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Original Paper

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The effect of growing locality on the nutritive value of maize silage hybrids with various FAO number

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The effect of locality on nutritive value of maize silage with various FAO number was evaluated. There were 8 maize silage hybrids (FAO 220, FAO 230, FAO 260, FAO 280, FAO 390, FAO 450, FAO 550) grown in two similar localities. All 16 groups were cut at milk-wax stage for whole plant silage and ensiled for 1 month in 4 dm^3 glasses. Silages were sampled and analyzed for crude protein, NDF, ADL, Starch and IVDMD. There were found significant differences (P <0.05) between localities within the type of hybrid in crude protein content of FAO 280, FAO 360, FAO 450, in ADL content of FAO 230, in NEL content of FAO 280, in DINAG of FAO 230 and FAO 280. When compared all groups, IVDMD of the silage from FAO 450 grown in locality 2 has been found significantly higher (P <0.01) than all silages of locality 1, except FAO 550. Calculated content of NEL 7.24 MJ kg^{-1} and value of DINAG 46.8 for FAO 450 were the highest in the experiment.

Keywords: forage, maize silage, digestibility, earliness, net energy of lactation

1. Introduction

During the years 2007–2011 the area sown on maize (*Zea mays* L.) for silage production was between 27–33 % of whole arable land in Slovakia (Slovstat, 2012). As the result, maize silage prevails as the source of energy from forage in dairy feed rations in Slovakia. Diversity of agro environmental conditions determines home producers to use wide sortiment of maize silage hybrids. There are several opportunities in forage management largely influencing resulting silage quality. FAO (Food and Agricultural Organization of the United Nations) maturity ranking represents number indicating the length of vegetation period needed to reach harvest maturity. The selection of hybrids with various FAO number can enable producers to plan the harvest more effectively (Marton et al., 2007). The growth and biosynthesis of maize is regulated through auxins. Therefore, the expression of plant genotype depends on external factors. The fit of microclimatic conditions, soil fertility and crop management with maize silage hybrid can produce highly digestible dry matter not only for its starch content, but also for its degradable cell walls. One of the main factor influencing the rate and quality of cell wall lignifications and overall nutritive value is plant maturity (Argillier et al., 2000; Jung, 2012). Neither harvesting premature plants nor wet biomass out of recommended 30–35 % dry matter content can produce silage high in digestible energy (Rajčáková and Mlynár, 2009). The opportunity for substantial milk production increase through improved NDF digestibility is recognized (Oba and Allen, 1999). Improved digestibility of whole plant maize can act antagonistic to DM yield, but it could be compensated by higher dairy cow performance (Neylon and Kung, 2003).

Andrieu (1995) use the digestibility of dry matter determined according to Aufrère (1982) as the reference method for calculation of net energy of lactation. Actually, there is no precise, widely accepted direct method for NDF digestibility determination in ruminants. Maize breeders are used to utilize in their programs parameter DINAG (Barrière et al., 1996) reflecting the digestibility of non-starch and insoluble carbohydrate part while assuming that starch and soluble sugars are completely digestible. Argilier et al. (1998) concluded that effect of environment is dominant factor influencing *in vitro* digestibility of cell walls, because apart of other statistically significant factors, those due to environment were always higher.

The aim of this experiment was to determine the effect of locality and FAO number on nutrient contents and organic matter digestibility of silages from maize hybrids.

2. Materials and methods

The maize hybrids were planted in the area of towns Čakajovce (locality 1) and Dvory nad Žitavou (locality 2) located 148 m and 120 m above sea level, respectively. There were muck soils (pH 6.8), standard pre-treated

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and fertilized by 138 kg of N per hectare. There were no extreme annual precipitations recorded in both localities. The average annual temperatures were 9.0 °C in locality 1 and 9.7 °C in locality 2. The assortment of 8 maize hybrids consisted of FAO 220, FAO 230, FAO 260, FAO 280, FAO 360, FAO 390, FAO 450, FAO 550 referring on both type of genetic origin and FAO number. In locality 1, maize hybrids were sown on April 18 and on April 15 in locality 2. The available fields in given localities had distinguished parcel where the hybrids were sown to plots in the planting rate 74 000 seeds per hectare. Each plot consisted of 6 rows 168 m long with spacing 71 cm for each hybrid.

The whole plant DM has been monitored through milk line of grain and gravimetric measurement after treatment by microwave. Harvest was managed to three dates, first for FAO 220 – FAO 280, second for FAO 360 – FAO 390 7 days later, third for FAO 450 – FAO 550 16 days later from the first date. Plants were collected in number 14 from each plot to chop them by manual chopper set up for theoretical chop length 20 mm. Glasses (4 dm^3) were filled by chopped biomass in two replications from each plot, hermetically sealed and stored for 1 month for further analysis. Determination of nutrients content was executed according to procedures of Commission Regulation (EC) 152/2009 on two (n = 2) dried samples with reduced particle size to pass 1mm sieve of laboratory mill (Fritsch, GER). Neutral detergent fiber (NDF) and acid detergent lignin (ADL) were determined according to Van Soest et al. (1991) by Ankom 200 Fiber Anylyzer (Ankom, USA). Reducing sugar (Su) was determined by Luff Schoorl method. After combustion in Muffle furnace at 520 °C ± 10 °C the ash (Ash) content was measured gravimetrically as well as dry matter (DM) content. Starch content was determined by polarimetric method and crude protein (CP) by Kjeldahl method × 6.25. The enzymatic *in vitro* dry matter digestibility (IVDMD) was measured according to Aufrére et al. (1982). Every sample has been incubated in triplicate in Daisy[II] Incubator (Ankom, USA). 0.5 g of sample was weighted to F57 Filter bags (Ankom, USA). Net energy of lactation (NEL) was calculated by equation introduced by Andrieu (1995) using IVDMD. The parameter DINAG proposed by Barrière et al. (1996) was calculated using equation:

$$DINAG = \frac{100 \times (IVDMD - Starch - Su)}{100 - (IVDMD - Starch - Su)}$$

where:

IVDMD is the *in vitro* digestibility of DM, Starch is the content of starch in % of DM and Su is the content of sugar in % of DM. Net energy of lactation (NEL) was calculated according to Andrieu et al. (2000). One-way analysis of variance was calculated using SAS 9.3 (SAS Inst., 2008) to determine the significant differences in the content of CP, ADL, starch and NDF between localities comparing only parallel groups. The GENMOD procedure has been used to test the mean values of IVDMD coefficient of all groups and the LSD multiple range method was applied on the probability level $\alpha < 0.05$ and $\alpha < 0.01$. The locality represented the main effect and FAO number was the nested effect.

3. Results and discussion

The range of DM content was 259.4–321.7 g kg^{-1} where most of samples fall into the recommended scale of DM suitable for ensiling (Table 1). The lowest DM were determined in FAO 220 in locality 1 and FAO 280 in locality 2 which could compromise silage energy content, ensiling characteristics and DM yield (Rajčáková and Mlynár, 2009). The locality 2 had higher SET than locality 1 during

Table 1 Harvest dry matter (DM) and sum of effective temperatures (SET)

	Maize hybrids			
Determinants	**FAO 220**	**FAO 230**	**FAO 260**	**FAO 280**
SET in locality 1	1620 °C			
DM in locality 1 in g kg^{-1}	259.4	282.9	306.1	270.8
SET in locality 2	1670 °C			
DM in locality 2 in g kg^{-1}	274.6	310.4	269.0	262.7
Determinants	**FAO 360**	**FAO 390**	**FAO 450**	**FAO 550**
SET in locality 1	1757 °C		1911 °C	
DM in locality 1 in g kg^{-1}	311.7	276.2	311.8	306.5
SET in locality 2	1803 °C		1958 °C	
DM in locality 2 in g kg^{-1}	300.0	277.4	321.7	290.8

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whole harvest period. SET is the sum of temperatures under which the plant growth occurs. This parameter is in relationship with phenological phase of maize (Cross and Zuber, 1971) and consequently its nutritive value. Differences in SET were more favourable for DM accretion of hybrids with lower FAO. When grouped according to harvest date, hybrids with lower FAO number had always higher harvest DM than hybrids with higher FAO number harvested at the same date regardless of locality. This is in agreement with Fuksa et al. (2003) reported significant effect of SET on silage maize DM production comparing hybrids with FAO number 210 and 260. As it comes to differences between locations within one type of hybrid, there were inconsistent, therefore we may assume that the effect of higher temperatures in locality 2 is negligible.

There were significant differences (P <0.05) found in FAO 280, FAO 360 and FAO 450 in CP content. The CP content in maize was low among forages not exceeding 89.6 g kg^{-1} in locality 2 and 87.0 g kg^{-1} in locality 2 (Table 2) in this experiment. It is used as the predictor of OM digestibility and energy evaluation for ruminants in equations of Andrieu (1995). Therefore, CP could play important role in prediction of NEL content of FAO 280 where higher CP content in locality 1 certainly did not contribute to higher NEL concentration. The lowest content of CP has been found in FAO 550 in locality 1 and the highest CP content in locality 2 in FAO 360. Generally, silages from locality 2 had higher mean values of CP content than from locality 1. CP content decreased with progressing maturity in the experiment of Filya (2004) who recorded CP content 69 g kg^{-1} DM in the sample of whole plant maize silage harvested at DM 295 g kg^{-1}.

FAO 230 in locality 1 had significantly higher (P <0.05) ADL concentration than in locality 2. The ADL content of FAO 230 in locality 2 was the lowest in the experiment. The extent of determined values is in agreement with other authors (Filya, 2004; Thomas et al., 2001). Interestingly, higher DM content had FAO 230 in locality 2 what is in contrary with well acknowledged pattern of increased ADL content with progressing plant age (Argillier et al., 2000). Location could modify lignification through light intensity, air temperature or soil composition among plenty of factors (Jung, 2012).

DINAG value was significantly different (P <0.05) between localities in FAO 230 and FAO 280. Quality of hybrids has been largely variable from poor (FAO 390, FAO 360) to high (FAO 450) according to DINAG parameter. FAO 450 in locality 1 had DINAG value similar to mean of three elite hybrid (55.65) tested by Argilier et al. (1998). Degradation of hemicelluloses and partially lignin during extraction is the major drawback of crude fibre analysis (Huhtanen et al., 2006). NDF

Table 2 Harvest crude protein, acid detergent lignin, NEL content and DINAG parameter of tested silages of maize hybrids (x ±S.D.) in locality 1 and locality 2

Maize hybrids (FAO) *n* = 2		**CP**		**ADL**		**NEL**		**DINAG**	
		g kg^{-1} of dry matter		g kg^{-1} of dry matter		MJ kg^{-1}			
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
220	$\bar{x}$	88.3	87.8	3.21	2.85	6.65	6.37	40.9	39.3
	S.D.D	±0.06	±0.23	±0.80	±0.46	±0.13	±0.17	±6.11	±3.03
230	$\bar{x}$	81.8	84.0	2.96 a	1.68 a	6.30	6.68	38.8 b	43.8 b
	S.D.	±0.05	±0.07	±0.09	±0.1	±0.03	±0.30	±0.31	±1.45
260	$\bar{x}$	84.9	89.6	2.28	2.44	6.28	6.47	37.0	40.9
	S.D.	±0.03	±0.60	±0.05	±0.26	±0.08	±0.19	±0.90	±1.51
280	$\bar{x}$	87.0 a	79.2 a	2.45	1.96	5.77 b	6.28 b	22.4 c	39.9 c
	S.D.	±0.15	±0.06	±0.39	±0.18	±0.04	±0.13	±4.85	±2.32
360	$\bar{x}$	82.3 a	89.7 a	1.90	2.07	5.41	5.39	22.3	19.0
	S.D.	±0.01	±0.08	±0.03	±0.07	±0.12	±0.02	±3.03	±0.51
390	$\bar{x}$	79.1	81.1	1.89	2.02	5.31	5.68	16.7	23.3
	S.D.	±0.14	±0.27	±0.08	±0.25	±0.07	±0.14	±1.11	±3.28
450	$\bar{x}$	78.9 a	88.2 a	1.9	1.94	7.13	7.24	46.8	41.8
	S.D.	±0.01	±0.10	±0.06	±0.59	±0.11	±0.31	±3.51	±2.14
550	$\bar{x}$	76.0	80.1	2.21	1.87	6.58	6.64	37.6	36.5
	S.D.	±0.20	±0.08	±0.64	±0.19	±0.34	±0.02	±0.80	±1.12

means with the same superscript within the row are significantly different at (P <0.05) content presented cell walls of whole plant maize silage consisted of structural polysaccharides and lignins observed in content 384.1–414.6 g kg^{-1} DM (Argilier et al., 1998) and 357.0–451.0 g kg^{-1} DM (Barrière et al., 2003) of maize hybrids harvested at DM 300 g kg^{-1}. This fraction was markedly variable due to other than environmental factors as the differences in DINAG among tested hybrids are huge.

The largest difference of NEL mean values between localities was significantly different (*P* <0.05) in FAO 280, followed by non significant differences in FAO 230 and FAO 390. The range was large similarly to digestibility determinants from 5.31 to 7.24 MJ kg^{-1} DM. This is comparable with Barrière et al. (2003) who measured the content of NEL in the range 5.82–6.95 MJ kg^{-1} DM. Prediction of NEL from datasets of chemical parameters (Petrikovič et al., 2000) is often more attributed to DM content than to reality of *in vivo* degradability of organic nutrients (Vencl, 1990). It could be assumed that DINAG values reflected important effect of NDF degradability on NEL content, because our results shown in Table 2 presents low DINAG values in hybrids with low NEL content and conversely. Andrieu et al. (1999) illustrated that almost half of total *in vivo* digestibility variation is not explained by CP and IVDMD Aufrére et al. (1982) relationship in equations for prediction of NEL, although narrow relationship between *in vivo* digestibility and DINAG has shown some potential.

The relationship between some nutrients content (Starch, NDF) and earliness of maize silage hybrids used in this experiment is presented in Figure 1. There were no significant differences (*P* >0.05) in Starch and NDF content between localities. Though, there was tendency for Starch to increase with increasing FAO number and for NDF content to decrease likewise.

FAO 450 in locality 2 had the highest Starch content which was accompanied by drop of NDF content in DM of whole plant. High content of easily degradable maize starch (Šimko et al., 2006) could hide hindered NDF digestibility in IVDMD coefficient of sampled silages. Inversely, FAO 220 in locality 2 had the lowest Starch content and the second highest NDF content. Ivan et al. (2005) shown that cows fed by maize silage with 3.6 % higher NDF content with 4.1 % higher NDF digestibility increased milk production and dry matter intake when substitution of low NDF content and low NDF digestibility occurred on a DM basis. These findings indicate that high NDF content in FAO 360 in both localities, FAO 230 in locality 1 and FAO 220 in locality 2 do not have to neglect the quality of silages because intrinsic characteristics of cell walls are more important. On the other hand, high NDF content was often connected with low Starch content. Givens et al. (1995) reported highly negative (r = -0.89) correlation of starch and NDF concentration in maize silage. Finaly, Starch and NDF concentrations were two distinct fractions with opposite tendencies in the whole plant weakly related to earliness in this experiment, where the known effect of increasing DM concentration was suppressed due to experimental design.

There have been large variability spred over the IVDMD coefficient mean values within the range (59.57–77.06 %) in the obtained data (Figure 2). The IVDMD coefficients of FAO 450 in both localities have been found to be the highest in the experiment. FAO 450 in locality 1 has been found significantly higher (*P* <0.01) in IVDMD coefficient than 6 of 8 hybrids in locality 2. Only in silage

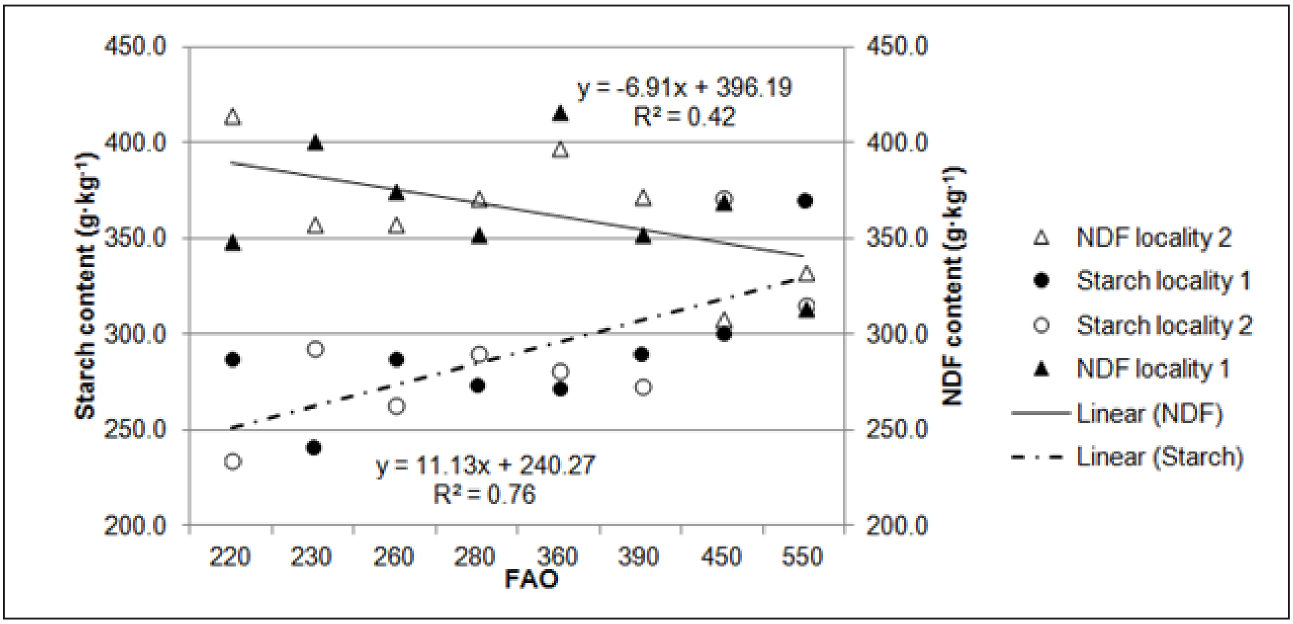

Figure 1 Contents of starch and NDF in both localities

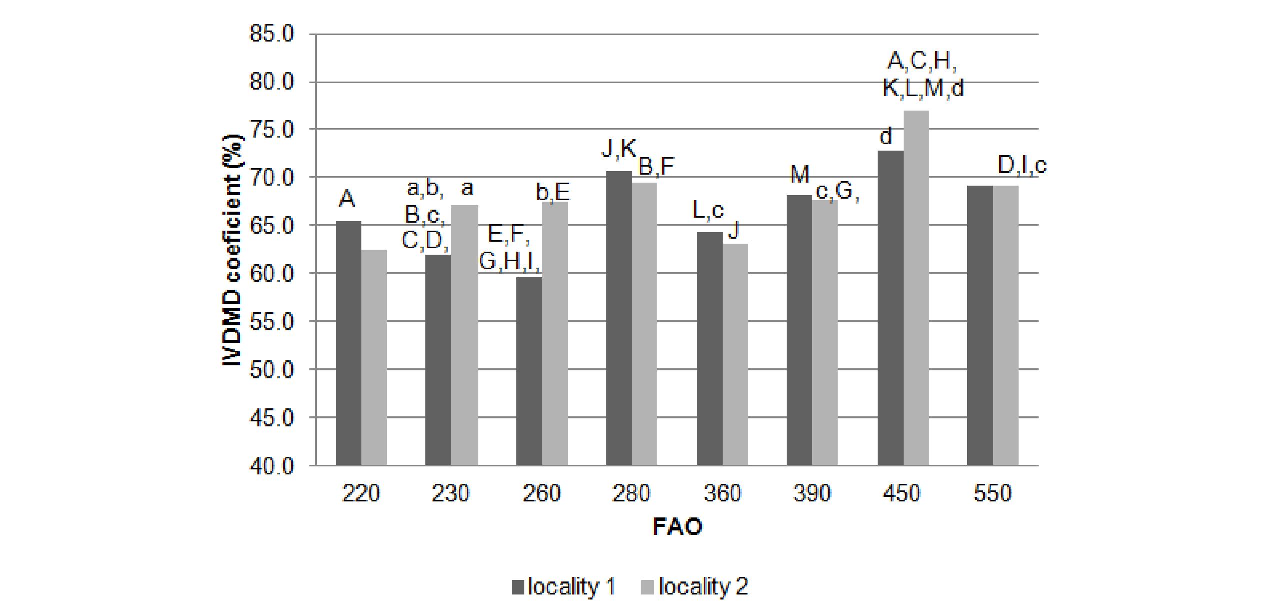

Figure 2 IVDMD coefficient comparisons in locality 1 and locality 2
Bars with the same upper-case letters are significantly different at (P <0.01) and with lower-case letters at (P <0.05)

of FAO 550 in locality 2 no significant difference (P >0.05) with FAO 450 in locality 1 has been found. These findings may indicate that early and medium hybrids were synthesizing other types of lignin-carbohydrate bonds in given conditions (Jung, 2012). *In vitro* digestibility method may not necessarily imitate complex digestion process of ruminants, but deterioration and hydrolysis of feed particles should be in predictable relationship with *in vivo* (Givens et al., 1995). The significant differences (P <0.05) between localities within the type of hybrid were found in FAO 230, FAO 260 and FAO 450. All three hybrids had the digestibility lower in locality 1. In hybrids FAO 220, FAO 280, FAO 360, FAO 390, FAO 550, the differences between localities within the type of hybrid were not significant (P >0.05) being determined in a range 0.1–3.03 %. Low IVDMD coefficient directly influenced the value of parameter DINAG in FAO 360 and FAO 390 on both localities (Table 2), nevertheless, the content of NEL were not affected so obviously.

4. Conclusions

The effect of locality had the substantial influence on nutritive value across the whole FAO range in this experiment. There were found significant differences (P <0.05) in CP, ADL, NEL and DINAG between silages from one type of hybrid grown in both localities. The highest IVDMD coefficient had FAO 450 in locality 2 which was significantly higher (P <0.01) than 6 hybrids in locality 2 (FAO 230 – FAO 390). Starch and NDF content were not significantly different (P >0.05); however the tendency of increased content with increased FAO number occurred.

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