Fragm. Agron. 35(1) 2018, 94–105
DOI: 10.26374/fa.2018.35.09

EVALUATION OF NUTRITIVE VALUE AND QUALITY OF MAIZE (*ZEA MAYS* L.) SILAGE DEPENDING ON CUTTING HEIGHT AND ENSILING ADDITIVE

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Abstract. Feeding dairy and beef cattle is based on forage produced on the farm, such as e.g. maize silage, a very good and frequently used feed. Due to its high contents of carbohydrates, low contents of protein and ash, maize is one of the best ensiling plants, providing feed of good overall characteristics and digestibility. The aim of this study was to determine the effect of ensiling additives on aerobic stability and nutritive value of maize silage depending on cutting height of maize at harvest. Analyses were conducted in 2006 and 2007 on silage produced from maize cultivar PR 39A98, grown in the fields of the Stud Farm of Pępowo Sp. z o.o. The experiment was conducted in a two-factorial design in three replications in the randomized blocks system. In this experiment cutting height (CH) of maize plants: 20 cm, 30 cm, 40 cm, was adopted as the 1st degree factor. The 2nd degree factor comprised randomly allocated ensiling additives (EA): Inokulant 11A44 (I 11A44), Inokulant 11.32 (I 11.32), Bioprofit (B), Pro–Stabil AP 80 L (Pr S), as well as the control with no ensiling additives added. Harvested plant material was cut into chaffs of approximately 1 cm in length and ensiled in microsilos. The conducted analyses showed that the applied ensiling additives – microbial and chemical, had an effect both on the chemical composition and quality of maize silage. The application of biological additives promoting ensilage resulted in a reduced starch content in silage dry matter and in comparison with the control increased the contents of glucose and fructose. Variation in cutting height of maize had an effect on contents of lactic and propionic acids and ethanol in silage.

Key words: aerobic stability, chemical composition, cutting height, ensiling additive, maize silage

INTRODUCTION

Feeding of dairy and beef cattle is based on forage produced on the farm, such as e.g. maize silage, a very good and frequently used feed [Hasselmann et al. 1998, Neylon and Kung 2003]. Ensiling is a process of feed production from plants with high water contents minimising losses of nutrients [Adesogan 2006]. In the course of ensilage under the influence of microorganisms fermentation processes take place, as a result of which organic acids are formed, primarily lactic acid [McDonald et al. 1991]. Quality of silage is determined by availability of oxygen. The presence of oxygen promotes the development of putrefactive bacteria, moulds, etc., thus anaerobic conditions need to be provided for ensiled feed [Woolford 1990]. Susceptibility to ensilage is an important factor determining quality and digestibility of produced feed [Ashbell et al. 2002]. Due to its high content of carbohydrates, low contents of protein and ash, maize is one of the best ensiling crops, providing feed characterised by good overall properties, digestibility and a positive effect on animal metabolism [Hasselmann et al. 1998]. Maize may be ensiled practically with no additives, under almost any conditions, although in such cases silage is frequently of poor quality. In order to improve the ensiling process different chemical and biological ad-

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ditives are used [Adesogan and Salawu 2004, Adesogan et al. 2007, Faligowska et al. 2014, Sucu and Filya 2006]. Thus it is important to find such additives, which from the beginning of ensilage would inhibit growth of putrefactive bacteria and fungi and prevent the development of aerobic conditions [Filya et al. 2006].

To provide good ensiling material with 30–35% contents of dry matter (DM) maize should be harvested when kernels are at the dent stage [Daccord et al. 1996], which prevents drip of percolating juices and losses of nutrients [Kowalik and Michalski 2006]. Content of DM in harvested maize is dependent, among other things, on cultivation conditions, such as stocking and cutting height at harvest [Caetano et al. 2011].

Lower fragments of maize stems are considered to be less valuable and less digestible [Tolera and Sundstl 1999]. Increasing plant cutting height at harvest increases the share of ears and contents of dry matter in the ensiled material [Kowalik and Michalski 2006], resulting in improved feed digestibility and animal productivity [Bernard et al. 2004, Curran and Posch 2000]. However, the increased cutting height leads to a reduction of maize yields, although in the opinion of Undersander et al. [1993] thanks to their better quality the potential feed productivity, manifested in milk yields, is increased. Nylon and Kung [2003] were of the opinion that increasing plant cutting height at harvest may improve nutritive value of maize feed. In turn, Wu and Roth [2005] stated that an increased cutting height during harvest resulted in increased contents of crude protein (CP) and net energy percentage, in contrast to the content of neutral detergent fiber (NDF).

The aim of this study was to determine the effect of ensiling additives on aerobic stability and nutritive value of maize silage depending on cutting height of maize during harvest.

MATERIAL AND METHODS

The field part of the experiment was conducted in the years 2006–2007 sowing the stay-green maize cv. PR 39A98 (FAO 240) grown for silage in the fields of the Stud Farm of Pępowo Sp. z o.o. (51°43′ N, 17°01′ E). All cultivation measures were performed in accordance with the principles of good cultivation practice for this species and crop use. Plants were harvested at the milk stage of maize (BBCH 75), at dry matter contents of 30–35%, using a John Deere 6650 maize silage chopper. The laboratory experiment was conducted in a randomized blocks as 2-factorial design in 3 replications. Cutting height (CH) of maize plants, i.e. 20 cm, 30 cm and 40 cm, was adopted as the 1st degree factor. The ensiling additive (EA) was adopted as the 2nd degree factor: Inokulant 11A44 (I 11A44), Inokulant 11.32 (I 11.32), Bioprofit (B), Pro–Stabil AP 80 L (Pr S) and the control with no additives used. The ensiling additive Pr S used in this experiment is a chemical preparation, while the other ensiling additives were biological preparations. The detailed composition of preparations used in this experiment was described in an earlier study by Szymańska et al. [2014].

The harvested plant material was cut into chaffs of approximately 1 cm in length and ensiled in polyethylene microsilos (Ø 15 cm, height 50 cm). Microsilos were sealed with rubber stops with a glass fermentation tube, releasing gas fermentation products. Microsilos were stored under laboratory conditions at 10–15±2 °C. After six months the microsilos were opened and the nutritive value and quality of produced silage were determined. Additionally, the aerobic stability test was also performed. Individual components of analysed silage, such as dry matter (DM), crude protein (CP), starch (STA), neutral detergent fibre (NDF), acid detergent fibre (ADF), crude ash (CA), glucose (GLU), fructose (FRU), mannose (MAN), lactic acid (LA), acetic acid (AA), butyric acid (BA), propionic acid (PRO), ammoniacal nitrogen ($N–NH_3$), ethanol (ETH) and pH of silage were determined by near infrared reflectance spectroscopy (NIRS) using the

Foss NIR System 5000 calibrated at the University of Padova, Department of Animal Science. Analyses were done in Pioneer company laboratory.

After the silos were opened the aerobic stability of silage was tested. Temperature was measured at every 30 minutes from the moment of microsilo opening until it stabilised. Temperature was determined using Hydrochron Temperature & Humidity iButtons sensors, model DS1923-F5# produced by Embedded Data Systems (USA).

Results collected in the two years of analyses are presented as means for years. The effect of cutting height and application of ensiling additives on the evaluated parameters was subjected to a 2-way analysis of variance using the SAS software (SAS Institute, 1999). The least significant difference (LSD) was verified using Tukey's test at P = 0.05 and P = 0.01.

RESULTS

Results of analyses of the chemical composition of silage depending on the experimental factors are presented in Table 1. The mean content of dry matter in the tested silage ranged from 318 to 331 $g \cdot kg^{-1}$. The conducted analysis of variance showed a significant effect of both tested factors on dry matter content in silage. Increasing cutting height from 20 to 40 cm led to a significant increase in the content of dry matter in the analysed silage. In contrast, the application of ensiling additives, irrespective of their type, significantly reduced dry matter contents in comparison to the control.

The greatest contents of crude protein, amounting to 76.2 and 76.1 $g \cdot kg^{-1}$ DM, respectively, were found in silage produced from plants cut at an increased height (30 and 40 cm). In turn, the concentration of crude protein in dry matter of silage varied significantly under the influence of the applied ensiling additive. Irrespective of the cutting height, the share of crude protein in dry matter silage was significantly greater in the control and in the silage with the chemical additive (Pr S).

Contents of NDF, ADF and crude ash (CA) in dry matter of silage decreased with an increase in cutting height. However, it needs to be stressed that in the case of NDF and crude ash this reduction was not confirmed statistically. Irrespective of cutting height a positive effect was found for additives stimulating the ensiling process on contents of NDF, ADF and crude ash, which was most evident after the application of microbial preparations (I 11A44 and I 11.32).

In this study an increase in cutting height significantly changed the content of starch in silage dry matter. Significantly the greatest content of this component (257 $g \cdot kg^{-1}$ DM) was found in silage prepared from plants cut at a height of 40 cm. The application of biological additives promoting ensilage led to a decrease in starch contents in dry matter of silage. Significantly the greatest contents of this component were recorded in the control silage and that with the chemical additive (Pr S).

Variation in cutting height had no significant effect on the concentration of glucose or mannose in silage dry matter. Only the content of fructose decreased significantly under the influence of increased cutting height of harvested plants. The application of tested ensiling additives, both biological and chemical, significantly increased contents of glucose and fructose in comparison to the control.

Quality attributes of maize silage depending on the tested factors are presented in Table 2. Increasing the cutting height of maize reduced contents of lactic and propionic acids and ethanol in silage. Significantly greater contents of these components were recorded in silage prepared from maize cut at a height of 20 and 30 cm than in the case of cutting at a height of 40 cm. Variation in cutting height has a slight effect on contents of such components as acetic and butyric

Table 1. Chemical composition of maize silage depending on cutting height and ensiling additive (average for years)

CH (A)	EA (B)	DM	CP	NDF	ADF	CA	STA	GLU	FRU	MAN
		$g \cdot kg^{-1}$			$g \cdot kg^{-1}$ DM			% DM		
20 cm	Control	323 a*	75.8 a	440 a	246 a	41.4 a	252 a	0.63 bc	0.58 a	2.10 a
	I 11A44	318 a	75.3 a	443 a	249 a	43.5 a	246 a	0.63 bc	0.60 a	2.12 a
	I 11.32	330 a	75.1 a	441 a	249 a	44.1 a	249 a	0.65 a	0.60 a	2.14 a
	B	321 a	76.1 a	439 a	247 a	42.3 a	249 a	0.64 ab	0.59 a	2.10 a
	Pr S	321 a	77.1 a	438 a	247 a	41.2 a	257 a	0.63 bc	0.59 a	2.11 a
Mean		320 B**	75.9 A	440 A	248 A	42.5 A	251 B	0.63 A	0.59 A	2.11 A
30 cm	Control	324 a	76.6 a	436 a	245 a	39.3 a	258 a	0.62 cd	0.59 a	2.13 a
	I 11A44	318 a	76.0 a	449 a	249 a	43.3 a	251 a	0.64 ab	0.60 a	2.11 a
	I 11.32	321 a	75.7 a	444 a	249 a	43.7 a	241 a	0.63 bc	0.59 a	2.07 a
	B	321 a	75.5 a	428 a	248 a	42.7 a	245 a	0.64 ab	0.59 a	2.10 a
	Pr S	323 a	77.2 a	436 a	245 a	40.6 a	259 a	0.63 bc	0.59 a	2.14 a
Mean		321 B	76.2 A	437 A	247 AB	41.9 A	251 B	0.63 A	0.59 A	2.11 A
40 cm	Control	331 a	76.9 a	439 a	245 a	40.2 a	265 a	0.61 d	0.57 a	2.06 a
	I 11A44	324 a	75.6 a	439 a	247 a	43.3 a	253 a	0.64 ab	0.59 a	2.12 a
	I 11.32	326 a	75.7 a	440 a	246 a	41.3 a	255 a	0.62 cd	0.58 a	2.08 a
	B	324 a	75.7 a	438 a	246 a	41.6 a	252 a	0.63 bc	0.58 a	2.12 a
	Pr S	325 a	76.4 a	435 a	245 a	41.3 a	257 a	0.65 a	0.58 a	2.05 a
Mean		326 A	76.1 A	438 A	246 B	41.6 A	256 A	0.63 A	0.58 B	2.09 A
Mean (B)	Control	326 A	76.4 A	438 AB	245 B	40.3 C	259 A	0.62 B	0.58 B	2.10 A
	I 11A44	320 B	75.6 B	441 A	248 A	43.4 A	250 B	0.64 A	0.59 A	2.12 A
	I 11.32	322 B	75.5 B	441 A	248 A	43.0 A	248 B	0.63 AB	0.59 A	2.10 A
	B	322 B	75.8 B	435 B	247 AB	42.2 AB	248 B	0.64 A	0.59 A	2.10 A
	Pr S	323 B	76.9 A	436 AB	245 B	41.0 BC	258 A	0.64 A	0.59 A	2.10 A

*small letters a, b, c indicate statistical significance for interaction (cutting height x additive to ensilaging), values followed by the same letter are not significantly different at the 0.01 level according to the Tukey's test

**capital letters A, B, C indicate statistical significance for cutting height or additive to ensilaging, values followed by the same letter are not significantly different at the 0.05 or 0.01 level according to the Tukey's test

Table 2. The effect of cutting height and ensiling additive on quality attributes of maize silage (average for years)

CH (A)	EA (B)	LA	AA	BA	PRO	ETH	N-NH_3	pH
		$g \cdot kg^{-1}$ DM					mg N·100 g^{-1} DM	
20 cm	Control	58.6 a*	17.5 a	0.74 b	3.21 a	8.64 a	46.6 a	3.68 ab
	I 11A44	65.0 a	18.1 a	0.77 ab	3.26 a	9.02 a	49.1 a	3.64 c
	I 11.32	67.8 a	18.3 a	0.76 b	3.29 a	8.98 a	52.8 a	3.64 c
	B	60.0 a	17.8 a	0.76 a	3.24 a	8.89 a	50.1 a	3.68 ab
	Pr S	60.2 a	17.7 a	0.74 b	3.21 a	8.59 a	50.8 a	3.67 a-c
Mean		62.3 A**	17.9 A	0.75 A	3.24 A	8.82 A	49.9 A	3.67 A
30 cm	Control	55.6 a	17.3 a	0.73 b	3.16 a	8.47 a	45.2 a	3.69 a
	I 11A44	62.4 a	18.2 a	0.74 b	3.25 a	8.86 a	48.4 a	3.67 a-c
	I 11.32	63.4 a	17.8 a	0.75 b	3.24 a	9.03 a	49.4 a	3.67 a-c
	B	62.5 a	17.9 a	0.74 b	3.22 a	8.99 a	48.6 a	3.66 a-c
	Pr S	60.2 a	17.9 a	0.74 b	3.18 a	8.61 a	49.8 a	3.66 a-c
Mean		60.8 AB	17.8 A	0.74 A	3.21 A	8.79 A	48.3 A	3.67 A
40 cm	Control	55.8 a	17.2 a	0.67 b	3.04 a	8.41 a	48.6 a	3.69 a
	I 11A44	63.9 a	17.7 a	0.82 a	3.19 a	8.82 a	50.6 a	3.65 bc
	I 11.32	58.3 a	17.4 a	0.77 ab	3.17 a	8.66 a	49.0 a	3.69 a
	B	59.9 a	17.5 a	0.72 b	3.17 a	8.82 a	49.0 a	3.66 a-c
	Pr S	59.2 a	18.1 a	0.77 ab	3.15 a	8.47 a	49.9 a	3.68 ab
Mean		59.4 B	17.6 A	0.75 A	3.15 B	8.64 B	49.4 A	3.68 A
Mean (B)	Control	56.7 D	17.3 B	0.71 B	3.14 C	8.51 B	46.8 B	3.69 A
	I 11A44	63.8 A	18.0 A	0.77 A	3.24 A	8.90 A	49.4 A	3.66 B
	I 11.32	63.2 AB	17.8 A	0.76 A	3.24 A	8.89 A	50.4 A	3.67 B
	B	60.8 BC	17.8 A	0.74 AB	3.21 AB	8.90 A	49.3 A	3.67 B
	Pr S	59.8 C	17.9 A	0.75 A	3.18 BC	8.56 B	50.2 A	3.67 B

*small letters a, b, c indicate statistical significance for interaction (cutting height x additive to ensilaging), values followed by the same letter are not significantly different at the 0.01 level according to the Tukey's test

**capital letters A, B, C indicate statistical significance for cutting height or additive to ensilaging, values followed by the same letter are not significantly different at the 0.05 or 0.01 level according to the Tukey's test acids, ammoniacal nitrogen and pH of silage. In comparison to the control the application of ensiling additives significantly increased the silage contents of lactic, acetic and propionic acids as well as ethanol. The greatest contents of lactic acid were recorded in silage prepared with the microbial additives I 11A44 and I 11.32, containing *Lactobacillus buchneri* and strains *Lactobacillus plantarum* and *Enterococcus faecium*, respectively. Irrespective of cutting height the application of all tested ensiling additives led to a significant increase in contents of acetic acid and ammoniacal nitrogen in silage. In the case of ethanol contents of this component in silage were significantly greater after the application of all tested biological preparations than it was in the control or after the introduction of the chemical additive (Pr S). A similar dependence was observed for propionic acid. An exception in this respect was found for the combination with the addition of Bioprofit (B), which in the case of this component had a similar effect to that of the chemical additive (Pr S). The lowest level of butyric acid was recorded in the control silage containing no additives. We also need to focus here on silage supplemented with the microbial preparation Bioprofit (B), in which butyric acid content was comparable to that of the control silage. The applied ensiling additives had a significant effect on changes in pH of silage. Irrespective of the type of the used ensiling additive, pH of silage was significantly lower than in the control. It also needs to be stressed that the type of ensiling additive did not cause a significant variation in pH of tested silages.

Aerobic stability of silages determined on the basis of the temperature test is presented in Figures 1–3 depending on cutting heights. Stability of tested silages varied. Temperature of the

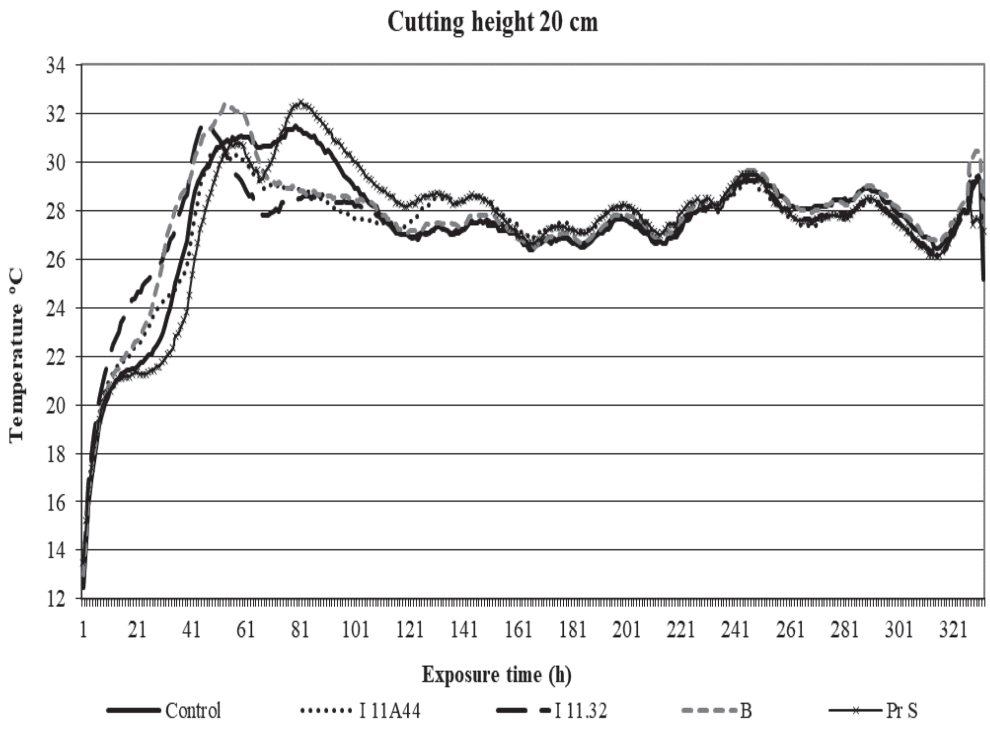

Fig. 1. Changes of temperature of maize silage during the aerobic stability test, depending on cutting height (20 cm) and ensiling additive

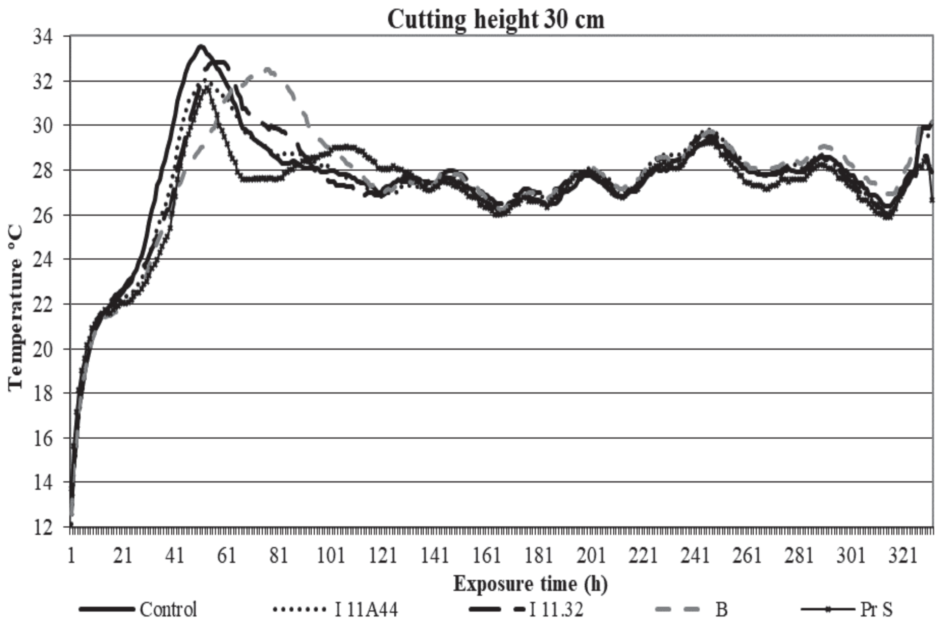

Fig. 2. Changes of temperature of maize silage during the aerobic stability test, depending on cutting height (30 cm) and ensiling additive

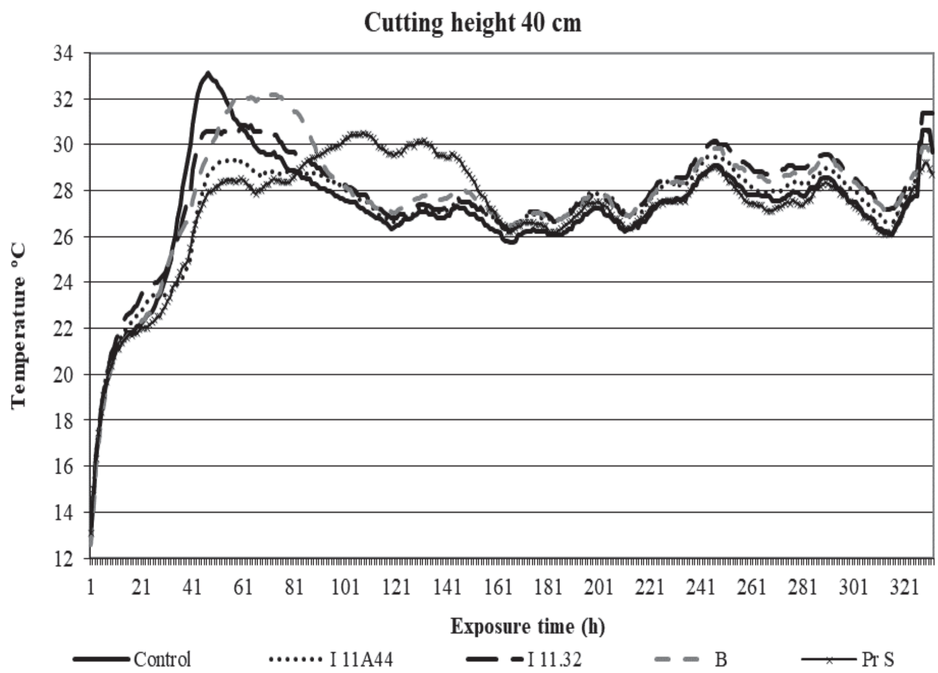

Fig. 3. Changes of temperature of maize silage during the aerobic stability test, depending on cutting height (40 cm) and ensiling additive

control silage prepared from plants cut at a height of 30 and 40 cm increased the most after 41 h of exposure to air. In turn, in silages with ensiling additives (EA) temperature increased at a slower pace, which was particularly evident in silage prepared from plants cut at a height of 30 cm. The best aerobic stability, irrespective of cutting height of harvested maize, was found in silage prepared with the chemical additive (Pr S). In turn, silage prepared from plants cut at a height of 20 cm, irrespective of the type of applied microbial additives, showed an inferior aerobic stability in comparison to the control. It also needs to be stressed here that the temperature of this silage during air exposure was lower than in silage prepared from plants cut at a height greater by 10 and by 20 cm. A trend was also observed for silage prepared with the chemical additive (Pr S) from plants cut at a height of 20 cm after a longer exposure to air (80 h) to be of an inferior aerobic stability than silage prepared with microbial additives or the control silage.

DISCUSSION

It is generally known that ensiling is one of the best methods to preserve fodder crops. Silage is the basic source of nutrients for ruminants, while silage produced from whole maize plants is the primary feed used in Poland. Preparation of high quality silage is a necessary condition for the optimal utilisation of nutritive value of this crop. This objective may be achieved thanks to the application of various types of additives promoting the ensilage process and preventing secondary fermentation at exposure to air by inhibiting the growth of aerobic microorganisms [Filya and Sucu 2007, Jatkauskas and Vrotniakiene 2013, McDonald et al. 1991, Selwet 2011, Szymańska et al. 2014, Váradyová et al. 2013].

Creating optimal conditions for the growth of lactic acid bacteria in silages guarantees production of good quality feed both in terms of its chemical and microbiological parameters. Based on the results of studies presented in available literature it is known that in good quality silage the content of lactic acid should range from 65 to 70% of total acids contained in silage. This means that the use of microbial ensiling additives results in a reduction of silage pH, an increase in lactic acid content and minimisation of butyric acid content [Skládanka et al. 2012]. In this study the applied microbial preparations caused an increased content of lactic acid and a reduction of pH in comparison to the control. These results are consistent with those recorded in his study by Selwet [2011], who showed an increase in the concentration of lactic acid in silage following the application of microbial ensiling additives. In this study only the silage supplemented with the chemical ensiling additive Pr S, containing propionic acid, showed a slightly lower concentration of lactic acid, although it needs to be stressed that the content of this acid was greater than in the control. These results do not confirm those presented by Selwet [2008], who showed that the concentration of lactic acid in silage prepared with an addition of organic acids was lower than in the control. In that study [Selwet 2008] it was also shown that the application of formic and propionic acids, either singly or in combination, leads to a reduction of acetic acid concentration in silage, while it causes an increase in ethanol contents. Similar results were also recorded by Kleinschmitt et al. [2005]. These results are not consistent with those obtained in this study, since irrespective of the type of applied ensiling additives the content of acetic acid was greater than in the control. Also the course of the dependence for the concentration of ethanol in silage supplemented with the chemical additive Pr S was not consistent with the results of previously cited authors. The content of ethanol in this silage was comparable to that of the control. In contrast, in silages with biological additives (I 11A44, I 11.32 and B) the concentration of ethanol was significantly higher than in the control, which is consistent with studies conducted by Kung and Ranjit [2001]. Those authors when investigating barley silage showed that the application of ensiling additives containing *Lactobacillus buchnerii* and enzymes at different combinations and concentrations causes increased ethanol contents in silage. However, an increase in the content of ethanol in silage is not desirable, since according to literature data a reduction of the level of ethanol in silage may have a highly advantageous effect on its aerobic stability, while under aerobic conditions ethanol may be oxidised to acetic acid, potentially leading to a deterioration of nutritive value of silage [Kung et al. 2004].

Most biological ensiling additives used for maize silage contain, next to typical homo- and heterofermentative bacteria, also special strains of heterofermentative bacteria, producing acetic acid exhibiting fungicidal properties (mainly *L. buchnerii*). Thus produced acetic acid ensures better aerobic stability of silage [Danner et al. 2003]. Literature sources ascribe a particular role in protection of silages against secondary aerobic fermentation also to propionic acid [Kleinschmitt et al. 2005, Selwet 2008]. This was confirmed in the results of this study, since in the material ensiled with the ensiling additive I 11A44, containing heterofermentative bacteria *L. buchnerii*, greater contents of acetic and propionic acids were found in comparison to the control. It also needs to be stated that in comparison to the silage prepared with the other tested ensiling additives, concentrations of these acids were also slightly higher. This study also showed that the additive I 11A44 containing heterofermentative bacteria *L. buchnerii* was a more effective inhibitor of aerobic decomposition of organic matter in silage prepared from plants with lower contents of dry matter (cut at a height of 20 cm) than additives containing strains of *L. plantarum, Enterococcus faecium* (I 11.32) or a stabilised mixture of lactic acid and propionic acid bacteria (B). A weaker effect of ensiling additive B in the maintenance of aerobic stability in silage may be explained by the fact that lactic acid is one of its primary components, i.e. an acid considered to be a poor preservative under aerobic conditions, in which it is rapidly degraded by yeasts, initiating the process of secondary decomposition [Kung et al. 2004, McDonald et al. 1991]. Kleinschmitt et al. [2005] also reported that the ensiling additive I 11A44, containing *L. buchnerii* at a higher dose (4 x 10^5 CFU·g^{-1} silage) than that typically commercially available, causes a greater concentration of acetic acid in silage and improves its aerobic stability. These results were also confirmed in the investigations conducted by Kung and Ranjit [2001]. Among the ensiling additives tested in this study the best aerobic stability, irrespective of maize cutting height, was found for silage with the chemical additive Pr S, containing propionic acid and ammonium propionate. These results were confirmed in studies conducted by many authors [Adesogan and Salawu 2004, Adesogan et al. 2007, Kleinschmitt et al. 2005, Selwet 2008].

One of the methods to improve feeding value of maize silage is to increase the cutting height at harvest. Thanks to an increased share of ears in the yield and increased contents of dry matter, this method makes it possible to produce better silage with a greater energy content, leading to better results of animal feeding [Caetano et al. 2011, Neylon and Kung 2003]. In the opinion of Kowalik et al. [2013], the nutritive value of maize plants is determined also by the proportions between ears and the stalk, which contains large amounts of structural carbohydrates. In contrast, ears contain up to 2-fold greater amounts of dry matter than the stalk with leaves and they are the main energy sources. Literature data indicate that cutting off lower sections of the stalks generates losses in harvested yield mass, but also facilitates improvement of its nutritive value [Neylon and Kung 2003]. This study showed that increasing cutting height to 40 cm during harvest increased the content of dry matter in the ensiled material. This was confirmed in studies by other researchers [Kowalik and Michalski 2006, Kowalik et al. 2013] and it is connected with a greater stalk diameter and a higher share of parenchyma in stalk sections left in the field as post-harvest residue [Wilhelm et al. 2011]. It was also found in this study that nutrient contents changed with an increase in cutting height. This was manifested in increased contents of starch and protein in silage at an increase in cutting height from 20 to 40 cm. In contrast, an opposite dependence was found for crude ash as well as NDF and ADF. Results of this study were confirmed by those reported by other authors [Johnson et al. 2010, Kowalik et al. 2013, Neylon and Kung 2003, Wu and Roth 2005]. Also Bernard et al. [2004], when investigating cutting height of maize stated that increasing this height from 10.2 cm to 30.5 cm leads to a reduction of ADF concentration in maize silage. Similar dependencies were also recorded in studies by Caetano et al. [2011], in which increasing cutting height of maize plants led to a decrease in contents of NDF and hemicellulose in silage. Such a dependence may be explained by the reduced share of vegetative parts and an increased share of grain in the yield of dry matter in the case of whole plants. In turn, in a study conducted by Neylon and Kung [2003] a certain trend was found for an increase in NDF contents in maize silage prepared from plants cut at a height of 45.7 cm in comparison to cutting height of 12.7 cm. This dependence was not confirmed in this study. Increasing cutting height from 20 to 40 cm in our experiments led to a reduction of contents of lactic, acetic and propionic acids as well as ethanol. These results were confirmed in a study conducted by Neylon and Kung [2003], who showed that the concentration of lactic and acetic acids did not change significantly under the influence of changes in cutting height of maize plants, but they were lower in silage prepared from plants cut at a greater height. In turn, Kowalik and Michalski [2006] reported at an increased cutting height a trend towards a lesser formation of acids in silage, resulting in a slight increase in the silage reaction. They were also of an opinion that the decision not to harvest the lower section of stalks (15–40 cm) causes lesser losses during ensiling. Such a dependence between acid contents in silage and pH was not observed in this study. Apart from reaction, the quality of silage is also shown by the contents of butyric acid and ammoniacal nitrogen, which in the analysed silages were low and were not modified by cutting height, which is confirmed by investigations conducted by Kowalik and Michalski [2006].

CONCLUDING REMARKS

The application of ensiling additives – microbial and chemical – affected positively both on the chemical composition and quality of maize silage. The application of the tested additives increased the contents of lactic acid, acetic acid and ammoniacal nitrogen in the analyzed silage and decreased its pH. Among compared additives, applying a chemical silage additive Pro-Stabil AP 80 L, containing the propionic acid, increased the protein content and starch in the analyzed silage. In addition, it favorably increased the content of acetic acid and decreased ethanol content in the silage. By increasing the maize cutting height its increased the dry matter content in the material for silage and the starch content in the silage. It also reduced the content of lactic acid and ethanol in the silage.

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OCENA WARTOŚCI POKARMOWEJ ORAZ JAKOŚCI KISZONKI Z KUKURYDZY (*ZEA MAYS* L.) W ZALEŻNOŚCI OD WYSOKOŚCI CIĘCIA ORAZ DODATKU KISZONKARSKIEGO

Synopsis. W żywieniu bydła mlecznego i opasowego podstawowe znaczenie mają pasze objętościowe wyprodukowane we własnym gospodarstwie, a jedną z bardzo dobrych i często stosowanych pasz jest kiszonka z kukurydzy. Ze względu na wysoką zawartość węglowodanów, niską białka i popiołu kukurydza jest jedną z najlepiej kiszących się roślin, dających paszę charakteryzującą się dobrymi właściwościami oraz strawnością. Celem badań było określenie wpływu dodatków kiszonkarskich na stabilność tlenową i wartość pokarmową kiszonki z kukurydzy w zależności od wysokości cięcia kukurydzy w trakcie zbioru. Badania przeprowadzono w latach 2006 i 2007 na kiszonce sporządzonej z kukurydzy odmiany PR 39A98, uprawianej na polach Stadniny Koni „Pępowo" Sp. z o.o. Doświadczenie przeprowadzono jako dwuczynnikowe w układzie losowanych bloków w trzech powtórzeniach. W doświadczeniu przyjęto jako I czynnik wysokość cięcia (CH) roślin kukurydzy: 20 cm, 30 cm, 40 cm. Jako II czynnik rozlosowano dodatek konserwujący (EA): Inokulant 11A44 (I 11A44), Inokulant 11.32 (I 11.32), Bioprofit (B), Pro–Stabil AP 80 L (Pr S) oraz obiekt kontrolny bez dodatków. Zebrany materiał roślinny pocięto na sieczkę o długości ok. 1 cm i zakiszono w mikrosilosach. Przeprowadzone badania wykazały, że zastosowane dodatki kiszonkarskie – mikrobiologiczne i chemiczny miały wpływ zarówno na skład chemiczny jak i jakość kiszonki z kukurydzy. Stosowanie biologicznych dodatków wspomagających kiszenie prowadziło do obniżenia zawartości skrobi w suchej masie kiszonki a podniosło w porównaniu z kontrolą zawartość glukozy oraz fruktozy. Zróżnicowanie wysokości cięcia kukurydzy wywarło wpływ na zawartość w kiszonce kwasu mlekowego, propionowego oraz etanolu.

Słowa kluczowe: stabilność tlenowa, skład chemiczny, wysokość cięcia, dodatki kiszonkarskie, kiszonka z kukurydzy

Accepted for print – Zaakceptowano do druku: 24.01.2018

For citation – Do cytowania:
Szymańska G., Sulewska H., Faligowska A., Ratajczak K. 2018. Evaluation of nutritive value and quality of maize (*Zea mays* L.) silage depending on cutting height and ensiling additive. Fragm. Agron. 35(1): 94–105.