Original Paper

Nutritive value and fermentation characteristics of maize silages from different hybrids

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The aim of this study was to determine the effect of early hybrids of maize (*Zea mays* L.) with different FAO number (220, 230, 260 and 280) harvested in milk-wax maturity stage on nutritive value and parameters of fermentation process of whole plant maize silages. In laboratory conditions we conserved maize hybrids without additives in laboratory silos with capacity 4 dm^3. After 1 month of fermentation process, the nutrient content (dry matter, crude protein, fat, nitrogen free extract, starch and organic matter) and parameters of fermentation (lactic acid, acetic acid, butyric acid, alcohols, active acidity and acidity of water extract) were analyzed in the average samples. Dry matter content of maize silages ranged from 262.7 to 310.5 g kg^{-1}. The highest significant content of dry matter (P <0.05) was found in silages with FAO number 230. Compared to the silages FAO 260, we found significantly higher content (P <0.05) of fat in silages FAO 230. The analyzed silages had the highest content of organic matter (P <0.05) and starch. The content of lactic acid in maize silages was higher than 10 g per 1 kg of original matter in all silages. The highest content of lactic acid was found in maize silage FAO 220. The content of acetic acid in all maize silages did not exceed 20.0 g kg^{-1} of DM and the highest content was detected in silages FAO 260 and FAO 280. In the maize silages FAO 260 we determined the lowest content of alcohols and the lowest value of pH.

Keywords: silage, maize, hybrids, nutrients, fermentation

1. Introduction

Quality of maize silages affects the animals‘ performance and quality of animal products. Maize silage is a major forage source for ruminants in climates where maize is moderately to well adapted. It is high energy, low protein forage commonly used for growing and finishing beef cattle, as a supplemental energy for cow and calf production (Allen et al., 2003). Maize silage is a stabilizing component of rumen fermentation in terms of content and structure of saccharides in feed rations. High-quality maize silage is a good source of structural as well as non-structural saccharides as an efficient source of ruminal proteosynthesis (Juráček et al., 2012). The selection of appropriate hybrids is critical for the production of quality maize silages (Johnson et al., 2002; Bíro et al., 2007; Araújo et al., 2012). Maturity is a term that refers to whether a hybrid is adapted to a particular environment. Several systems have been developed to aid breeders and producers to place genotypes into the correct adaptation zones. In North America, the Minnesota Relative Maturity (RM) system, Growing Degree Days (GDDs), and Ontario Corn Heat Units (OCHUs) are commonly used, while in Europe the Food Agriculture Organization developed the FAO system (Bennetzen and Hake, 2009). In past years, breeders concentrated mainly on increasing the grain yield, but currently they concentrate on increase digestibility of several plant parts (Allen et al., 2003). The purpose of breeding new maize hybrids is mainly increasing the neutral-detergent fiber digestibility. Silage hybrid affects maturity at harvest, digestibility of nutrients, nutritive value, composition of epiphytic microflora, dry matter yield, energy and nutrients yield, production efficiency per 1 kg of silage and the overall efficiency of livestock production (Bal et al., 2000; Weiss and Wyatt, 2002; Donkin et al., 2003).

The aim of the study was to determine the effect of early hybrids with different FAO number harvested in milk-wax maturity stage on nutritive value and parameters of fermentation process of whole plant maize silages.

2. Material and methods

In this study we ensiled maize (*Zea mays* L.) of four early hybrids with different FAO number (FAO 220, FAO 230, FAO 260, FAO 280). Maize hybrids were grown in the same agroecological conditions at the farm ZAD Dvory nad Žitavou (Sout-Western Slovakia) and harvested in the same phenological stage: milk-wax maturity of grain. The farm ZAD

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Dvory nad Žitavou is situated in the Nitra Region, south-west Slovakia, 110–125 m above the sea level. The whole plants of maize were cut to pieces of average length of 20 mm and ensiled without silage additive. Silage material was packed into laboratory silos with capacity of 4 dm^3, sealed and stored at 20 ±2 °C in three repetitions (n = 3). After 1 month of the fermentation process, the laboratory silos were opened and the content of nutrients and parameters of fermentation were detected in the average samples according to the Regulation no. 2145/2004-100. The dry mater content was determined by the gravimetric method, crude protein by the Kjeldahl's method, fat by extraction and starch by polarimetric method.

The content of nitrogen free extract (*NFE*) and organic matter (*OM*) was calculated (*NFE = dry matter - crude protein - crude fiber - fat - ash*; *OM = dry matter - ash*). The content of fermentative organic acids (lactic acid, acetic acid, butyric acid) was determined by analyzer EA 100 (Villa Labeco, SR) using the method of ionic electrophoresis. The content of alcohols was detected by Conway microdiffusion method, the content of water extract acidity (*AWE*) by alkalimetric titration to pH 8.5 and active acidity (pH) by the electrometric method. The results were statistically processed using one factorial variance analysis (ANOVA) of SAS. Means were separated by using the Fischer LSD multiple range test.

3. Results and discussion

After 1 month of fermentation, we detected the content of dry matter (*DM*) in maize silages varied from 262.7 to 310.5 g.kg^{-1} (Table 1). Significantly the highest content of dry matter (P <0.05) was in silages with FAO number 230. The optimal content of dry matter for maize silage is 280–330 g kg^{-1} (Doležal et al., 2012), or 310–350 g kg^{-1} (Rajčáková and Mlynár, 2009). Only maize silage FAO 230 marked higher content of dry matter than 280 g kg^{-1}. In the crude protein content, which is typically deficient in maize silage (Millner et al., 2005), we detected significant differences (P <0.05) between silages FAO 230 and 280. Compared to the silages FAO 260, we found significantly higher content (P <0.05) of fat in silages FAO 230. In the content of nitrogen free extract, significant differences were not detected. The content of starch, which is an important source of energy, ranged from 233.9 to 289.8 g kg^{-1} DM. Mitrík (2010) recommends the minimum content of starch for maize silages of 1st class quality to reach 275 g kg^{-1} DM. We found the content of starch higher than 275 g kg^{-1} DM only in maize silages FAO 230 and 280. Significantly the highest content of organic matter (P <0.05) was found in maize silages FAO 230. The content of organic matter varied from 955.0 (FAO 280) to 961.0 g kg^{-1} DM (FAO 230). The lower content of organic matter in maize silages (905.5–935.1 g kg^{-1} DM) was reported by Forouzmand et al. (2005).

The content of lactic acid in maize silages was higher than 10 g per 1 kg of original matter in all silages. We determined the significantly (P <0.05) highest content of lactic acid in maize silages FAO 220 (Table 2). In the content of lactic acid we detected higher values compared to Bíro et al. (2008). The content of acetic acid under 20 g kg^{-1} of DM is one of basic parameters for classification of silage in 1st qualitative class (Škultéty, 1999). The content of acetic acid in all maize silages did not exceed 20.0 g kg^{-1} of DM. The highest content of acetic acid was detected in silages FAO 260 and FAO 280. The ideal ratio of lactic acid to acetic acid should not be less than 3 : 1 (Jalč, et al., 2010). We found ratio of lactic acid to acetic acid reaching from 4.4 : 1 (FAO

Table 1 Nutritive values of maize silages

Maize silages		Dry matter	Crude protein	Fat	NFE	Starch	Organic matter
		g kg^{-1}	g kg^{-1} of dry matter				
FAO 220	$\bar{x}$	274.7a	87.8	29.0	636.8	233.9a	955.7ab
	S.D.	2.62	2.26	0.82	7.00	3.61	0.21
	CV%	1.0	2.6	2.8	1.1	1.5	0.02
FAO 230	$\bar{x}$	310.5abc	84.1a	30.1a	659.9	292.4	961.0acd
	S.D.	1.77	0.78	0.49	12.94	16.19	0.35
	CV%	0.6	0.9	1.7	2.0	5.5	0.04
FAO 260	$\bar{x}$	269.1b	89.7	27.9a	641.4	263.1	957.1bce
	S.D.	4.88	6.01	0.79	6.01	8.13	0.35
	CV%	1.8	6.7	2.8	0.9	3.1	0.04
FAO 280	$\bar{x}$	262.7c	79.2a	31.7	648.5	289.8a	955.0de
	S.D.	5.23	0.64	1.70	3.25	0.85	0.42
	CV%	2.0	0.8	5.4	0.5	0.3	0.04

NFE – nitrogen free extract, the values with identical superscripts in a column are significantly different at P <0.05

Table 2 Results of fermentation process of maize silages

Maize silages		Lactic acid	Acetic acid	Alcohols	pH	AWE
		g kg^{-1} of dry matter				
FAO 220	$\overline{x}$	68.4ab	8.5a	8.8abc	3.82a	1172.5
	S.D.	3.87	0.44	0.20	0.01	55.86
	CV%	5.7	5.2	2.3	0.4	4.8
FAO 230	$\overline{x}$	51.4a	7.8bc	2.2ad	3.93	1027.0
	S.D.	2.78	0.75	0.22	0.05	59.40
	CV%	5.4	9.6	10.0	1.3	5.8
FAO 260	$\overline{x}$	68.2	11.6ab	1.9be	3.79	1227.5
	S.D.	6.75	0.45	0.01	0.05	81.32
	CV%	9.9	3.9	0.6	1.3	6.6
FAO 280	$\overline{x}$	51.1b	11.6c	7.7cde	3.98a	1128.0
	S.D.	2.23	1.15	0.23	0.01	43.84
	CV%	4.4	9.9	3.1	0.3	3.9

AWE: water extract acidity – mg KOH per 100 g of silage, the values with identical superscripts in a column are significantly different at $P < 0.05$

280) to 8.1 : 1 (FAO 220). The highest significant content of alcohols (P <0.05) was found in maize silages FAO 220. In silages FAO 280 with the lowest content of dry matter we found the lowest content of lactic acid and the highest acetic acid content, what negatively affected the value of pH. The values of pH from 3.7 to 4.3 are target levels for maize silage in 1st qualitative class according to Škultéty (1999), and 3.7–4.2 according to Adesogan (2006). In our experiment, the values of pH ranged from 3.79 to 3.98, what correspond with the results of Cherney et al.(2004).

4. Conclusions

The nutrient content and quality of the fermentation process are important factors that determine the quality of maize silages. Based on the evaluated silages made from early maize hybrids with different numbers FAO (220, 230, 260, 280) we found that the highest content of starch, nitrogen free extract and organic matter was marked in silages with the highest dry matter content (FAO 230). Maize silages of all hybrids reached higher content of lactic acid than 10 g per 1 kg of original matter and the content of acetic acid did not exceed 20.0 g kg^{-1} of dry matter. We found the lowest acetic acid content and second lowest content of alcohols in maize silages FAO 230.

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