Journal of Agricultural Science (2017), **155**, 1253–1262. © Cambridge University Press 2017
doi:10.1017/S0021859617000259

CROPS AND SOILS REVIEW

The effect of ensiling on variety rank of forage maize

J. SWANCKAERT[1,2]*, J. PANNECOUCQUE[1], J. VAN WAES[1], G. HAESAERT[3], J. DE BOEVER[4] AND D. REHEUL[2]

[1] *Plant Sciences Unit, Institute for Agricultural and Fisheries Research (ILVO), Burg. Van Gansberghelaan 109, 9820 Merelbeke, Belgium*
[2] *Department of Plant Production, Faculty of Bioscience Engineering, Ghent University, Proefhoevestraat 22, 9090 Melle, Belgium*
[3] *Department of Applied biosciences, Faculty of Bioscience Engineering, Ghent University, Valentin Vaerwyckweg 1, 9000 Ghent, Belgium*
[4] *Animal Sciences Unit, Institute for Agriculture and Fisheries Research (ILVO), Scheldeweg 68, 9090 Melle, Belgium*

(*Received 17 June 2016; revised 22 February 2017; accepted 20 March 2017; first published online 17 April 2017*)

SUMMARY

The objective of the present study was to calculate an optimal harvest period for both fresh and ensiled samples of forage maize and to calculate a set of harvest dates (called a harvest window), for which the variety ranking of the fresh forage corresponds with the variety ranking at the optimal harvest period calculated from the ensiled forage. Forage maize is fed almost exclusively as silage, but official variety trials with silage maize determine quality parameters in fresh (i.e. non-preserved) forage. Eight silage maize varieties were monitored at six harvest dates (from 25 to 40% dry matter content) in Merelbeke (Belgium) in 2013–15. At each harvest date, fresh samples were taken and half of the sampled material was ensiled in micro silos for 20 weeks. An optimal harvest period was calculated based on frequently measuring starch concentration and organic matter digestibility for both fresh and ensiled forage. Eventually, harvesting the silage maize at a dry matter content of 32–35% guaranteed an optimal harvest period. Based on the results of eight varieties, reporting variety ranks without going through the ensiling process continues to be a scientifically justified practice in Belgian official variety trials. Varieties with a superior fresh quality keep their leading position after ensiling, but variety differences become smaller after ensiling.

INTRODUCTION

Forage maize (*Zea mays* L.) is fed almost exclusively as silage. Ensiling is a common preservation technique based on anaerobic conversion of water-soluble carbohydrates into organic acids. Stage of maturity at time of harvest influences the quality of the ensiling process and the quality of the ensiled forage (Filya 2004; Wambacq *et al*. 2016). Indeed, as the plant matures, water-soluble carbohydrate levels decrease and starch levels increase as a result of the translocation of sugars from the stover to the ear (Hunt *et al*. 1989). Therefore, at the end of maturation, less fermentable substrate is available for organic acid production and when the forage is too dry at harvest, the most digestible part of the crop is used for oxidation (McDonald *et al*. 1991). At earlier harvest dates, when the forage is too wet at harvest, part of the soluble sugars is lost into effluents.

Although feed analyses by accredited institutes or private companies are performed on ensiled forage, reports of official variety trials regarding forage quality provide data based on analyses of fresh (non-ensiled) forage. Yet, there are a number of publications dealing with the effect of plant maturity on the quality of forage and potential differences between quality of fresh and ensiled forage. Effects of advancing plant maturity on quality have been evaluated for fresh forage (Hetta *et al*. 2012; Swanckaert *et al*. 2016) and ensiled forage (Ettle & Schwarz 2003;

* To whom all correspondence should be addressed. Email: Jolien.Swanckaert@ugent.be

Cone *et al*. 2008; Arriola *et al*. 2012). Silage is generally higher in protein and starch content because of respiration losses (Cherney *et al*. 2007). Although not directly fermented by lactic acid bacteria, the fibrous fraction of silages decreases as a result of solubilization of fibre (Der Bedrosian *et al*. 2012). Cell wall digestibility (NDFD) declines most severely due to ensiling (Darby & Lauer 2002).

Trials with animals fed maize silage have been used to determine the optimal harvest period (H_{opt}), the latter being a compromise between dry matter (DM) intake, digestion and milk production (Bal *et al*. 1997; Phipps *et al*. 2000). The H_{opt}, as a compromise between quantity and quality, has been studied in fresh forage (Wiersma *et al*. 1993; Barriere *et al*. 1997) and ensiled forage (Darby & Lauer 2002), but to our knowledge no comparisons have been made between fresh and ensiled forage. Differences in quality between fresh and ensiled forage may result in differences in variety ranks when comparing them. Leaning on analyses of non-ensiled samples, Swanckaert *et al*. (2016) demonstrated that changes in forage maize quality during maturation do not jeopardize variety ranks. Darby & Lauer (2002) also reported a stable variety rank during maturation in fresh forage, but the variety rank changed with increasing DM levels after ensiling. So the key question remains: to what extent do varieties with a superior fresh quality maintain their characteristics when ensiled?

The objectives of the present study were (1) to calculate an H_{opt} for both fresh and ensiled forage maize and (2) to calculate a set of harvest dates (called a harvest window), for which the variety ranking of fresh forage corresponds with the variety ranking at the H_{opt} calculated from the ensiled forage.

MATERIALS AND METHODS

Experimental site, design and plant material

Eight varieties of forage maize were grown on sandy loam soil in Merelbeke (50°59′N, 3°47′E, 20 m a.s.l.), Flanders (the northern part of Belgium) during three consecutive years (2013–15). Eight varieties representing variation in maturity, energy content and plant type between varieties available on the Belgian market were chosen: Banguy (Limagrain), Kalientes (KWS), LG 30·222 (Limagrain), LG 30·224 (Limagrain), LG 3220 (Limagrain), MAS 17E (Maisadour), NK Falkone (Syngenta) and Ronaldinio (KWS). Their development was monitored using Ontario Units (OU) (Brown 1969). Maximum and minimum temperatures necessary to calculate OU were registered at a weather station 5 km away from the experimental fields. The OU required for varieties to reach 35% DM content differed up to a maximum of 120 OU. The experimental design was a randomized complete block with three replicates. Plots consisted of four 8-m long rows: row spacing was 0·75 m and the plant density was 100 000 plants/ha. Sowing dates were between 17 and 24 April (depending on the year). A total of 175 kg N/ha, 60 kg P_2O_5/ha and 135 kg K_2O/ha were applied to the field in the form of manure and fertilizers.

Weather conditions and monitoring dates

The growing season of 2013 was characterized by normal daily average temperatures and normal precipitation in July followed by a dry August (Table 1). The growing season of 2014 was characterized by a rather chilly August and a warm October. Precipitation was high in July and August, followed by below-average rainfall in September and October. In 2015, the growing season was characterized by normal temperature and precipitation in July and August but a chilly September and October.

Six harvest dates were applied during plant maturation. Harvesting was initiated when kernels of the earliest hybrid Kalientes were at the dent stage (R5) (Ritchie *et al*. 1997) targeting a whole-crop DM content of about 25%. The first harvest date coincided with 2546–2632 OU depending on year (Table 2). Subsequent harvest dates were taken with intervals of 1 week (74–130 OU), targeting a whole-crop DM content of the earliest hybrid of about 40% at the last harvest date. At each harvesting moment, all varieties were harvested on the same day. Ten plants randomly chosen from the middle rows per plot were cut by hand 10 cm above soil level and were completely chopped (6–8 mm). Chopped material was subdivided into two sub-samples. The first was dried at 70 °C for 72 h to determine DM content and chemical parameters of the dried, unensiled material. The second was ensiled in airtight micro silos of 2·75-litres capacity at 200 kg DM/m^3. Ensiled forage was removed from the silos after 20 weeks, frozen and transferred into a freeze drier. Compared with oven drying, freeze drying reduces the loss of readily available organic constituents in fermented forages, such as volatile acids (Danley & Vetter 1971). All dry material

Table 1. *Monthly average temperatures and rainfall from July to October in 2013–2015*

	Average temperature (°C)			Historic means	Rainfall (mm/month)			Historic means
	2013	2014	2015	(1981–2010)	2013	2014	2015	(1981–2010)
July	19·9	19·4	18·6	18·3	87·2	90·5	41·1	70·7
August	19·0	16·7	18·8	18·0	16·8	159·7	72·0	72·7
September	15·1	16·4	13·6	15·0	70·1	34·4	75·3	69·7
October	12·9	14·2	10·4	11·4	83·5	61·4	42·8	77·1

Data registered in Merelbeke.

Table 2. *Ontario Units per harvest date and year*

Harvest date	2013	2014	2015	Mean
1	2632	2546	2619	2599
2	2749	2698	2735	2727
3	2852	2816	2828	2832
4	2949	2969	2910	2943
5	2987	3085	3005	3026
6	3106	3213	3031	3117

was milled over a 1-mm screen using a cutting mill (Retsch Model PK 1000, Retsch, Aartselaar, Belgium).

Determination of forage quality

Chemical parameters, including protein concentration, starch concentration, neutral detergent fibre (NDF), organic matter digestibility (OMD) and NDFD were estimated using near-infrared spectra (NIRS) measured at 1100–2500 nm at 4-nm intervals using an Infralyzer 500 spectrophotometer (Bran & Luebbe, Norderstedt, Germany). After scanning all samples with NIRS, a calibration set was chosen to represent the chemical variability using the algorithm SELECT. Prediction equations were developed based on the chemical values of the calibration set for both fresh and ensiled samples. Statistics relating to NIRS predictions are provided in Table 3. It was possible to use a more accurate prediction with a larger number of samples because NIRS calibrations for fresh maize were already available. Due to the lower number of ensiled samples, the high standard error of calibration could not be verified. Therefore, NDFD results should be interpreted carefully.

The samples in the calibration set were subjected to standard wet chemical analyses. Crude protein concentration was determined by the Kjeldahl method (ISO, 2005). Starch concentrations were analyzed polarimetrically (ISO, 2000). The determination of NDF was based on the laboratory procedures given by Goering & van Soest (1970) using heat-stable amylase and sodium sulphite. Cell wall digestibility, expressed as percentage digestible NDF, was determined after 48 h incubation with buffered rumen fluid followed by NDF determination of the undigested residue. The determination of OMD was based on the *in vitro* cellulase technique (De Boever *et al*. 1997).

Determination of the harvest window

The harvest window is defined as the set of harvest dates that results in a stable variety rank, adapted from the methodology in Swanckaert *et al*. (2016). The harvest window was calculated according to the methodology presented in Table 4. First, the H_{opt} was calculated as the date(s) where both starch concentration and OMD were at maximum. It was calculated for both fresh and ensiled forage using fresh and ensiled starch and OMD values, respectively. This calculation of H_{opt} was performed using a Tukey Test comparing harvest dates with the date showing the highest values for these two parameters. All dates with values not significantly different from the date with maximal values were designated as H_{opt}. In consideration of requirements for conservation, only dates with whole-crop DM contents between 25 and 40% were used in the calculation of H_{opt}. Second, the mean value of each parameter at H_{opt} was calculated, resulting in a variety rank across all H_{opt} per parameter. Third, the difference between the mean value for the fresh parameter and its mean value for the ensiled parameter at H_{opt} was calculated for each harvest date. Fourth, a harvest window per parameter was calculated based on analyses of variance (ANOVAs) using the differences in step 3 as independent variables with the factors variety (V), harvest date (HD), year (Y) and all interactions. Harvest dates

Table 3. *Statistics relating to near-infrared spectroscopy (NIRS) predictions of protein concentration, starch concentration, organic matter digestibility (OMD), neutral detergent fibre (NDF) and cell wall digestibility (NDFD)*

Parameter	*N**	Mean	SEC†	SEV(C)‡	R^2
Fresh forage					
Protein concentration (g/kg DM)	6529	7·6	0·37	0·38	0·90
Starch concentration (g/kg DM)	7283	28·7	1·66	1·68	0·97
OMD (g/kg organic matter (OM))	2902	72·5	1·89	1·93	0·92
NDF (g/kg DM)	192	41·7	1·28	1·49	0·92
NDFD (g/kg NDF)	192	63·3	2·36	2·84	0·82
Ensiled forage					
Protein concentration (g/kg DM)	63	7·4	0·22	0·32	0·84
Starch concentration (g/kg DM)	62	35·4	1·71	2·24	0·91
OMD (g/kg OM)	63	73·8	1·68	2·01	0·77
NDF (g/kg DM)	63	34·0	1·92	2·28	0·68
NDFD (g/kg NDF)	63	49·1	5·31	7·61	0·78

DM, dry matter.

* *N*, number of data points used to develop NIRS calibration.

† SEC, standard error of calibration.

‡ SEV(C), standard error of cross-validation.

were included in the harvest window if interactions HD × V, HD × V × Y were not significant. ANOVAs were iteratively recalculated by stepwise elimination of the harvest date that deviated most from H_{opt} until all interactions including HD × V became non-significant. The remaining dates represented the harvest window. Statistical analyses were performed using the statistical program R (version 3.1·1). Significance was declared at $P < 0·05$. Normality and equal variances were checked with a quantile–quantile plot and Levene's test, respectively.

RESULTS

Whole-crop DM content increased linearly during maturation with 1·9 % units per 100 OU (Table 5 and Fig. 1(*a*)). Whole-crop DM contents were on average 26% at the first harvest date, corresponding with an average of 2600 OU. At the last harvest date, DM contents varied between 36·5 and 39% depending on the variety. The difference in DM content between all compared varieties ranged from 1·6 to 3% units at any harvest date. The DM recovery (expressed as a ratio of DM in the silage to DM in the fresh harvested forage) varied between 953 and 997 g silage DM/kg DM at harvest. Crude protein concentrations of the fresh forage decreased linearly from 80 to 70 g/kg DM (Table 5 and Fig. 1(*b*)), while protein concentrations of the ensiled forage remained constant (76 g/kg DM). Starch concentrations increased quadratically in the ensiled forage; the difference between fresh and ensiled forage increased from 30 g/kg DM at 2600 OU to 60 g/kg DM at 3200 OU (Table 5 and Fig. 1(*c*)). Average values for OMD were lower for the ensiled forage compared with the fresh forage at the first harvest date. Ensiling did not change average values for OMD from harvest date 2 to 6 (Table 5 and Fig. 1(*d*)). Linear models best explained the relationship between NDF and OU (Table 5 and Fig. 1(*e*)): NDF concentrations of fresh and ensiled forage decreased with 5·8 g/kg DM per 100 OU and 8·4 g/kg DM per 100 OU, respectively. Neutral detergent fibre concentrations were 54 g/kg higher at 2600 OU for fresh forage compared with ensiled forage. Different relationships were observed for fresh and ensiled forage in the regression of NDFD on OU (Table 5 and Fig. 1(*f*)). In the fresh forage, NDFD increased linearly with 1·2 g/kg NDF per 100 OU. In the ensiled forage, NDFD decreased following a cubic model. At 3200 OU, the difference in NDFD between fresh and ensiled forage was 207 g/kg NDF.

Average values for each quality parameter at H_{opt} are shown in Table 6 for both fresh and ensiled forage and the corresponding difference. Supported by a Levene test, standard error of the mean (S.E.) values in Table 6 demonstrate that OU, DM concentration at harvest, starch concentration and NDF

Table 4. *Steps to calculate the harvest window* (*adapted from Swanckaert* et al. 2016)

For each	Calculation	Output
Step 1		
Variety* × year†	Calculate from available HDs the H_{opt} where starch concentration and OMD were calculated as not significantly different from the date with maximal values for both fresh and ensiled material, statistically secured by a Tukey test	Optimal harvest period (H_{opt})
Step 2		
Variety* × year† × parameter‡	Determine mean silage value of each parameter at H_{opt}	Mean value at H_{opt}
Step 3		
Variety* × year† × HD§ × replicate × parameter‡	Determine for each harvest date the difference between the actual fresh value of a parameter and its mean ensiled value at H_{opt}	Deviation of the actual fresh value to the mean silage value at H_{opt}
Step 4		
Parameter‡	Perform an ANOVA using differences defined in Step 3 as independent variables with the factors variety (V), harvest date (HD), year (Y) and all interactions. In case of interaction HD × V, HD × V × Y, the ANOVA is iteratively calculated by stepwise eliminating HDs deviating most from H_{opt}. The calculation is stopped when all interactions including HD × V become non-significant.	Harvest window

HD, harvest date; OMD, organic matter digestibility; ANOVA, analyses of variance; NDF, neutral detergent fibre; NDFD, cell wall digestibility.
* Variety = Banguy, Kalientes, LG30·222, LG30·224, LG3220, Mas 17E, NK Falkone, Ronaldinio.
† Year = 2013, 2014, 2015.
‡ Parameter = starch concentration, protein concentration, OMD, NDF, NDFD.
§ Harvest date = 1, 2, 3, 4, 5, 6.

Table 5. *Regression equations for fresh and ensiled forage quality*

Parameter	Fresh		Ensiled	
	Regression equation	R^2	Regression equation	R^2
DM content (%)	$-23\cdot3 + 0\cdot019x$	0·89	$-23\cdot1 + 0\cdot019x$	0·89
Protein concentration (g/kg DM)	$108 - 0\cdot011x$	0·87	$66 + 0\cdot0032x$	0·35
Starch concentration (g/kg DM)	$-2147 + 1\cdot6x - 2\cdot5 \times 10^{-4}x^2$	0·70	$-2461 + 1\cdot8x - 2\cdot8 \times 10^{-4}x^2$	0·75
OMD (g/kg OM)	$343 + 0\cdot27x - 6\cdot3 \times 10^{-5}x^2 + 6\cdot4 \times 10^{-9}x^3$	0·79	$2806 - 2\cdot8x + 1\cdot2 \times 10^{-3}x^2 - 1\cdot6 \times 10^{-7}x^3$	0·61
NDF (g/kg DM)	$566 - 0\cdot058x$	0·61	$577 - 0\cdot084x$	0·53
NDFD (g/kg NDF)	$567 + 0\cdot012x$	0·66	$-25570 + 27\cdot0x - 9\cdot2 \times 10^{-3}x^2 + 1\cdot0 \times 10^{-6}x^3$	0·69

DM, dry matter; OMD, organic matter digestibility; NDF, neutral detergent fibre; NDFD, cell wall digestibility; x, Ontario Units.
Data were pooled across year, variety and replication ($n = 72$) and regressed against OU ($n = 6$).

varied equally in fresh and ensiled forage. For protein concentration and OMD, s.e. values decreased after ensiling. For NDFD, s.e. values were three times larger in the ensiled forage compared with the fresh forage. The number of OU to reach H_{opt} depended on variety in the ensiled forage ($P < 0\cdot01$) but not in the fresh forage. Changes in OU at H_{opt} due to ensiling did not depend on variety. Accordingly, DM content

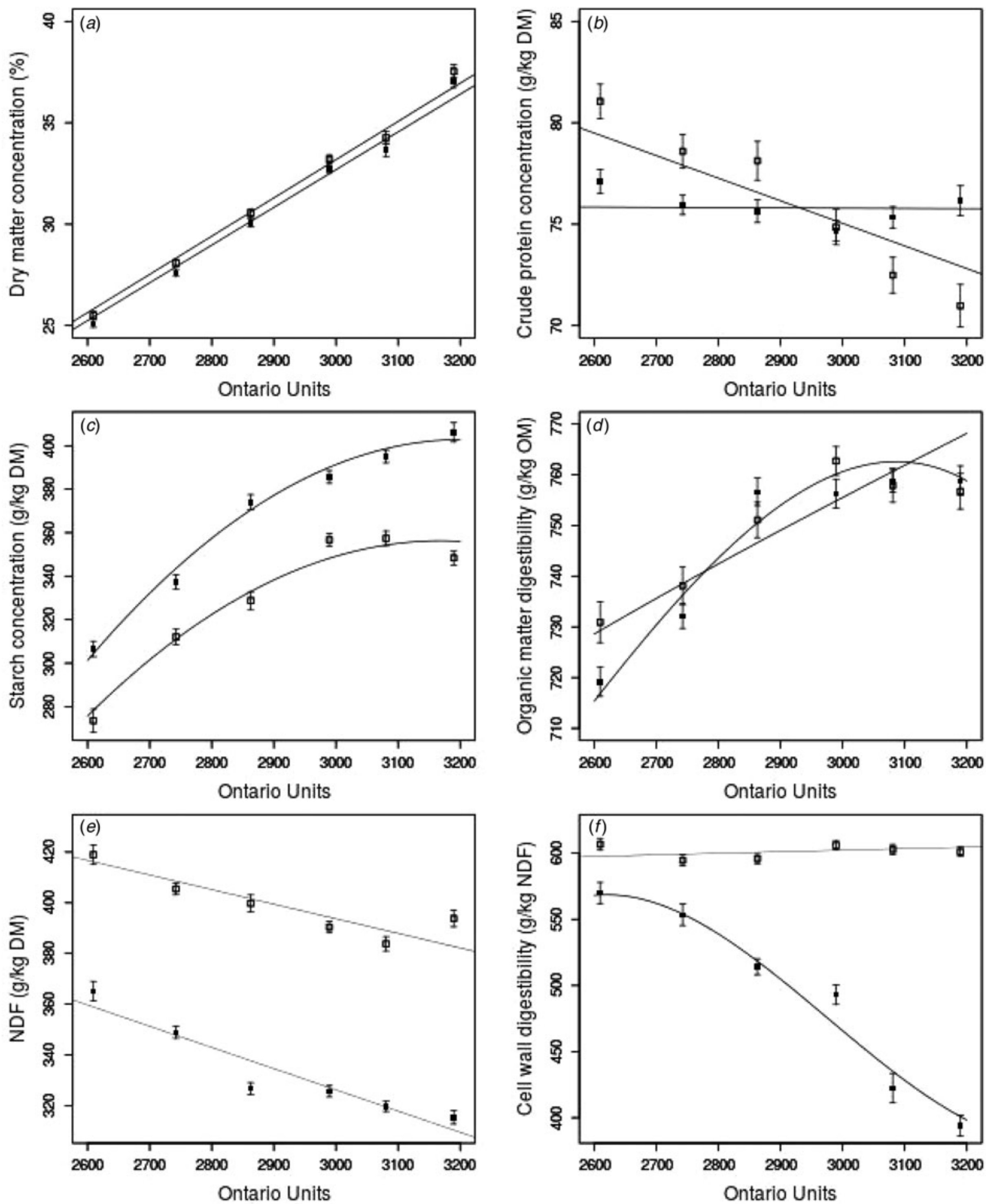

Fig. 1. Relationship between (*a*) dry matter content, (*b*) protein concentration, (*c*) starch concentration, (*d*) organic matter digestibility, (*e*) neutral detergent fibre and (*f*) cell wall digestibility and Ontario Units for fresh (□) and ensiled forage (■). Each data point is the mean across eight varieties, three replicates and 3 years. Equations and coefficients of determination (R^2) for Fig. 1 are reported in Table 5.

at harvest differed between varieties when H_{opt} was calculated with data from ensiled forage ($P < 0{\cdot}01$), but no difference was found when H_{opt} was calculated with data from fresh forage. At H_{opt}, protein and starch concentrations were always higher in the ensiled forage. The change in protein and starch concentrations

https://doi.org/10.1017/S0021859617000259 Published online by Cambridge University Press

Table 6. *Evaluation of Ontario Units (OU), dry matter (DM) content at harvest, protein concentration, starch concentration, organic matter digestibility (OMD), neutral detergent fibre (NDF) and cell wall digestibility (NDFD) at the optimal harvest period for fresh forage, ensiled forage and corresponding differences as means of the years 2013–2015*

Variety	OU	DM content at harvest (%)	Protein concentration (g/kg DM)	Starch concentration (g/kg DM)	OMD (g/kg OM)	NDF (g/kg DM)	NDFD (g/kg NDF)
Fresh forage							
Banguy	3038	34·1	71·0	364	775	379	628
Kalientes	3031	33·5	75·5	356	751	376	563
LG30·224	2999	32·8	73·3	348	760	398	614
LG30·222	3037	34·5	71·3	347	774	380	622
LG3220	3076	33·7	75·0	361	765	386	605
Mas 17E	3070	33·8	77·3	344	749	394	583
Nk Falkone	3025	33·2	72·1	346	744	402	591
Ronaldinio	3027	33·2	74·9	357	760	391	610
S.E.	26·4	0·25	0·86	2·2	3·0	2·4	3·2
P value	NS	NS	<0·001	NS	<0·001	<0·001	<0·001
Ensiled forage							
Banguy	3017	34·6	73·6	412	776	305	457
Kalientes	3037	33·2	78·3	397	766	314	445
LG30·224	2957	32·0	74·3	385	758	326	469
LG30·222	3078	35·0	74·6	407	767	306	405
LG3220	3083	33·1	76·8	400	769	311	452
Mas 17E	3042	33·1	78·2	392	759	320	415
Nk Falkone	3012	32·6	74·5	382	747	331	470
Ronaldinio	3018	32·5	75·1	389	750	328	434
S.E.	26·6	0·33	0·54	2·6	2·0	1·8	10·6
P value	<0·01	<0·01	<0·001	<0·05	<0·001	<0·001	NS
Ensiled – fresh forage							
Banguy	−21	0	2·7	48	1	−73	−171
Kalientes	6	−0·3	2·9	40	15	−62	−118
LG30·224	−42	−0·8	1·0	37	−2	−73	−145
LG30·222	23	0·4	2·7	59	−7	−75	−217
LG3220	8	−0·6	1·8	39	4	−75	−153
Mas 17E	−28	−0·7	0·9	47	10	−74	−168
Nk Falkone	−13	−0·6	2·4	36	3	−70	−120
Ronaldinio	−9	−0·7	0·2	32	−9	−63	−176
S.E.	16·6	0·12	0·55	2·9	2·8	2·3	10·4
P value	NS	<0·05	NS	NS	NS	NS	<0·05

S.E., standard error of mean; NS, non-significant.

varied between 0·2–3 g/kg DM and 32–59 g/kg DM, respectively, but these changes were not dependent on variety. Values for OMD at H_{opt} depended on variety for both fresh and ensiled forage ($P < 0·001$). Neutral detergent fibre concentrations at H_{opt} were 62–75 g/kg DM lower in the ensiled forage compared with fresh forage. The decrease in NDFD at H_{opt} varied between 118 and 217 g/kg NDF. Differences in NDFD between varieties were similar for fresh and ensiled forage, but NDFD in the ensiled forage was not dependent on variety.

The harvest window included all harvest dates for the parameters protein concentration, OMD, NDF and NDFD (Fig. 2). For starch concentration, the harvest window covered harvest dates 3–6. Consequently, the smallest harvest window comprised harvest dates

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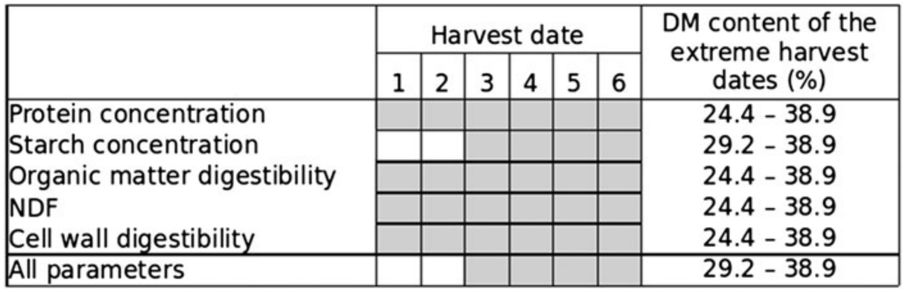

Fig. 2. Harvest window (presented by grey lanes) indicating harvest dates with a stable variety rank.

3–6 (2832–3117 OU); these harvest dates corresponded with a DM content of 29–39%.

DISCUSSION

The current trials were conducted in Belgium with a limited set of eight varieties. Although variety trials are usually performed at a regional level, the results most probably apply to any set of comparable varieties in any country with similar climatic conditions. These eight varieties differed in earliness and energy source, so physiological differences were expected to influence quality parameters, ensiling process and optimum harvest date. The difference in earliness was rather limited because the difference in DM content in the whole-crop was maximum 3% units at any harvest date. Both starch, which is almost completely digestible, and cell walls, which are partly digestible indicated by NDFD, contribute to the nutritive value indicated by OMD. Banguy scored best for OMD because of its high starch concentration, low NDF and high NDFD. The variety LG30·222 had a high OMD because the low NDF and high NDFD could compensate for the low starch concentration. Next in the ranking for OMD is LG3220 with a high starch concentration and average values for NDF and NDFD. LG30·224 and Ronaldinio had average values for OMD as a result of average values for starch, NDF and NDFD. Kalientes had below average values for OMD because it had the lowest NDFD. Mas 17E and NK Falkone had the lowest OMD because these varieties had the lowest values for starch, the highest values for NDF and lowest values for NDFD.

Quality changes due to ensiling were numerically comparable with Lynch *et al*. (2012), who studied six maize varieties in Ireland at three harvest dates. Similarly to Johnson *et al*. (2003), DM recovery values ranging from 953 to 997 g silage DM/kg DM at harvest, depending on variety and harvest date, were observed in the present study. At the first harvest date, the effluent losses were on average 15 g/kg ensiled forage (data not shown). As a result, OMD values for silage were lower than OMD values for the fresh forage at the first harvest date. If the fermentation occurs without effluent losses, usually a small DM loss associated with respiration of sugars is noticed. Due to this DM loss, protein concentration in the silage increased at later harvest dates. Values for starch concentrations were generally higher in ensiled forage compared with fresh forage. This suggests that relatively little breakdown or loss of starch occurred as part of the ensilage process. As hemicellulose is partially hydrolysed under acidic conditions (Filya 2004), forages with a high cell wall fraction tend to lose more hemicellulose than those with a small cell wall fraction, leading to a smaller variation in NDF between varieties in the ensiled forage. From all quality parameters, ensiling most severely influenced NDFD. The difference in NDFD between fresh and ensiled forage increased with increasing DM content at harvest, in line with Darby & Lauer (2002).

The H_{opt} was defined by optimizing starch concentration and OMD, as these parameters are analysed in variety trials in almost all EU countries. Ensiling did change the starch concentration and OMD, but the harvest date(s) with maximal values for fresh forage also showed maximal values after ensiling, resulting in a similar H_{opt} for fresh and ensiled forage. The average DM content for each variety at H_{opt} was between 32 and 35% with an overall mean of 33·4%. This range corresponds with the recommended range suggested by Johnson *et al*. (1999). Since H_{opt} corresponded with a range in DM content of 32–35%, monitoring DM content was a valuable proxy for monitoring OMD and starch to determine H_{opt} in the current set of varieties. The variation in quality differed between fresh and ensiled

https://doi.org/10.1017/S0021859617000259 Published online by Cambridge University Press

forage: compared with fresh forage, s.e. of silage was higher for NDFD; numerically lower for protein concentration, NDF and OMD. The s.e. value for NDFD of the ensiled forage was remarkably high. Therefore, the reliability of the NIRS-predicted NDFD values for silage are called into question. Indeed, statistics of the NIR predictions showed a high standard error of calibration for NDFD of the ensiled forage. Therefore, the results of NDFD will not be discussed further. At H_{opt}, changes in protein concentration, starch concentration, OMD and NDF due to ensiling did not depend on the variety. Lynch *et al*. (2012), who calculated quality differences due to ensiling at three harvest dates, found no effect of variety on differences of starch concentration and OMD, but differences of protein concentration and NDF were dependent on variety.

A harvest window for variety trials was defined by Swanckaert *et al*. (2016) as a set of harvest dates where the variety rank at the calculated H_{opt} is not statistically different from the rank at a given harvest date. By calculating H_{opt} using ensiled forage, the present study included the effect of ensiling in the harvest window. The harvest window for all parameters included harvest dates 3–6 (OU of 2832–3117). This span of about 300 OU offered a flexible harvest period of about 21 days. The variety rank based on fresh forage at any harvest date within this range equalled the variety rank based on ensiled forage of all studied varieties at H_{opt}. It is noted that it is easier to find no difference at a low P value than to find a significant difference. Therefore, the harvest window was calculated with $P <$ 0·1 and the results remain unchanged. The Belgian variety trials, currently based on fresh forage at a single harvest date (at a DM content of approximately 35%), correspond well to the conditions described above. This means that the variety rank currently based on analysing fresh samples is valid; there is no need to ensile the forage and to conduct analyses of ensiled material to rank varieties reliably.

CONCLUSION

The H_{opt} of the set of studied forage maize varieties could be predicted by frequently measuring starch concentration and OMD of fresh (i.e. non-preserved) forage. Eventually, harvesting the silage maize at a DM content of 32–35% guaranteed an H_{opt}. Based on the current results, reporting variety ranks without going through the ensiling process continues to be a scientifically justified practice in the Belgian Official Variety Trials. Farmers do not need to worry: the varieties with the best quality according to the Official National List Trials continue to be the best when fed as silage to animals. The key question 'to what extent do varieties with a superior fresh quality maintain their characteristics when ensiled?' can be answered as follows: varieties with a superior fresh quality keep their leading position after ensiling, but variety differences become smaller after ensiling.

The authors would like to thank Chris Van Waes for his contribution to the laboratory analyses and NIRS calculations.

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