{-3} simulated the failures that occur in practice. After 56 days of ensiling, experimental containers were opened and representative samples were taken for chemical analysis. The parameters of chemical composition and silage quality were determined in the Laboratory for nutrition of domestic and reared animals at the Faculty of Agriculture, Zemun (AOAC, 2002). The calculation of evaporated substances in silage dry matter (volatile fatty acids, alcohol, and ammonia) was corrected according to Dulphy and Demarquilly (1981). The amount of ammonia nitrogen was analyzed with modified Kjeldahl procedure (Dulphy and Demarquilly, 1981). A statistical analysis of the obtained results was done by analysis of variance procedure with software package Statsoft in order to determine the significance of each factor (Statsoft, 2006).

RESULTS AND DISCUSSION

The amount of dry matter in all silages was higher than 300 gkg^{-1} and it is considered as the main condition for preventing the separation of juices and maximal control of butyric fermentation (Table 1). Silage dry matter was corrected at the expense of volatile substances (organic acids, alcohols and ammonia) to be slightly different from the dry matter of starting material.

The chemical composition of silages was not much different from the starting material, except that the fat content showed some variation. Almost double quantity of ether extract in silages compared to the starting material can be explained with extraction of the part of lactic acid (which is not volatile) with diethyl-ether (Barnett, 1954). In addition, diethyl-ether also extracts other fat-like

substances such as plant pigments, waxes, ether oils, fat soluble vitamins and others (Đorđević et al., 2003), and all this is increasing the raw fat content. The differences in protein amount between the starting material and silages occurred because of the drying process of the samples during which some ammonia was lost. Other differences can be partially explained by the change of specific ingredients relative ratio.

Table 1. Chemical composition of starting materials and silages, g kg^{-1} DM

Starting material			DM gkg^{-1}	Proteins	Fats	Cellulose	NFE	Ash
Whole maize plant, FAO 4			314.07	70.43	22.58	196.94	661.45	48.60
Whole maize plant, FAO 7			352.43	66.87	19.36	205.68	662.06	46.03
Silages								
Hybrid	Compression degree	Inoculant	DM gkg^{-1}	Proteins	Fats	Cellulose	NFE	Ash
(A_1) Whole maize plant FAO 4	(B_1) 700 gdm^{-3}	(C_1) No	307.24	69.74	44.35	198.05	639.58	48.28
		(C_2) With	320.02	70.33	38.29	200.33	642.55	48.50
	(B_2) 550 gdm^{-3}	(C_1) No	312.37	67.28	40.41	201.07	642.36	48.88
		(C_2) With	330.03	67.81	42.73	199.92	641.31	48.23
(A_2) Whole maize plant FAO 7	(B_1) 700 gdm^{-3}	(C_1) No	361.26	66.39	34.95	208.26	644.22	46.18
		(C_2) With	354.47	66.62	44.18	214.86	628.39	45.95
	(B_2) 550 gdm^{-3}	(C_1) No	359.04	66.07	30.45	218.27	639.33	45.88
		(C_2) With	354.38	66.19	37.04	210.55	640.16	46.06
Average for A_1			317.42	68.79	41.44	199.84	641.45	48.47
Average for A_2			357.29	66.32	36.66	212.98	638.02	46.02
Average for B_1			335.75	68.27	40.44	205.38	638.68	47.23
Average for B_2			338.96	66.84	37.66	207.45	640.79	47.26
Average for C_1			334.98	67.37	37.54	206.41	641.37	47.30
Average for C_2			339.72	67.74	40.56	206.42	638.10	47.18
Significance for A			**	ns	ns	*	ns	**
Significance for B			ns	ns	ns	ns	ns	ns
Significance for C			ns	ns	ns	ns	ns	ns

ns - no significance; * ($p<0.05$); ** ($p<0.01$)

Differences in silage chemical composition between the examined hybrids are minimal and can be explained, first of all, by the influence of plant density on the proportion of specific plant parts (leaf, stem and ear). Differences in dry matter total yield, and energy, between the hybrids with different maturity time and at different plant density are considered as the most significant for practice (Budakli et al., 2010).

The use of inoculants at the beginning of fermentation had a purpose to provide the optimal number of homofermentative lactic bacteria, which are normally rare in nature. As stated by Jambor and Šiške (1997), the number of epiphytic lactic acid bacteria on plants is only $10\text{-}10^2$ bacteria per gram of green mass, while the number of enterobacteria is much bigger and amounts to $10^2\text{-}10^7$ per gram. Commercial products used as inoculants are used with the doses that

provide 10^5-10^6 lactic acid bacteria per gram of ensiled mass, which enables them to become dominant over the enterobacteria (Prikryl, 1997).

Table 2. Parameters of biochemical changes in silages, gkg^{-1} DM

Hybrid	Compression degree	Inoculant	pH	NH_3-N, $gkg^{-1}N$	Lactic acid	Acetic acid	Butyric acid
(A_1) Whole maize plant FAO 4	(B_1) 700 gdm^{-3}	(C_1) No	3.96	96.54	48.74	20.18	0.00
		(C_2) With	3.82	87.06	55.23	23.07	0.00
	(B_2) 550 gdm^{-3}	(C_1) No	4.14	112.42	42.18	24.56	0.00
		(C_2) With	4.03	103.71	47.04	26.71	0.00
(A_2) Whole maize plant FAO 7	(B_1) 700 gdm^{-3}	(C_1) No	3.93	93.25	46.37	18.10	0.00
		(C_2) With	3.85	88.97	50.98	23.46	0.00
	(B_2) 550 gdm^{-3}	(C_1) No	4.10	99.21	40.15	22.26	0.00
		(C_2) With	3.98	92.83	46.04	25.11	0.00
Average for A_1			3.99	99.93	48.30	23.63	0.00
Average for A_2			3.96	93.56	45.88	22.23	0.00
Average for B_1			3.89	91.46	50.33	21.20	0.00
Average for B_2			4.06	102.04	43.85	24.66	0.00
Average for C_1			4.03	100.36	44.36	21.28	0.00
Average for C_2			3.92	93.14	49.82	24.59	0.00
Significance for A			ns	*	*	ns	ns
Significance for B			**	**	**	*	ns
Significance for C			**	**	**	*	ns

ns - no significance; * ($p<0.05$); ** ($p<0.01$)

The use of inoculants in this test led to the intensification of fermentation, and consequently to an increase in production of lactic and acetic acids (Table 2). The result is a decrease in pH in the inoculated silage and in proteolysis as well, expressed through the amount of ammonia nitrogen. The identified tendency is not really significant for the practice of corn silage, since this plant contains a small amount of protein. Ammonia nitrogen is one of the most important parameters that reflect changes in nutrient contents. It is produced by the action of proeolytic enzymes from plant cells and microorganisms, mostly butyric *Clostridia*. A presence of ammonia in the silage containing no butyric acid is a result of plant enzyme activity (McDonald et al., 1991). Values of pH and dry matter content are the most important factors that dictate the intensity of proteolysis, but they cannot stop it completely (Carpintero et al., 1979).

In silages with higher degree of compression, significantly more lactic acid was detected and significantly less acetic acid. The influence of compression degree on intensity of fermentation is explained by the shorter duration of the aerobic phase in the better compacted material, and therefore lower production of acetic acid. One of the biggest problems for the practice of using corn silage is the subsequent fermentation that occurs due to irregular use of silage and prolonged exposure to air. Lactic acid as the main product of sugar

homofermentative fermentation in ensiling mass represent very strong bactericidal but very weak fungicidal agent. Contrary to that, acetic, propionic and butyric acids have a very strong fungicidal effect, and therefore the small amounts of these acids are even desirable in silage corn, and other crops (Hu et al., 2009). Nevertheless, large amounts of residual sugar in the form of a NFE are responsible for a small aerobic stability of silage corn (Lynch et al., 2012; Arriola et al., 2011; Tabacco et al., 2011).

It was discovered that butyric acid was not present in most silages. That can be explained with the adequate conditions during the ensiling, and the fact that raw material was not contaminated with soil, which is the main source of butyric *Clostridia*. The explanation lies also in the higher dry matter content, which limits the activity of butyric bacteria. (Đorđević et al., 2004).

CONCLUSIONS

In this experiment it is found that there is a significant influence of the compression degree and silage inoculation material on the main parameters of biochemical changes (pH, degree of proteolysis and the amount of lactic and acetic acids). A selected hybrid as a studied factor did not influence significantly the chemical composition of silage (except the fiber content and mineral matter), while the significant effect on the parameters of the biochemical changes in silage was made through differences in the dry matter content. In future research, the impact of different hybrids on the basic production parameters in different conditions of Montenegro should be explored.

Based on the research conducted it can be concluded that the compression degree is the most important measure in the technology of feed ensiling. The adequate compression shortens the duration of the aerobic phase and limits the activity of the proteolytic enzymes. In practice, maximum attention should be paid to the factors on which directly or indirectly depends the degree of compression of ensiling material: the degree of maturity, chop length, choice of the object for silage and/or choosing machines for compression.

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UTICAJ STEPENA SABIJENOSTI I INOKULACIJE NA HEMIJSKI SASTAV I KVALITET SILAŽE RAZLIČITIH HIBRIDA KUKURUZA

SAŽETAK

Eksperiment je postavljen po statističkom modelu $2\times2\times2$ (2^k), gdje je faktor A hibrid kukuruza (A_1 = hibrid FAO grupe zrenja 4 i A_2 = hibrid FAO grupe zrenja 7), faktor B je stepen sabijenosti silirane mase (B_1 = 700 gdm^{-3}, B_2 = 550 gdm^{-3}) i C je inokulacija siliranog materijala (C_1 = bez inokulanta; C_2 = sa inokulantom). Siliranje je obavljeno u eksperimentalnim silosima zapremine 60 dm^3. Eksperimentalni silosi su otvoreni posle 56 dana i iz reprezentativnih uzoraka su utvrđeni osnovni parametri hemijskog sastava i kvaliteta silaža.

Na osnovu rezultata hemijskih analiza utvrđeno je u silažama od bolje sabijenog materijala (700 gdm^{-3}) smanjenje količine amonijačnog azota, kao i sirćetne kisjeline, i povećanje količine mlečne kisjeline ($P<0,01$). Inokulacijom siliranog materijala je došlo do intenziviranja fermentacije i smanjenja pH vrednosti i stepena proteolize ($P<0,01$). Uticaj izabranog hibrida silažnog kukuruza nije bio značajan za većinu parametara hemijskog sastava, osim za sadržaj sirove celuloze i mineralnih materija.

Na osnovu izvedenih ispitivanja može se zaključiti da je stepen sabijanja najvažnija mjera u tehnologiji siliranja hraniva. Adekvatnim sabijanjem skraćuje se trajanje aerobne faze i ograničava djelatnost proteilitičkih enzima. U praksi treba posvetiti maksimalnu pažnju faktorima od kojih direktno ili indirektno zavisi stepen sabijenosti siliranog materijala: stepenu zrelosti, dužini seckanja, izboru tipa objekta za siliranje i/ili izboru mehanizacije za sabijanje. Faktor inokulacije (inokulantima na bazi homofermentativnih bakterija mlečne kiseline) je od malog značaja za praksu siliranja kukuruza. Faktor izbora hibrida nije bio značajan za najvažnije prametre hemijskog sastava ali se može predpostaviti (na osnovu pregleda literature) da je prije svega značajan za ukupne prinose suve materije, naročito u interakciji sa faktorom gustine sjetve.

Ključne riječi: kukuruz, silaža, hibrid, stepen sabijenosti, inokulacija, hemijski sastav, kvalitet