NATIONAL AGRICULTURAL AND FOOD CENTRE
RESEARCH INSTITUTE FOR ANIMAL PRODUCTION NITRA

Slovak J. Anim. Sci., 49, 2016 (1): 17–22

ISSN 1337-9984

NUTRIENT CONTENT AND ORGANIC MATTER DEGRADABILITY OF DIFFERENT MORPHOLOGICAL PARTS OF MAIZE HYBRIDS DENT AND DENT X FLINT

Z. MLYNEKOVÁ*, Z. ČEREŠŇÁKOVÁ, M. RAJSKÝ

NPPC – Research Institute for Animal Production Nitra, Slovak Republic

ABSTRACT

The aim of our study was to determine the nutrient content and organic matter degradability of different morphological parts (whole plants, stalks, leaves) of maize hybrids dent and dent x flint. Ruminal degradability was determined by *in sacco* method. Hybrids dent x flint - Mesnil, Chambord, Queen, and hybrids dent - Aude, Meridien, KX 1393, Omero were used.
The content of ADF, NDF and lignin in the stalks was higher in the dent than in dent x flint hybrids. Concentration of crude protein (CP) in leaves was two times higher than in stalks (117.0 $g.kg^{-1}$ DM and 53.0 $g.kg^{-1}$ DM on average, respectively). The differences were also noted in CP among the hybrids in all plant parts. Large differences were found in starch content among the hybrids in whole plants: in Mesnil it was 329.0 $g.kg^{-1}$ of DM, whereas in Meridien the starch content was 193.0 $g.kg^{-1}$ of DM only.
In sacco experiment was carried out on three rumen cannulated cows. Hybrids dent x flint had on average higher effective organic matter degradability in whole plants (56.1 %), stalks (38.8 %) and leaves (49.2 %) than hybrids dent (53.8 %, 35.2 % and 43.3 %). Also, the rate of degradation of organic matter (OM) was higher for hybrids dent x flint than for dent. Organic matter in the stalks was degraded more slowly than in leaves.

Key words: morphological parts; maize plant; dent; dent x flint; organic matter; rumen degradability; *in sacco* method

INTRODUCTION

Maize is an important carbohydrate feedstuff by virtue of its rich chemical composition and nutrient content. Maize is characterized by high content of energy, which is a basic assumption of nutrition, although it does not cause abnormalities, but significantly reduces the utility (Sommer *et al*., 1985).

Individual morphological parts of the plant maize, according Struik (1983), are as follows: 43 % grain, 16 % leaves, 1 % panicle, 10 % stems and 12 % bracts, and contain several other nutrients which implies the various contents of energy. The vegetative components (stalk, leaf, husk and cob) can constitute approximately 70 % of the whole plant dry matter and can affect the quality of forage from the maize plant (Caetano *et al*., 2011).

Some studies have shown that in addition to the grain, the vegetative components of the maize plant are also important in the improvement of forage quality (Silva *et al.*, 2008). The concentration of crude protein, fat, non-fibre carbohydrate, neutral detergent fibre and the digestibility of these nutrients influence the energy value of feedstuffs (Weiss, 1994).

In the assessment of the feed quality for ruminants it is important to examine the degradability of nutrients in the rumen. Effective degradability characterizes the changes of feed, the kinetics of its degradation, taking into account the rate of passage from the rumen to duodenum (Ørskov and McDonald, 1979). *In sacco* method allows to obtain these data for several feeds at the same time.

The aim of our study was to determine the nutrient

***Correspondence:** E-mail: mlynekova@vuzv.sk
Zuzana Mlyneková, NPPC – Research Institute for Animal Production Nitra, Hlohovecká 2, 951 41 Lužianky, Slovak Rebublic
Tel.: +421 37 6546 235

Received: October 20, 2015
Accepted: February 27, 2016

content of different morphological parts of maize hybrids dent and dent x flint and degradability of organic matter in different morphological parts of maize by *in sacco* method.

MATERIAL AND METHODS

Maize hybrids with the type dent (Aude, Meridien, KX 1393, Omero) and dent x flint (Mesnil, Chambord, Queen) were used in our experiment. Oganic matter degradability in the morphological parts of maize was determined by *in sacco* method (Harazim and Pavelek, 1999). All the maize hybrids are stay green with different FAO (Table 1).

The samples of maize hybrids were harvested at the time of milk-waxy maturity. The samples were divided into different parts whole plants (stalks + leaves + stems), leaves and stalks. In the whole plant and individual morphological parts original dry mater (DM) and chemical composition were determined. Materials designed to degradability determination were freeze-dried and ground. These samples were weighed (approx. 2.50 g dry matter) into bags (9 x 15 cm) made of Uhelon 130T (HEDVA, "Moravská Třebová", the Czech Republic) with pore size of 47 µm. Minimum of three separate bags for hybrids, incubation time and animals were used. The bags with samples were incubated for 2, 3, 4, 6, 9, 16, 24, 48, 72 and 96 hours. The 0 h time bags were only washed in water to determine washing losses.

In sacco experiments were carried out in three non-lactating cows with large rumen cannulae (an average of 10 cm). The animals were fed twice a day with a diet consisting of 70 % forage and 30 % concentrate on a dry matter basis at maintenance level. Nutrient intake to one cow/day in our experiment was followed: 9770 g dry matter; 1170 g crude protein; 5050 g nitrogen free extract; 2660 g fibre; 1980 g starch and 650 g ash. Access to water was *ad libitum*.

Fifteen mg samples were inserted into the rumen just before morning feeding. The content of organic matter was determined in morphological parts of maize and in the residues after all incubation times. The content of nutrients was analyzed according to AOAC (2000). Contents of ADF, NDF and lignin were determined according to Van Soest (Lutonská and Pichl, 1983). The parameters of degradability (a, b, c, and "effective degradability") were calculated using the equations by Ørskov and McDonald (1979) with outflow rate of $0.06.h^{-1}$.

The data on nutrient content and organic matter (OM) degradability were evaluated statistically (mean and standard deviation). The statistical package Statistix 8.0 was used for statistical methods. Statistical evaluation of the results was performed by the one-way ANOVA and Tukey test for multiple comparisons at the level of significance $P < 0.05$ and $P < 0.01$.

RESULTS AND DISCUSSION

The nutritional value of different morphological parts of the plant is decreased with increasing maturity (Pesche and Gross, 1980). It reduces the nutritional value of whole maize plant. At the time of maize harvesting (milk – waxy stage), leaves had higher content of dry matter than stalks, regardless of the type of hybrids. Small differences were found only for dry matter of whole plants except for hybrid Queen and Aude (Table 2).

Differences among hybrids in the nutrient content of whole plants and dry matter are not caused only by actual differences between morphological parts, but also shared by various morphological parts of ripeness stage at harvest (Verbič *et al*., 1995). Harika *et al*. (1995) asserted that the quality of maize stover depends on the proportions of leaf and stem fractions of the stover.

Table 1: Characteristics of maize hybrids

Hybrid	FAO	Type of corn	Type of hybrid
Mesnil	290/300	dent x flint	Sc
Chambord	300/300	dent x flint	Sc
Queen	320/340	dent x flint	Sc
Aude	380/380	dent	Sc
KX 1393	450/450	dent	Sc
Meridien	420/420	dent	Sc
Omero	480/480	dent	Sc

Table 2: Nutrient content of morphological parts of selected maize hybrids (g.kg^{-1} DM)

	Dry matter			Crude protein			Organic matter			Starch	ADF			NDF			Lignin		
Maize hybrids	WP	S	L	WP	S	L	WP	S	L	WP	WP	S	L	WP	S	L	WP	S	L
Mesnil	374	228	268	78	54	144	965	959	911	329	232	363	287	429	585	537	23	45	25
Chambord	372	281	323	74	35	116	964	965	855	246	231	380	282	436	599	520	28	46	26
Queen	403	287	356	83	52	108	957	947	896	312	252	462	294	455	737	559	32	49	21
Aude	436	300	384	80	57	101	953	952	883	261	246	382	296	480	646	562	27	32	25
KX 1393	375	275	338	90	52	126	953	960	898	205	258	414	314	490	683	576	29	46	29
Meridien	375	274	337	84	62	122	955	951	903	193	287	455	318	566	714	589	24	55	23
Omero	376	234	370	87	56	104	948	938	882	253	280	440	336	549	721	603	30	51	37

WP – whole plants, S – stalks, L – leaves, ADF – acid detergent fibre, NDF – neutral detergent fibre

Table 3: Statistical comparison of nutrient content in maize hybrids at the level of significance $P < 0.05^{*}$ and $P < 0.01^{**}$

Nutrients	Whole plants	Stalks	Leaves
ADF	1:(3,4,5,6,7)**, 2:(3,4,5,6,7)**, 3:(7,6)** 4:(5,6,7)**, 5:(6,7)**, 6:7*	1:(3,4,5,6,7)**, 2:(3,5,6,7)** 3:(4,5,7)**, 4:(5,6,7)** 5:(6,7)**, 2:1*, 7:6*	1:(5,6,7)**, 2:(5,6,7)**, 3:(5,6,7)**, 4:(5,6,7)**, 7:(5,6)** , 2:(3,4)*
NDF	1:(3,4,5,6,7)**, 2:(4,5,6,7)**, 3:(4,5,6,7)** 4:(6,7)**, 5:(6,7)**, 2:3*	1:(3,4,5,6,7)**, 2:(3,4,5,6,7)** 3:(4,5,6)**, 4:(5,6,7)** 5:(6,7)**, 3:7*, 1:2*	1:(3,4,5,6,7)**, 2:(3,4,5,6,7)**, 3:(6,7)**, 4:(6,7)**, 5:7**, 1:2*, 3:5*
Lignin	3:(1,6)**, 7:1**, 1:(2,5)*	4:(1,2,3,5,6,7)**, 6:(1,2,3,5)** 7:1**, 7:(2,5)*	1:(3,7)**, 2:7**, 3:(5,7)**, 7:(4,5,6)**, 6:(1,5)*, 3:2*
Crude protein	1:(5,6,7)**, 2:(3,4,5,6,7)**, 3:5**, 4:(5,7)**, 5:6** 1:(2,3)*, 3:7*, 4:6*	1:(2,6)**, 2:(3,4,5,6,7)** 6:(3,5)**, 4:(3,5)*, 7:(5,6)*	1:(2,3,4,5,6,7)**, 2:(3,4,5,7)**, 3:(5,6)**, 4:(5,6)**, 7:(5,6)**, 2:6*, 3:4*

1 – Mesnil, 2 – Chambord, 3 – Queen, 4 – Aude, 5 – KX 1393, 6 – Meridien, 7 – Omero

Table 4: Characteristics of degradability and effective degradability of organic matter in morphological parts of selected maize hybrids

Parameter		Maize hybrids						
		Mesnil	Chambord	Queen	Aude	Meridien	KX 1393	Omero
a (%)	WP	41.3[d]	37.8	28.3[bd]	34.6[a]	46.9[abc]	37.1	35.1[c]
	S	27.7	31.0	27.5	25.8	25.2	25.6	23.7
	L	36.3	32.3	23.2	34.7	25.6	27.0	29.6
b (%)	WP	41.0	43.7	52.7	45.8	42.0	48.9	49.6
	S	32.2	36.2	46.1	37.5	44.5	37.8	43.8
	L	49.6	51.7	55.2	52.4	55.5	59.1	48.6
c (%.h^{-1})	WP	0.056[c]	0.042	0.063[ab]	0.047	0.021[c]	0.027[a]	0.036
	S	0.046	0.027	0.024	0.022	0.023	0.037	0.028
	L	0.031	0.038	0.070	0.021	0.028	0.030	0.038
Edg (%)	WP	56.4[d]	56.1[c]	55.9[b]	55.3[a]	54.6	51.9[abcd]	53.2
	S	40.4[abcdef]	40.1[cghijk]	36.0[bh]	33.9[ag]	35.1[ej]	36.8[di]	35.0[fk]
	L	52.8	49.0	49.1	41.9	43.2	42.9	45.2

WP – whole plants, S – stalks, L – leaves, Edg – effective degradability. Means with the same letters in the same row are significantly different at $P < 0.05$ and $P < 0.01$.

Starch in whole plants was the highest in hybrid Mesnil (329 g.kg^{-1} DM) and the lowest in Meridien (193 g.kg^{-1} DM).

The differences in the contents of ADF, NDF and lignin were found by Kohler *et al*. (1990) among the hybrids as well as between morphological parts. It corresponds with our results (Table 2). Higher contents of ADF, NDF and lignin were found in the stalks of dent hybrids than dent x flint hybrids (Table 2), except hybrid Queen. The similar tendency was observed also in leaves and whole plants. Tolera and Sudstøl (1999) noted the highest contents of crude fibre, ADF, NDF and lignin in stalks.

The concentration of crude protein in leaves ranged from 101 to 126 g.kg^{-1} DM of hybrids dent and from 108 g.kg^{-1} to 144 g.kg^{-1} DM of dent x flint hybrids. The results indicate that the maize leaves have about three times more crude protein than stalks. Average crude protein content in whole plant was higher in dent hybrids as in dent x flint hybrids (85 g.kg^{-1} vs. 78 g.kg^{-1} DM). However, the quality of maize proteins is poor because they are deficient at the essential amino acids lysine and tryptophan (Shewry, 2007). Significant differences between hybrids in content of nutrients are presented in Table 3.

Among the morphological parts of maize plants and also among maize hybrids there are differences in the chemical composition, which results in the differences of the effective organic matter degradability. Many authors (Liu *et al*. 1988, Negi *et al*. 1988; Susmel *et al*. 1990; Mir *et al*. 1991) referred to the differences in degradability of morphological parts of maize plant. According to Verbič *et al*. (1995), it can be used in the selection of suitable hybrids for ensilaging.

The effective OM degradability (Edg) was found to be the highest for whole plants of maize (from 51.9 to 56.1 %) (Table 4). The differences were statistically significant between the hybrids dent x flint and hybrid dent KX 1393 (Table 4). The effective OM degradability for leaves was in the range from 41.9 to 52.8 % but they were not statistically significant. A higher amount of lignin in the stalks was reflected in low levels of all parameters of OM degradability. Particularly in the fraction "a", effective OM degradability was lower in the stalks than in leaves and whole plants. The differences among dent and dent x flint hybrids were significant for parameters "a" and "c", the effective OM degradability in the whole plants and for Edg (effective degradability) in the stalks.

The rate of degradation "c" of the insoluble fraction "b" was the highest in the leaves (Table 4). The higher content of lignin reduces the degradation of cell walls in the rumen, but does not affect the loss of soluble substances such as sugar. We found that the hybrid Meridien with the highest concentration of lignin in whole plants and stalks had the lowest rate of degradation (parameter c) of organic matter. Higher degradability of leaves compared with stems was reported for most cereals (Kernan *et al*., 1984; Ramanzin *et al*., 1986; Shand *et al*., 1988).

CONCLUSION

The content of nutrients was different in hybrids and changed with morphological parts of maize hybrids. We found the lowest effective degradability of organic matter in stalks followed by the leaves and the highest effective degradability of OM was in the whole plants. From our results it may be concluded that there are differences in chemical composition and differences in effective degradability of maize between morphological parts of the maize plant as well as among maize hybrids. Therefore it is necessary to select the correct maize hybrid on the basis of objectively determined nutritive value.

ACKNOWLEDGEMENT

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-14-0637.

REFERENCES

AOAC. 2000. Official Methods of Analysis. 17th ed. Washington: Association of Official Analytical Chemists Inc., 2000.

CAETANO, H. – OLIVIERA, M. D. S. d. – FREITAS JÚNIOR, J. E. d. – RÊGO, A. C. d. – RENNÓ, F. P. – CARVALHO, M. V. d. 2011. Evaluation of corn cultivars harvested at two cutting heights for ensilage. *Revista Brasileira de Zootecnia*, vol. 40, 2011, p. 12–19.

HARAZIM, J. – PAVELEK, L. 1999. Stanovení degradability dusíkatých látek a aminokyselin metodou „*in situ*" v bachoru přežvýkavců. *Stanovení využitelnosti živin u přežvýkavců*: Zbor. z medzinár. odbor. sem., Opava, 1999, p. 41–46.

HARIKA, A. S. – TRIPATHI, H. P. – SAXENA, V. K. 1995. Maize stover. In: Singh, K., Schiere, J. B. (Eds.), *Handbook for Straw Feeding Systems*. ICAR, New Delhi, India, 1995, p. 379–391.

KERNAN, J. A. – COXWORTH, E. C. – CROWLE, W. C. – SPURR, D. T. 1984. The nutritional value of crop residues from several wheat cultivars grown at different fertilizer levels. *Animal Feed Science and Technology*, vol. 11, 1984, p. 301–311.

KOHLER, R. – JEROCH, H. – FLACHOWSKY, G. – GEBHARD, G. – HILSCHER, H. – KAPPEL, W. 1990. Futtermittelkundliche Bewertung verschiedener Maisgenotypen. *Archives of Animal Nutrition*, vol. 40, 1990, p. 267–274.

LIU, J. X. – OKUBO, M. – KONDO, S. – SEKINE, J. – ASAHIDA, Y. 1988. Voluntary intake and ruminal digestion of fibrous materials of grass or corn silage by sheep. *Journal of the Faculty of Agriculture*, Hokkaido Univ., vol. 63, 1988, p. 335–344.

LUTONSKÁ, P. – PICHL, I. 1983. *Vláknina* (chemické zloženie, metódy stanovenia, význam vo výžive), edícia MP SR Bratislava, 1983, p. 141. ISBN 64-222-83.

MIR, P. S. – MIR, Z. – HALL, J. W. 1991. Comparison of effective degradability with dry matter degradability measured at mean rumen retention time for several forages and forage: concentrated diets. *Animal Feed Science and Technology*, vol 32, 1991, p. 287–296.

NEGI, S. S. – SINGH, B. – MAKKAR, H. P. S., 1988. Rumen degradability of nitrogen in typical cultivated grasses and leguminous fodders. *Animal Feed Science and Technology*, vol. 22, 1988, p. 79–89.

ØRSKOV, E. R. – MCDONALD, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science*, vol. 92, 1979, p. 499–503.

PESCHE, W. – GROSS, F. 1980. Nährstoffgehalt und Verdaulichkeit von Silomais. 2. Mitteilung: Nährstoffgehalt und Verdaulichkeit von Maisstroh (Maispflanze ohne Kolben). *Das Wirtschaftseigene Futter*, vol. 20, 1980, p. 66–74.

RAMANZIN, M. – ØRSKOV, E. R. – TUAH, A. K., 1986. Rumen degradation of straw from two barley cultivars. *Animal Production*, vol. 43, 1986, p. 271–278.

SHAND, W. J. – ORSKOV, E. R. – MORRICE, L. A. F. 1988. Rumen degradation of straw 5. Botanical fractions and degradability of different varieties of oat and wheat straws. *Animal Production*, vol. 47, 1988, p. 387–392.

SHEWRY P. R. 2007. Improving the protein content and composition of cereal grain. *Journal of Cereal Science*, vol. 46, 2007, p. 239–250.

SILVA, L. F. P. – CASSOLI, L.D. – ROMA JÚNIOR, L. C. – DE OLIVEIRA RODRIGUES, A. C. – MACHADO, P. F. 2008. In situ degradability of corn stover and elephant-grass harvested at four stages of maturity. *Scientia Agricola*, vol. 65 (6), 2008, p. 595–603.

SOMMER, A. – ANTAL, J. – KOČÍ, Š. 1985. *Výživa a kŕmenie hospodárskych zvierat*. Príroda, n. p. Bratislava, 1985, 279 p. ISBN 508-21-85.

STRUIK, P. C. 1983. Physiology of forage maize (*Zea mays* L.) in relation to its production and quality. PhD. Diss. Agricultural University Wageningen, The Netherlands. 1983, 252 p.
SUSMEL, O. – STEFANON, B. – MILLS, C. R. – SPANGHERO, M. 1990. Rumen degradability of organics matter, nitrogen and fibre fractions in forages. *Animal Production*, vol. 51 (3), 1990, p. 515–526.
TOLERA, A. – SUDSTØL, F. 1999. Morphological fractions of maize stover harvested at different stages of grain maturity and nutritive value of different fractions of the stover. *Animal Feed Science and Technology*, vol. 81, 1999, p. 1–16.
VERBIČ, J. – STEKAR, J. M. A. – RESNIK-ČEPON, M. 1995. Rumen degradation characteristics and fibre composition of various morphological parts of different maize hybrids and possible consequences for breeding. *Animal Feed Science and Technology*, vol. 54, 1995, p. 133–148.
WEISS, W. P. 1994. Estimation of digestibility of forages by laboratory methods. *Forage Quality, Evaluation, and Utilization*. American Society Agronomy, Madison, WI, 1994, p. 644–681. ISBN 0891181199.