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Hygienic condition of maize silage (*Zea mays* L.) depending on cutting height and ensiling additive

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Abstract: Maize silage is a high energy bulk feed, extensively used in the nutrition of dairy and meat purpose cattle due to the high yielding potential of this crop, high concentration of energy, palatability, and easy application in the total mixed ration feeding regime. A necessary precondition for the complete utilization of the nutritive value of maize is to prepare high quality silage. In North America and Europe, cattle nutrition is increasingly based on maize silage fed throughout the year, resulting in the need to store silage in silos for 14 months or even longer. Thus, it is necessary to collect a greater amount of data on the microbial composition of silage throughout its storage. In view of the above, the aim of this study was to assess the effect of cutting height (CH) and the application of ensiling additives (EAs) on the hygienic status and aerobic stability of maize silage. The experiment was run in a 2-factorial design with 3 replications. The first factor was CH of the maize plants: 20 cm, 30 cm, and 40 cm. The second degree factor was connected with the EAs: Inokulant 11A44, Inokulant 1132, Bioprofit, Pro-Stabil AP 80 L, and the control with no additives. Analyses showed that the applied EAs, both microbial and chemical, influenced both the quality and stability of maize silage. Applied EAs in the tested silage reduced the counts of mold fungi, yeasts, bacteria from the genus *Clostridium*, and coliform bacteria. The chemical preparation containing propionic acid (E–280) and ammonium propionate (E–284) was found to be the most effective at limiting microbial counts in silage.

Key words: Aerobic stability, cutting height, ensiling additive, maize silage

1. Introduction

Maize silage is a high energy bulk feed (Gül et al., 2008), extensively used in the nutrition of dairy and meat purpose cattle as well as other ruminants (İptaş and Yavuz, 2008). In many countries, the production of maize silage equals or even exceeds that of grass silage (Wilkinson and Toivonen, 2003). This is also observed in Poland; the area cropped with maize for silage from whole plants in the period from 1995 to 2011 increased by 320% (CSO, 2012).

Silage from whole maize plants is a popular source of fodder due to the high yielding potential of that crop, high concentration of energy, palatability, and easy application in the total mixed ration feeding regime (Neylon and Kung, 2003; Cherney et al., 2004). The basic method of preservation for plants with high water content is ensiling, which protects the material against losses of valuable nutrients (McDonald et al., 1991). A necessary precondition for the complete utilization of the nutritive value of maize is to prepare high quality silage. This may be provided by the application of an appropriate ensiling technology, including an appropriate harvest date, degree of material comminution, and compaction, as well as the type and chemical composition of the applied additives stimulating lactic acid fermentation (Suterska et al., 2009).

Ensiling of bulk feeds may be improved by the use of lactic acid bacteria (LAB) cultures, containing selected strains from the genus *Lactobacillus*, which improve the quality and aerobic stability of silage and inhibit the development of such aerobic microorganisms as bacteria, yeasts, or molds (Luchesse and Haerigan, 1990; Mäki, 1996; Filya and Sucu, 2007). Lactic acid produced by bacteria in the ensiling process lowers pH to a level that inhibits protein degradation processes as a result of the action of aerobic microorganisms and plant tissue enzymes (McDonald et al., 1991; Rowghani and Zamiri, 2009). Numerous literature sources (Cleale et al., 1990; Kung and Ranjit, 2001; Raczkowska-Werwinska et al., 2008; Selwet et al., 2008; Rowghani and Zamiri, 2009; Dulceta, 2010; Selwet, 2011; Váradyová et al., 2013) indicate that the application of ensiling additives (EAs) prevents losses during ensiling and storage, improves palatability of silage, increases its consumption by animals, and improves digestibility. The commercially available range of preparations aiding feed ensiling is relatively extensive, although new preparations

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are sought to improve not only the quality of ensiled fodders but also to reduce their contents of molds and mycotoxins (Suterska et al., 2009). In North America and Europe, cattle nutrition is increasingly based on maize silage fed throughout the year; thus, it is necessary to store silage in silos for 14 months or even longer. In view of the above, more information on the microbial composition of silage during its storage needs to be collected (Storm et al., 2010).

The quality and nutritive values of maize silage are determined, first of all, by the maturity phase of plants during harvest and related content of dry matter (Johnson et al., 1999). The optimal harvest date of maize for silage according to many literature sources (Daccord et al., 1996; Barrière et al., 1997; Darby and Lauer, 2002; Filya, 2004; Caetano et al., 2011) comes at the dough stage, with dry matter content in whole plants amounting to 30%–35%. Harvest of plants at this stage ensures a compromise between yield volume on the one hand and quality and digestibility of produced fodder on the other. One of the methods to improve the quality of green forage is to raise the cutting height (CH) of maize. Literature data (Neylon and Kung, 2003; Kennington at al., 2005) indicate that, thanks to this measure, the least valuable, lower parts of plants are left in the field as harvest residue. This improves the quality of the raw material due to the increase in the share of ears and dry matter content, reflected in a higher energy value of silage. However, it needs to be remembered that an elevated CH reduces the yield of green matter (Wu and Roth, 2005). The aim of this experiment was to assess the effect of CH and application of EAs on the hygienic status and aerobic stability of maize silage.

2. Materials and methods

Analyses were conducted in 2007 and 2008 on silage produced from maize cultivar PR 39A98 (FAO 240), grown in the fields of the Stud Farm of Pępowo Sp. z o.o. The experiment was run in a 2-factorial design with 3 replications in the split-plot system. The first factor in this experiment was the CH of the maize plants: 20 cm, 30 cm, and 40 cm. The second order factor was the EA: 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.

According to the label supplied by the manufacturer, Inokulant 11A44 contains a specific bacterium, *Lactobacillus buchneri* LN 3957. The guaranteed content of live bacteria is 1.0×10^{11} cfu g^{-1} inoculant. The product contains a dechlorinator, protecting bacterial strains against chlorine contained in water. Inokulant 1132 contains 7 bacterial strains: *Lactobacillus plantarum* DSM 286, *Lactobacillus plantarum* DSM 287, *Lactobacillus plantarum* DSM 329, *Lactobacillus plantarum* DSM 346, *Lactobacillus plantarum* DSM 347, *Enterococcus faecium* DSM 301, and *Enterococcus faecium* DSM 202. The guaranteed content of live bacteria is 1.25×10^{11} cfu g^{-1} inoculant. The microbiological preparation Bioprofit is a preservative containing a stabilized mixture of LAB and propionic acid bacteria. The ensiling additive Pro-Stabil AP 80 L contains propionic acid (E-280) and ammonium propionate (E-284).

In the course of the field trial, all cultivation measures were performed following the good farming practices for this species and type of end use. Plants were harvested at the milk stage of maize (BBCH 75). For this purpose, a John Deere 6650 mobile maize silage cutter was used. Harvested plant material was cut into chaffs of approximately 1 cm in length and ensiled in polyethylene microsilos of 15 cm in diameter and 50 cm in height. Microsilos were sealed with rubber stops equipped with glass safety funnel tubes, facilitating the evacuation of gas products during fermentation. After 6 months, microsilos were opened and the microbial composition of silage was determined.

Silage extracts were prepared by adding 90 cm^3 of sodium chloride physiological solution to 10 g of silage sample and homogenizing it for 10 min in a laboratory blender. Microbial counts were determined using a decimal dilution series of silage extracts. Yeasts and mold were counted on OGYE oxytetracycline-glucose-yeast-extract agar (Oxoid) after incubation for 120 h at 25 °C; LAB on MRS Agar (Oxoid) after incubation for 24 h at 37 °C; *Clostridium* on TSC Agar (Merck) after incubation for 24 h at 37 °C; and *Enterobacteriaceae* on Chromocult Agar (Merck) after incubation for 24 h at 37 °C. Forage samples (120 g) were used for the aerobic stability test. Samples were thoroughly shaken to ensure air exposure and then packed loosely in 500 mL plastic containers. Samples were covered with double-layered cheesecloth to prevent drying and contaminations, and were incubated for 7 days at 10–15 ± 2 °C. To permit air exchange, 4 small holes were made on the top and bottom of each container. An additional container filled with water was used to measure ambient temperature of 9 °C.

Results collected in the 2 years of the experiment were presented as means from years. The effect of CH and the application of EAs on the evaluated traits was subjected to a 2-way analysis of variance using SAS software (SAS Institute, 1999). The least significant difference (LSD) was verified with Tukey's test at $P = 0.05$ and $P = 0.01$.

3. Results

Results concerning the microbial composition of maize silages depending on CH and EA in 2007 and 2008 are presented in Table 1. When analyzing the method of maize preservation (4 variants), the highest mean count of mold fungi was determined in the control. Applied

Table 1. Microbiological analyses of maize silage depending on cutting height and ensiling additive.

CH (A)	EA (B)	M 10^3 CFU g^{-1}	Y 10^5 CFU g^{-1}	C 10^2 CFU g^{-1}	E 10^3 CFU g^{-1}	LAB 10^7 CFU g^{-1}
	Control	13.4 a	24.3 b	2.3 a	5.4 a	9.3
	I 11.32	8.2 e	12.2 f	1.1 de	3.6 de	11.7
20 cm	I 11A44	9.2 d	14.1 de	1.1 de	3.9 cd	14.4
	Pr S	2.8 g	7.9 g	0.5 gh	2.0 h	7.4
	B	7.0 f	15.0 cd	1.2 cd	3.5 d–f	14.3
Mean		8.1 a	14.7 b	1.2 a	3.7 a	11.4
	Control	12.0 b	26.0 a	1.9 b	4.5 b	9.0
	I 11.32	8.3 de	13.6 e	1.0 de	3.3 e–g	12.1
30 cm	I 11A44	7.5 ef	13.2 ef	1.2 cd	3.6 de	14.5
	Pr S	2.8 g	7.7 gh	0.3 h	2.0 h	7.2
	B	7.4 ef	16.0 c	0.8 ef	3.8 de	15.1
Mean		7.6 b	15.3 a	1.0 b	3.5 b	11.6
	Control	10.9 c	25.1 ab	1.4 c	4.3 bc	8.3
	I 11.32	9.2 d	14.2 de	1.0 de	3.1 fg	12.3
40 cm	I 11A44	8.0 e	15.2 cd	1.2 cd	3.6 de	14.5
	Pr S	2.0 g	6.6 h	0.4 gh	2.0 h	6.5
	B	6.9 f	16.1 c	0.6 fg	2.9 g	15.3
Mean		7.4 b	15.4 a	0.9 b	3.2 c	11.4
LSD (A)		0.48*	0.34**	0.13**	0.14**	n.s.
	Control	12.1 a	25.1 a	1.9 a	4.7 a	8.9 c
	I 11.32	8.6 b	13.3 d	1.0 c	3.3 c	12.0 b
Mean (B)	I 11A44	8.2 b	14.2 c	1.2 b	3.7 b	14.5 a
	Pr S	2.6 d	7.4 e	0.4 d	2.0 d	7.0 d
	B	7.1 c	15.7 b	0.9 c	3.4 c	14.9 a
LSD (B)		0.56**	0.66**	0.15**	0.25**	0.59**
LSD (A × B)		0.98**	1.15**	0.27**	0.43**	n.s.

LSD (A) is the least significant difference between cutting heights; LSD (B) is the least significant difference between additives to ensilaging.
*. **: statistical significance at the 5% and 1% levels of probability, respectively.
n.s.: not significant.
a, b, c, etc.: values followed by the same letter are not significantly different at the 0.05 or 0.01 level according to Tukey's test.

bacterial inoculants and chemical preservatives caused a reduction of population size in these fungi. The lowest counts of mold fungi were determined in samples treated with the chemical preparation Pro-Stabil AP 80 L, which most effectively inhibited the development of these fungi. With respect to the CH of the maize, the highest number of mold fungi was determined to be in silage from maize cut at 20 cm.

The highest mean count of yeast cells was recorded in the control. Applied bacterial and chemical inoculants significantly inhibited the development of these fungi at all CHs of maize plants. A range of effects were observed in the preservatives, among which the chemical preparation Pro-Stabil AP 80 L proved to be the most effective at inhibiting yeast development. The weakest inhibitory effect among all the applied additives was found with Bioprofit. As opposed to the effects observed in mold fungi, silage from maize cut at 20 cm contained the lowest count of yeasts. The highest count of *Clostridium* spp. was recorded in the control. All the applied EAs caused a significant reduction of counts in these bacteria and the preservative Pro-Stabil AP 80 L proved to be the most effective. Conducted analyses also confirmed a significant effect of maize CH on the count of *Clostridium* spp. The highest number of cells of these

bacteria was recorded in silage prepared from maize cut at a height of 20 cm. An increase in the CH of plants resulted in a reduction in the counts of *Clostridium* spp. in silage, although a difference between the cutting heights of 30 and 40 cm was not confirmed statistically.

The highest count of bacteria was also recorded in the silage from the control treatment. Application of EAs significantly reduced the count of these bacteria. Among all the used additives, Pro-Stabil AP 80 L had the strongest inhibitory effect on the development of *Enterobacteriaceae* and this effect was confirmed statistically. CH of maize also had a significant effect on counts of these bacteria and their number decreased significantly with the increase in cutting height.

Biological additives and the Bioprofit preservative caused a significant increase in the counts of LAB in silages compared to the control. Samples treated with the Pro-Stabil AP 80 L preservative contained significantly lower numbers of these bacteria in relation to the other combinations. In contrast, no statistically significant effect of cutting height in maize was found on the population size of LAB.

Table 2 presents results concerning the microbial composition of silages produced from maize subjected to the aerobic stability test. As a result of aeration, a significant increase was found in the counts of mold fungi in all combinations. The greatest number was recorded in the control silage. Samples ensiled with additives contained lower numbers of molds. The lowest count of these fungi was determined to be in silage with the chemical preservatives. CH of the maize had no statistically significant effect on changes in aerobic stability of silages.

The aeration process caused an increase in the counts of yeasts in all combinations. The greatest number of yeast cells was recorded in the control material. The applied preparations limited the development of these fungi. The strongest inhibitory effect, which was confirmed statistically, was observed with Pro-Stabil AP 80 L. In turn, the weakest action among all the tested EAs was observed with Bioprofit. Moreover, a significant effect of maize CH was found on the stability of silages. In terms of the count of yeast cells, the lowest CH (20 cm) proved to be the most advantageous. An increase in CH of maize by each 10 cm led to an increase in the counts of yeasts in silage, although the differences between 30 cm and 40 cm were not confirmed statistically.

Aeration of silages was caused by a reduction in the number of cells of *Clostridium* spp. The highest count of these bacteria was found in the control silage; the used additive caused a reduction in the counts of these bacteria. The strongest inhibitory effect, confirmed statistically, was observed with Pro-Stabil AP 80 L. In contrast, CH exhibited no effect on the changes in aerobic stability of silages, as measured based on the population size of these microorganisms.

Oxygen access caused a reduction of counts in bacteria from the family *Enterobacteriaceae*. The greatest count of *Enterobacteriaceae* was recorded in the control samples. The addition of ensiling preparations caused an inhibition of development in coliform bacteria. Growth of these bacteria was reduced the most significantly by Pro-Stabil AP 80 L. CH of the maize also had a significant effect on counts of *Enterobacteriaceae* in the analyzed samples. Silage produced from plants cut at a height of 40 cm had the lowest count of these microorganisms.

The population size of LAB decreased in the silage stability test. Such a reaction was observed in all the ensiling combinations. The greatest count of these bacteria was recorded in samples with an addition of Inokulant 11A44 and the preservative Bioprofit. Among all the tested additives, LAB development was reduced the most by the preservative Pro-Stabil AP 80 L. In contrast, analyses showed no effect of CH on changes in aerobic stability of silages (expressed in terms of LAB count).

4. Discussion

Silage produced from whole cereal plants such as wheat, sorghum, and maize is highly susceptible to spoilage under aerobic conditions, particularly in a warm climate. This is because aerobic yeasts are most active within a temperature range of 20–30 °C (Filya et al., 2004). McDonald et al. (1991) also reported that a lower count of yeasts and molds in the ensiled material results in a situation where the risk of silage spoilage during aerobic exposure is lower. Studies conducted by Storm et al. (2010) also indicated that storage of silage over an extended period of time is connected with considerable changes in bacterial flora. For this reason it is very important to find additives capable of inhibiting the development of fungi and protecting silage against spoilage at oxygen access (Filya et al., 2004).

Based on the results of studies presented in the literature, it is also known that ensiling whole maize plants with an addition of preparations promoting ensiling contributes to improved quality and aerobic stability of silage and inhibits development of aerobic microorganisms (McDonald et al., 1991; Filya and Sucu, 2007; Rowghani and Zamiri, 2009; Selwet 2011). As reported by Higginbotham et al. (1998) and Rowghani and Zamiri (2009), traditional EAs containing only formic acid or sulfuric acid are effective preservative preparations, but due to their corrosive effects on metal parts in machines for silage handling, their applicability is limited. Biological additives for fodder preservation are more advantageous, because they are safe and easy to use, are not corrosive to machines, and do not pollute the environment, since their action is based only on the modification of natural

Table 2. Microbiological analyses of maize silage after exposure to air depending on cutting height and ensiling additive.

CH (A)	EA (B)	M 10^3 CFU g^{-1}	Y 10^5 CFU g^{-1}	C 10^2 CFU g^{-1}	E 10^3 CFU g^{-1}	LAB 10^7 CFU g^{-1}
	Control	21.4 a	39.7 b	1.1 a	3.7 a	6.5 de
	I 11.32	13.4 cd	19.0 g	0.4 c–e	2.4 d–f	8.4 c
20 cm	I 11A44	15.0 b	21.3 ef	0.6 bc	2.6 cd	11.2 a
	Pr S	4.7 e	11.4 h	0.2 ef	1.6 h	5.6 fg
	B	12.3 d	22.0 de	0.7 b	2.5 c–e	11.6 a
Mean		13.4	22.7 b	0.6	2.5 a	8.7
	Control	20.7 a	41.4 a	0.7 b	3.3 b	7.0 d
	I 11.32	14.1 b	20.4 fg	0.5 b–d	2.0 g	9.2 c
30 cm	I 11A44	13.9 bc	20.9 ef	0.7 b	2.2 e–g	11.2 a
	Pr S	4.1 e	12.8 h	0.1 f	1.4 h	5.0 gh
	B	13.3 cd	24.1 c	0.4 c–e	2.7 cd	11.7 a
Mean		13.2	23.9 a	0.5	2.3 b	8.8
	Control	20.2 a	42.3 a	0.7 b	2.8 c	6.1 ef
	I 11.32	14.9 b	21.2 ef	0.6 bc	2.1 fg	10.3 b
40 cm	I 11A44	13.8 bc	22.9 cd	0.7 b	2.3 d–f	11.4 a
	Pr S	3.6 e	11.3 h	0.2 ef	1.4 h	4.3 h
	B	12.9 cd	24.1 c	0.3 d–f	2.0 g	11.4 a
Mean		13.1	24.4 a	0.5	2.1 c	8.7
LSD (A)		n.s.	0.60**	n.s.	0.12**	n.s.
	Control	20.8 a	41.1 a	0.8 a	3.3 a	6.6 c
	I 11.32	14.1 b	20.2 d	0.5 b	2.1 c	9.3 b
Mean (B)	I 11A44	14.2 b	21.7 c	0.7 a	2.4 b	11.3 a
	Pr S	4.1 d	11.8 e	0.2 c	1.5 d	4.9 d
	B	12.8 c	23.4 b	0.5 b	2.4 b	11.6 a
LSD (B)		0.74**	0.89**	0.11**	0.18**	0.49**
LSD (A*B)		1.28*	1.54*	0.20**	0.31**	0.85**

LSD (A) is the least significant difference between cutting heights; LSD (B) is the least significant difference between additives to ensilaging.
*. **: statistical significance at the 5% and 1% levels of probability, respectively.
n.s.: not significant.
a, b, c, etc.: values followed by the same letter are not significantly different at the 0.05 or 0.01 level according to Tukey's test.

fermentation processes (Váradyová et al., 2013). Most bacterial inoculants are added to silage in order to stimulate lactic acid fermentation, which causes a rapid decrease in pH and improves the ensiling process. Most of them contain selected strains of LAB (Filya et al., 2004). According to Váradyová et al. (2013), lactic acid content in good silage should represent at least 65% to 70% of the total silage acids.

In this study, the addition of bacterial preparations caused an increase in the counts of LAB, while the chemical preservative Pro-Stabil AP 80 L limited the population size of these bacteria. Selwet (2004a), when testing chemical additives containing formic acid, observed a limited count of LAB under the influence of their application. Another study by Selwet et al. (2008) is consistent with observations recorded by the authors of this study, since all of them indicate that the addition of both chemical preparations and bacterial and enzymatic preparations to silage caused an increase in the counts of LAB. Raczkowska-Werwinska et al. (2008) reported that counts of LAB were comparable both in the group of silages treated with a bacterial and enzymatic preparation and in those treated with a chemical preparation.

Improved aerobic stability of maize silages after the use of organic acids and their salts was reported by many researchers in their studies (Kung et al., 1998; Adesogan

and Salawu, 2004; Filya and Sucu, 2007). A particular importance in the protection of silages against secondary aerobic fermentation is ascribed to propionic acid (Higginbotham et al., 1998). This was confirmed by the results of these studies, in which the occurrence of mold fungi, yeasts, *Clostridium* spp., and *Enterobacteriaceae* was limited most effectively by Pro-Stabil AP 80 L, containing propionic acid. Information on the effect of chemical preservatives on the reduction of *Clostridium* counts may also be found in a study by Selwet (2004b). In turn, investigations conducted by McDonald et al. (1991) indicate that acetic and propionic acids exhibit fungicidal properties. Filya et al. (2004) and Filya and Sucu (2007) showed that high concentrations of acetic and propionic acids reduce the growth of yeasts and mold fungi in maize silage. When investigating maize silage produced with an addition of KemiSile 2000 (containing 55% formic acid, 9% propionic acid, 24% ammonium formate, and 7% propionic ester), Raczkowska-Werwinska et al. (2008) found that this chemical additive limited the population increase of yeasts and mold fungi in samples exposed to air. Selwet et al. (2008) reported that the application of KemiSile 2000 inhibits the development of mold fungi during exposure to oxygen, while it does not exhibit an inhibitory action on the development of yeasts. Moreover, in another study, Selwet (2005) showed that the strongest effect on the reduction of fungal counts was exercised by chemical additives containing organic acids. Literature sources on the subject contain information that an addition of chemical preparations containing organic acids may cause a more intensive growth of fungi or an enhanced production of mycotoxins as a reaction of molds to environmental stress (Deibel et al., 1957). This was particularly evident in the preservation of wet grain at access to oxygen and the application of the suboptimal dose of formic acid (Selwet, 2004a, 2005). In other studies by Selwet et al. (2008), those authors reported that the efficacy of chemical preparations, as well as bacterial and enzymatic, may depend on such factors as maize cultivars, the course of vegetation, or plant harvest date.

Providing optimal conditions for the development of LAB in silages guarantees the production of good quality fodder. This pertains to both the chemical and microbial composition of silage. An important aspect in fodder preservation is thus using microbial preparations that stimulate the development of microorganisms and are capable of improving the aerobic stability of silages exposed to oxygen. Filya and Sucu (2007), when testing heterofermentative LAB inoculant 11A44 containing *L. buchneri* and a PAB inoculant containing *P. acidipropionici*, stated that they were capable of ensuring aerobic stability in maize silage. In turn, Kung and Ranjit (2001) showed that the application of heterofermentative LAB inoculant 11A44 containing *L. buchneri* caused a limitation of yeast occurrence in barley silage. Muck et al. (2007) explained the action of the heterofermentative LAB inoculant containing *L. buchneri* by the fact that it causes an increase in the concentration of acetic acid in silage, which has an inhibitory effect on the development of fungi and thus prevents spoilage of silage upon exposure to oxygen.

These results were confirmed in this study, in which the addition of the heterofermentative LAB inoculant 11A44 to the ensiled material led to a limitation of occurrence of mold fungi, yeasts, and bacteria from the genus *Clostridium* as well as counts of *Enterobacteriaceae*. The application of inoculant 11A44 provided the prepared maize silage with aerobic stability. An exception in this respect was found only for bacteria from the genus *Clostridium*, whose count in silage exposed to oxygen was similar to that in the control. Moreover, it was found in this study that the compared biological preparations, both in silage immediately after silo opening and in that exposed to oxygen, showed a weaker effect in inhibiting the growth of yeasts, mold fungi, and bacteria from *Clostridium* and *Enterobacteriaceae* than the chemical preparation. However, they limited the counts of these microorganisms in comparison to the control. Such observations were also confirmed by Raczkowska-Werwinska et al. (2008). In turn, Selwet (2011), when testing bacterial additives containing, among other things, bacteria *L. plantarum* PCM 493 and *L. buchneri* DSMZ 5987, showed that they improved the course of fermentation and reduced the share of components of cell walls, but did not affect aerobic stability of silages during 7 days of aeration. Kleinschmit et al. (2005) recorded a marked reduction of fungal cells in silage after the application of a biological EA containing *L. buchneri*. However, they stated that, during silage, exposure to oxygen increased the number of fungal cells, which they explained by a lower content of acetic acid having an inhibitory effect on growth and development of fungi.

In the experiments conducted within this study, silage from the control treatments exposed to oxygen was characterized by lower counts of bacteria from the genus *Clostridium* and of coliform bacteria than in samples evaluated immediately after the opening of silos. Similar results for the silage from the control treatment were recorded by Raczkowska-Werwinska et al. (2008), who explained it by the fact that access to oxygen may inhibit or even prevent the growth of these bacteria. Those authors also showed that in silage from the control treatment during exposure to oxygen, the counts of yeasts and mold fungi increased. The increase in the counts of fungi in that period may contribute to considerable loss of nutrients in silages.

Caetano et al. (2011) reported that raising the CH improves silage quality due to a reduced share of stems

in the ensiled material and a reduced share of cell wall components. Elimination of lower sections of stalks from the harvested material and their reduced proportion in the harvested yield is recommended particularly when harvesting maize with a low content of dry matter and a low share of ears, with the aim of improving fodder quality and reducing ensiling losses (Kowalik, 2009). Results of studies conducted by Kennington et al. (2005) indicate that an elevation of CH in maize does not always result in an improvement of silage quality and digestibility; to a considerable degree, they are determined by properties of individual cultivars. This was confirmed in this study, in which no differences were shown in the counts of LAB depending on the CH of the maize plants. It was only stated that a CH above 20 cm resulted in a reduction of counts of mold fungi and bacteria from the genus *Clostridium*, at the same time causing an increase in the numbers of yeasts. When evaluating the investigated groups of microorganisms conducted after exposure to oxygen, a marked increase was observed in the population size of yeasts in silage irrespective of the CH of plants.

The application of EAs, both microbial and chemical, influenced both the quality of maize silage and its stability. In the tested silage they decreased counts of mold fungi, yeasts, bacteria from the genus *Clostridium*, and coliform bacteria. Among the compared additives, the chemical preparation containing propionic acid (E-280) and ammonium propionate (E-284) proved to be the most effective in limiting microbial counts in silage. Furthermore, in silage exposed to oxygen, this chemical additive most strongly limited the counts of analyzed microbial groups. An increase in the CH of maize plants reduced the occurrence of fungi and bacteria from the genus *Clostridium* and coliform bacteria.

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