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A note on the chemical composition and *in vitro* digestibility of contrasting stover components of maize grown in climatically marginal conditions and harvested at differing maturities

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This study evaluated the nutritive value of three contrasting components of maize stover (leaf, upper stem, lower stem) at three harvest dates. The leaf component had a greater *in vitro* dry matter digestibility (DMD) and a lower NDF concentration, compared to the stem components. Delaying harvest reduced the *in vitro* DMD of the stem components to a greater extent than leaf, reflecting lower increases in the NDF and lignin concentrations in leaf tissue. The stem components of maize stover had a lower nutritive value than the leaf component, and had a larger decrease in digestibility with delayed harvest.

Keywords: harvest date; leaf; maize; stem; stover

Introduction

The nutritive value of maize stover (total stem and leaves) is much lower than for the cob component (grain and rachis; Cook and Shinners 2011; Lascano and Heinrichs 2011), and generally supports similar rates of animal performance to what could be achieved with average quality grass silage (O'Kiely and Moloney 1995). However, maize stover can contribute over 50% of the whole-crop dry matter (DM) yield and changes in the chemical composition of maize stover during the later stages of crop development have a large impact on the whole-crop nutritive value(Lynch, O'Kiely and Doyle 2012, 2013). Recent interest in the potential of dual-purpose maize varieties to

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improve the overall efficiency of maize production systems (Blümmel, Grings and Erenstein 2013; Erenstein, Blümmeland Grings 2013) highlights the importance of understanding how crop management affects the stover component of maize. Such information is not readily available, particularly for crops grown under temperate but marginal conditions for crop growth and cob development.

Furthermore, stover consists of contrasting components, such as the leaf and the stem (Tolera and Sundstøl 1999; Tang *et al*. 2006). Knowledge of the detailed chemical composition and nutritive value of these individual components at various stages of maturity provides a basis for determining opportunities to improve the value of stover to whole-crop maize production. However, very little information is available on these maize stover components produced in climates that are marginal for maize growth due to insufficiently high temperatures during the growing season. The objectives of this study were to determine the effects of harvest date and stover fraction on the chemical composition and *in vitro* digestibility of maize stover.

Materials and Methods

Crop production and management

The maize cultivar Andante (Groupe Limagrain, Chappes, France) was sown under transparent plastic mulch (137 cm wide, 6 micron thick film, which covered two rows of seed; X-tend transparent photodegradable polythene, I.P Ltd., Gorey, Co. Wexford) at Grange, Dunsany, Co. Meath (53°30′ N, 6°39′ W and 83 m above sea level) on 2 April 2009 using a Samco 4 Row 4700 SP seed drill at a depth of approximately 5 cm and at a rate of 100,000 seeds per hectare. This cultivar had achieved a high cob proportion (> 500 g/kg whole-crop) and starch concentration (180–250 g/kg whole-crop DM) in previous trials at the same site (Lynch *et al*. 2012, 2013). Cattle slurry was applied to all plots prior to ploughing, at a rate calculated to provide 33 kg available N/ha. Inorganic N was applied at 135 kg N/ha in the form of calcium ammonium nitrate (CAN; 275 g N/kg) 4 h prior to sowing. For each of three replicate blocks of a split-plot design, three harvest date treatments (7 September, 5 October and 5 November) were randomly allocated among three main plots, within which sub-plots were randomly allocated to one of three stover components. Thus, 27 plots were sampled in total. The stover components consisted of leaf blade (separated at the point of the blade meeting the stem), upper stem (all herbage above the 5th node, excluding the leaf blade, husks, silks, rachis and grain) and lower stem (i.e., all herbage above 5 cm over ground level and below the 5th node, excluding the leaf blades; no husks, silks, rachis or grain were present). On each harvest date either the leaves, upper stem or lower stem were manually removed from all plants present in a sub-plot (10.0 m × 3.8 m), weighed for proportion determination, processed through a precision-chop harvester (set to a theoretical chop length of 19 mm; Pottinger Mex VI, Grieskirchen, Austria), and subsequently sub-sampled.

Chemical analysis

Dry matter (DM) concentration was determined by drying samples in an oven with forced air circulation at 98 °C for 16 hours, while duplicate samples were oven dried at 60 °C for 48 hours and ground using a hammer mill (1 mm apertures; Willey mill, PA, USA) prior to chemical analysis. The *in vitro* digestibility indices, chemical composition and protein fractionation of samples was determined as described by Lynch *et al*.

(2014). In addition, hemicellulose was calculated as neutral detergent fibre (NDF) – acid detergent fibre (ADF) and cellulose as ADF – acid detergent lignin (ADL).

Statistical analysis

The data were analysed using a model that accounted for harvest date (main plot; n = 3) and stover component (sub-plot; n = 3) within a three replicate block split-plot design. Stover components were harvested from separate sub-plots to allow for independent samples. All analyses were conducted using Proc GLM procedure (SAS 2004). Treatment means were compared using the Fisher's least significant difference.

Results

Harvest date did not affect ($P > 0.05$) the DM, NDF, hemicellulose, lignin, ash or crude protein concentration of stover components (Table 1). The cellulose concentration increased ($P < 0.05$) and the water soluble carbohydrates (WSC) concentration decreased ($P < 0.05$) with later harvesting.

The DM concentration of lower stem was lower ($P < 0.01$) than the upper stem and leaf components. Leaf had a greater ($P < 0.01$) *in vitro* DM digestibility (DMD) and NDF digestibility (NDFD) and a lower WSC concentration ($P < 0.001$) than upper stem and lower stem. Leaf had a lower ($P < 0.01$) NDF concentration than lower stem, and tended ($P = 0.052$) to have a lower NDF concentration than upper stem. The hemicellulose concentration of lower stem was lower ($P < 0.05$) than the upper stem and leaf components. The cellulose and lignin concentrations of lower stem were greater ($P < 0.001$) than the other components, while upper stem also had a greater lignin concentration ($P < 0.01$) than leaf. In addition, leaf had a greater ($P < 0.001$) crude protein concentration and a lower ($P < 0.001$) C_N proportion than the other components (Table 2).

Upper stem contributed a greater ($P < 0.001$) proportion of total stover and total whole-crop than the other stover components at all harvest dates, while the proportion of all stover components in whole-crop decreased ($P < 0.01$) with later harvesting.

Discussion

Component effects

The greater *in vitro* DMD of the leaf, compared to the stem components, primarily reflected a lower NDF concentration. Similarly, studies conducted with a range of maize hybrids by Tolera and Sundstøl (1999) and Tang *et al*. (2008) reported that the greater *in vitro* DMD for leaf compared to the total stem component reflected lower NDF and ADF concentrations. However, the present study also indicated that the higher NDFD of leaf also contributed to its greater nutritive value compared to the stem components, likely due to a lower lignin concentration which allowed for increased utilisation of the cell wall carbohydrates. Furthermore, the crude protein concentration of leaf was higher than in the other components, with a lower proportion of indigestible protein, allowing for 3.8 and 4.6 times higher concentrations of utilisable protein at harvest, compared to upper stem and lower stem, respectively.

Of the stem components, the lower section generally had a lower *in vitro* DMD, primarily due to higher NDF and lignin concentrations. The higher WSC concentration of the stem components compared to leaf was as expected, as stem tissues are utilised for the storage of excess

Table 1. The chemical composition and *in vitro* digestibility of maize stover components- harvest date effects

												Proportion[3]	
Component (C)	Harvest (H)	DM[1]	DMD[1]	NDFD[1]	WSC[2]	NDF[2]	Hemi[2]	Cellulose[2]	Lignin[2]	Ash[2]	CP[2]	In stover[4]	In whole-crop
Leaf	7 Sept.	166^{b}	701^{a}	582^{a}	$37^{c,d}$	667^{b}	316^{a}	329^{e}	22^{e}	90^{a}	150^{a}	$300^{b,c}$	$202^{b,c}$
	5 Oct.	$154^{b,c}$	$678^{a,b}$	605^{a}	23^{d}	696^{b}	319^{a}	$357^{d,e}$	20^{e}	90^{a}	$138^{a,b}$	$283^{b,c}$	$156^{e,f}$
	5 Nov.	190^{a}	$631^{b,c}$	566^{a}	21^{d}	708^{b}	$307^{a,b}$	$375^{c,d,e}$	$26^{d,e}$	90^{a}	125^{b}	272^{c}	135^{f}
Upper stem	7 Sept.	161^{b}	$658^{a,b,c}$	$349^{b,c}$	164^{a}	701^{b}	$302^{a,b}$	$366^{c,d,e}$	$33^{c,d,e}$	42^{c}	44^{c}	416^{a}	280^{a}
	5 Oct.	$153^{b,c}$	560^{d}	365^{b}	110^{b}	769^{b}	325^{a}	$405^{b,c,d}$	$39^{b,c,d}$	$48^{b,c}$	38^{c}	422^{a}	234^{b}
	5 Nov.	160^{b}	498^{e}	$304^{b,c}$	$50^{c,d}$	807^{a}	312^{a}	$452^{a,b}$	$43^{b,c}$	55^{b}	38^{c}	397^{a}	$195^{c,d}$
Lower stem	7 Sept.	134^{c}	624^{c}	$333^{b,c}$	$147^{a,b}$	$740^{a,b}$	$291^{a,b}$	$408^{b,c}$	$41^{b,c}$	43^{c}	38^{c}	$285^{b,c}$	$192^{c,d,e}$
	5 Oct.	135^{c}	$511^{d,e}$	298^{c}	113^{b}	$754^{a,b}$	270^{b}	$437^{a,b}$	47^{b}	$48^{b,c}$	25^{c}	$295^{b,c}$	$165^{d,e,f}$
	5 Nov.	134^{c}	437^{f}	$317^{b,c}$	68^{c}	816^{a}	$290^{a,b}$	465^{a}	61^{a}	54^{b}	38^{c}	330^{b}	$162^{d,e,f}$
s.e.	C	5.0	9.3	16.1	8.5	16.6	8.7	10.1	2.3	1.9	2.5	–	7.0
	H	2.9	10.0	17.0	4.8	14.1	3.6	4.7	3.0	1.5	3.1	–	6.3
	CxH	8.6	16.2	28.5	14.8	24.4	15.2	17.5	3.9	3.2	6.3	18.7	12.1
Significance	C	<0.001	<0.001	<0.001	<0.001	0.018	0.029	<0.001	<0.001	<0.001	<0.001		<0.001
	H	0.193	0.002	0.304	0.008	0.091	0.979	0.020	0.125	0.076	0.161	–	0.006
	CxH	0.201	0.027	0.338	0.042	0.595	0.511	0.776	0.357	0.250	0.542	0.2968	0.289

[1]g/kg DM = dry matter; DMD = *in vitro* DM digestibility; NDFD = *in vitro* neutral detergent fibre digestibility.
[2]g/kg DM; NDF = neutral detergent fibre; Hemi = hemicellulose; CP = crude protein; WSC = water soluble carbohydrates.
[3]Proportion that stover component contributes to total stover or whole-crop, gDM/kg DM.
[4]Analysed without the main effects, as no variation can occur when components are averaged across components.
Means (n = 3) with the same letters within a column are not significantly different ($P > 0.05$).
s.e. = standard error of the mean.

Table 2. Nitrogen fractions of maize stover components- harvest date effects

		Nitrogen fractions (g fraction N/kg N)[1]				
Component (C)	Harvest (H)	A_N	$B1_N$	$B2_N$	$B3_N$	C_N
Leaf	7 Sept.	146	109	199	489	57^{e}
	5 Oct.	195	83	187	467	$68^{d,e}$
	5 Nov.	190	103	209	382	$116^{c,d}$
Upper stem	7 Sept.	235	80	104	452	$128^{b,c}$
	5 Oct.	174	112	150	433	138^{c}
	5 Nov.	193	50	138	416	202^{a}
Lower stem	7 Sept.	267	98	84	419	$132^{b,c}$
	5 Oct.	104	115	215	387	$179^{a,b}$
	5 Nov.	190	97	190	307	215^{a}
s.e.	C	19.3	18.4	22.4	26.5	5.5
	H	20.3	22.8	19.3	22.7	15.5
	CxH	33.6	31.9	38.8	46.0	9.7
Significance	C	0.683	0.665	0.129	0.098	<0.001
	H	0.242	0.839	0.243	0.140	0.068
	CxH	0.094	0.757	0.442	0.804	0.308

[1]A_N = Non-protein N; $B1_N$ = rapidly degradable true protein; $B2_N$ = variably degradable true protein; $B3_N$ = slowly degradable true protein; C_N = Unavailable protein.
s.e. = standard error of the mean.
Means (n = 3) with the same letters within a column are not significantly different ($P > 0.05$).

carbohydrates and for the transportation of assimilate to the kernels (Slewinski 2012). However, this higher concentration of WSC was not substantial enough to negate the differential in *in vitro* digestibility between the components.

Harvest date

Delaying harvest reduced the *in vitro* DMD of the stem components to a greater extent than leaf, reflecting lower increases in the NDF and lignin concentrations in leaf tissue. Similarly, upper stem incurred a lower decrease in *in vitro* DMD with delayed harvest compared to the lower stem. This is in accord with previous studies on whole maize stover by Hunt, Kezar and Vinande (1989) and Lynch *et al.* (2012) that reported decreased DMD with delayed harvest was related to increases in the NDF and lignin concentrations in addition to reductions in the WSC concentration. The reduction in WSC concentrations of the stem components with delayed harvest was due to the transportation of assimilate to the cob component of the whole-plant for kernel-filling (Lynch *et al*. 2012; Slewinski 2012).

Delaying harvest resulted in a decline in the proportion of leaf in the stover, parallel to an increase in the proportion of lower stem. When the declining proportion of stover in the maize whole-crop was considered, delaying harvest decreased the leaf proportion in the total plant by 43% between 7 September and 5 November, compared to a decrease of only 16% for lower stem during the same period. Therefore, while the decrease in nutritive value of each individual stover component with delayed harvest partially contributes to the overall reduction in stover value, results from the present study indicate that the change in the ratio of leaf to lower stem also significantly influenced the nutritive value of stover.

While the current study was conducted with one variety during a single growing season, the findings are applicable to the majority of Irish maize production, as commercially selected cultivars are typically also early maturing and, therefore, variability between cultivars grown in Ireland is likely to be relatively modest.

Maximising stover nutritive value

The higher protein concentration and lower decline in digestibility with delayed harvest of the leaf component reflects a higher feed value compared to the lower stem. Thus, maximising the proportion of this component in the harvested forage relative to the poor-quality lower stem would partially offset the negative influence of the stover component on the whole-crop nutritive value for crops harvested at later maturity. This may be achieved on farms through an increase in cutting height at harvest (Neylon and Kung 2003).

Alternatively, the low NDFD of the stem components indicates that a high proportion of hemicellulose and cellulose is unavailable to ruminants at harvest time, and thus there may be an opportunity to improve the value of this lignocellulosic material using methods which increase the utilisation of lignin-bound carbohydrates.

Conclusion

The stem components of maize stover grown in a marginal climate had a lower nutritive value than the leaf component, and had a larger decrease in digestibility with delayed harvest. The negative influence of the stover component on the whole-crop nutritive value for crops harvested at later maturity may be diminished by increasing the proportion of leaf in the whole-crop and reducing the proportion of lower stem.

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