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Prediction of voluntary intake and digestibility of maize silages given to sheep from morphological and chemical composition, *in vitro* digestibility or rumen degradation characteristics

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Abstract

Eleven maize silages with crude protein (CP) and neutral detergent fibre (NDF) ranging from 77 to 93 and 359 to 542 g/kg dry matter (DM) respectively, were used to study the relationship between ear content, chemical composition, fermentative characteristics, in vitro *DM digestibility and ruminal degradation characteristics, on the one hand, and the voluntary DM intake by sheep or* in vivo *organic matter apparent digestibility (OM digestibility), on the other.*

The silages were offered ad libitum *to mature ewes given a daily supplement of 85 g of soya-bean meal. DM intake varied from 41·1 to 68·6 g DM per kg* $M^{0.75}$ *daily. OM digestibility and NDF apparent digestibility were measured, using the same ewes in a period subsequent to that of voluntary intake measurement. The silages, in this case, were offered at a feeding level of 1·2 maintenance. OM digestibility and NDF apparent digestibility ranged from 0·622 to 0·757 and from 0·377 to 0·605, respectively. Rumen DM disappearance was measured by incubating samples in nylon bags in the rumen of three silage-fed rumen-cannulated wethers for 3, 6, 12, 24, 48 and 72 h and by fitting the exponential model* $y = a + b(1 - e^{-ct})$ *to the results. Potential degradabilities (defined as* a + b*) for DM ranged from 728 to 815 g/kg.*

Accurate prediction of DM intake ($r = 0{\cdot}93$; $P < 0{\cdot}01$; *residual s.d. = 3·9) and OM digestibility (*$r = 0{\cdot}86$; $P < 0{\cdot}01$; *residual s.d. = 0·022) was achieved using the soluble fraction* (a) *and the insoluble but fermentable matter* (B) *and the insoluble but potentially degradable fraction* (b)*, respectively. However, looking for a compromise between accuracy and simplicity, reliability and inexpensiveness, ear content is proposed as a predictor of OM digestibility (*$r = 0{\cdot}85$; $P < 0{\cdot}01$*) and the pH and acetic acid concentration of the silages may be used as a predictor of DM intake (*$r = 0{\cdot}80$; $P < 0{\cdot}05$*).*

Keywords: *degradation, digestibility, food intake, maize silage, sheep.*

Introduction

Maize is probably one of the best plants to store as silage due to the high content of fermentable water-soluble carbohydrates, a low buffering capacity and a high dry matter (DM) content; that is to say, the characteristics of an ideal crop for preservation as silage (McDonald *et al.*, 1991). In spite of this, voluntary intake of maize silage is less than that of the same crop offered fresh (Andrieu and Demarquilly, 1974).

The difficulty of predicting the voluntary intake of silages has often been attributed to the effects of fermentation end products present in the silage, although these effects have not always been shown. For example, Wilkins et *al.* (1971) working with grass, cereal and legume silages, given to wethers, concluded that the voluntary intake is negatively correlated with the contents of acetic acid and ammonia, whereas Buchanan-Smith (1990) found that ammonia had no negative effect on intake of lucerne silage and Van Os *et al.* (1995) found that the addition of ammonia (NH_3) was not the causal factor in the negative correlations between silage NH_3-nitrogen content and intake observed by other authors. McLeod *et al.* (1970) concluded that the acids

produced during the normal grass silage fermentation can limit the intake in calves and wethers but Phillip *et al.* (1981) found that food intake was unaffected by intraruminal infusion of acetic acid. Finally, other products of protein degradation such as amines may also affect silage intake (Buchanan-Smith and Phillip, 1986) although Van Os *et al.* (1995) found that the amines tended to reduce DM intake only.

Several equations have been proposed to predict maize silage digestibility (Jones *et al.*, 1980; Andrieu, 1984) and DM intake of maize silages (Jones *et al.*, 1980) although none include cultivars with exotic germplasm in their pedigree. The aim of the present study was to assess the possibility of predicting voluntary DM intake and apparent organic-matter (OM) digestibility (OM digestibility) of maize silage, given to sheep, from morphological and chemical characteristics, *in vitro* digestibility and ruminal degradation characteristics.

Material and methods

Silages

Eleven maize (*Zea mays*) silages were made using plastic containers with a capacity of 1100 litres. Five adapted (S1 to S5) and six (S6 to S11) semiexotic materials (Table 1), obtained by crossing adapted and tropical populations provided by the International Maize and Wheat Improvement Centre (CIMMYT), were cultivated in Caldes de Montbui (north-east Spain) with irrigated conditions in the summers of 1993 and 1994. After harvesting, the plants were chopped with a precision-chop forage harvester, stored in containers, covered with plastic sheets and weighted with bricks. Two containers for each material were employed. Prior to ensilage, ear content, as a proportion of the contribution of the ear in the total yield, was measured and stover samples taken (except in the case of S9). The materials were harvested with an average DM concentration of 310 g/kg.

Voluntary intake of silages

The maize silages were offered to eight mature Manchega-bred ewes (average body weight 64·2 (s.d. 1·2) kg), which were neither lactating nor pregnant, kept in individual pens with free access to water and salt blocks. The eight ewes were randomly put into two groups each of four animals. Five experimental periods, each one lasting for 3 weeks, with 2 weeks of adaptation and 1 week of measurement, were used. During each period, two silages were selected at random, one of which was given to one group of four animals, and the other to the other group. The silage was offered every day, at the same time (09.00 h), *ad libitum* (proportionally 0·15 in excess of the previous day's consumption) together with 85 g soya-bean meal per animal to avoid a deficit of degradable protein. Prior to the experiment all sheep were given a commercial maize silage (AE703, Agrar Semillas S.A., Zaragoza, Spain), *ad libitum*, for 3 weeks. Silage and residue samples were taken daily and bulked over the last 7 days of each period for each treatment

Table 1 *Characteristics of cultivars*

Silage	Cultivar type	FAO maturity rate	Pedigree
S1	Adapted	700	Commercial hybrid AE703 (Agrar Semillas S.A., Zaragoza, Spain) of unknown pedigree
S2	Adapted	400	Commercial hybrid CARMINA (Pioneer Hi-Brand Intern., Inc., Johnston, USA) of unknown pedigree
S3	Adapted	700	Adapted open pollinated population Lancaster surecrop
S4	Adapted	700	Commercial hybrid A640 (Adour, Semillas Fitó S.A., Barcelona, Spain) of unknown pedigree
S5	Adapted	400	Commercial hybrid SABRINA (Pioneer Hi-Brand Intern., Inc., Johnston, USA) of unknown pedigree
S6	Semiexotic	900	(Mo17 × Brazil 1792) × B73†
S7	Semiexotic	1000	B73 × Brazil 1792†
S8	Semiexotic	1000	B73 × Across 8443‡
S9	Semiexotic	1000	B73 × V465§
S10	Semiexotic	1000	L696 × Across 8443‖
S11	Semiexotic	1000	B73 × Brazil 1741¶

† Mo17 B73: adapted public inbred; Brazil 1792: exotic open pollinated population with Cateto racial composition.
‡ Across 8443: exotic open pollinated population with Tuxpeño racial composition.
§ V465: exotic open pollinated population from Brazil of unknown racial composition.
‖ L696: experimental adapted inbred.
¶ Brazil 1741: exotic open pollinated population with Cateto Paulistic racial composition.

and stored at –20°C until analysis. Animals were weighed at the beginning and the end of each period, and the mean live weights were used to calculate the individual intakes per kg $M^{0.75}$ per day. The sheep were treated for nematoda (7·5 mg netobimin per kg live weight, Hapasil, Shering-Plough S.A., San Agustin de Guadalix, Spain) before starting the experimental period.

Apparent digestibility

In vivo apparent digestibility was recorded using the same design and the same ewes employed in the voluntary intake measurement, in a subsequent period. The silage was offered at a feeding level of 1·2 maintenance, together with 85 g soya-bean meal. Each period was of 3 weeks' duration, with 2 weeks of adaptation and 1 week of measurement. The ewes were housed in metabolism cages with free access to water and salt blocks. Faeces were collected daily and samples of silages and faeces were also taken and bulked over the last 7 days of each period and stored at –20°C. The *in vitro* DM digestibility (Tilley and Terry, 1963) was determined according to the modified method of Alexander and McGowan (1966).

DM degradation in situ

DM degradation was determined by incubating about 3 g dry sample in nylon bags in the rumen of the three cannulated wethers. The samples were dried for 72 h in a forced-air oven at 40°C and milled through a 1·5-mm screen. The bags measured 125 × 100 mm, with an average pore size of 50 µm. Duplicates of bags were withdrawn after 3, 6, 12, 24, 48 and 72 h, washed for 15 min in a washing machine and dried for 48 h at 60°C. Zero-time washing losses were estimated by soaking two bags per sample in warm tap water (39°C) for 30 min followed by washing and drying as before. The wethers were given a commercial maize silage (AE703, Agrar Semillas S.A., Zaragoza, Spain) *ad libitum* plus 85 g soya-bean meal.

Chemical analysis

Stover and faeces samples were dried in a forced air-oven at 60°C and milled through a 1 mm screen for chemical analysis. DM was determined at 103°C for 48 h. Ash content was measured gravimetrically by igniting samples in a muffle furnace at 550°C for 4 h. Crude protein (CP) was determined by Kjeldahl procedure (N × 6·25) on a Kjeltec Auto 1030 Analyser (Tecator, Höganäs, Sweden) and ether extract (EE) by the Soxhlet method (European Communities, 1984). Neutral-detergent fibre (NDF) was determined by the method of Van Soest *et al.* (1991), acid-detergent fibre (ADF) and acid-detergent lignin (ADL) according to the method of Goering and Van Soest (1970).

Silage samples were mixed thoroughly and two subsamples taken. One subsample was dried and milled for determination of DM, ash, EE, NDF, ADF and ADL content as described before. DM was corrected for volatile components lost (Dulphy and Demarquilly, 1981). The remaining wet subsample was analysed for concentration of total nitrogen (N) (Kjeldahl method) and NH_3-N (Association of Official Analytical Chemists, 1990) and used to obtain silage juice for the determination of pH and water-soluble N (Nsol) (Dulphy and Demarquilly, 1981) and volatile fatty acids (VFA). VFA were determined by gas chromatography. Samples were prepared according to the method of Guitart *et al.* (1996) with the modified amount of 2 ml of sample. Derivatized extract (0·5 µl) containing heptanoic acid as an internal standard was injected into a gas chromatograph equipped with a Stabilwax metallic capillary column of 60 m × 0·53 mm i.d. (Restek, Bellefonte, USA) using helium as a carrier gas at 14 m/min. The column was held at 50°C and then ramped at 2°C per min to 110°C. Injector and detector temperatures were 270°C.

Statistical analysis

The values for disappearance of DM with time were fitted to the exponential equation: $y = a + b(1 - e^{-ct})$ of Ørskov and McDonald (1979), where y is DM degradation at time t, a represents the immediately soluble material, b is the insoluble but potentially degradable material and c the rate of degradation. Potential degradability was defined as $(a + b)$. A was defined as the initial washing loss, while the insoluble but fermentable matter was defined as $B = (a + b) - A$. Data for DM intake and apparent OM digestibility of silages were submitted to a one-way variance analysis, using the general linear model procedure of Statistical Analysis Systems Institute (SAS, 1990). The comparison between adapted and semiexotic materials was also made by analysis of variance. A correlation matrix between the data for ear content, chemical composition, intake, *in vivo* and *in vitro* digestibility and *in situ* DM degradation was obtained. Stepwise regression was used to find the best fitting equation for DM intake and OM digestibilty using the stepwise procedure of SAS (1990).

Results

The ear content and the stover chemical composition are given in Table 2. At harvest, ear content ranged between 380 and 550 g/kg DM. Three cultivars, two adapted (S1, S4) and one semiexotic (S8) had an ear content higher than 500 g/kg DM. The stover NDF, ADF and ADL concentration, expressed as g/kg DM, varied from 570 to 696, from 311 to 403 and from 34 to 60, respectively.

Table 2 *Ear content of the whole plants and chemical composition of stover maizes*

Silages†	Ear content (g/kg DM)	Chemical constituents (g/kg dry matter (DM))				
		Ash	Crude protein	Neutral-detergent fibre	Acid-detergent fibre	Acid-detergent lignin
S1	550	92	63	639	354	46
S2	400	81	63	570	311	34
S3	460	85	63	586	333	48
S4	520	81	61	647	381	56
S5	400	81	64	571	312	34
S6	490	107	75	691	403	60
S7	420	106	76	642	372	56
S8	520	116	71	669	390	54
S10	380	102	62	696	328	39
S11	430	80	67	646	316	52
Mean	460	93	67	634	350	48
s.e.	18·8	4·3	1·8	14·5	10·9	3·0

† 59 was not measured.

The chemical composition and the fermentative characteristics of silages are given in Table 3. The CP concentration ranged from 77 to 93 g/kg DM. Cell wall concentration (as defined by NDF) varied from 359 to 542 g/kg DM and ADL ranged from 26 to 45 g/kg DM. The mean values of the fermentative characteristics (Table 3) showed that, in general, the silages were of good quality according to the classification of Dulphy and Demarquilly (1981). The best silage, in relation to the fermentative characteristics, was S10 and the worst S5, S6 and S7. In the case of S6, the high level of volatile fatty acids was due to a high level of propionic acid although the acetic acid content was low. The pH of silages ranged from 3·50 to 3·83.

The degradation characteristics are given in Table 4. The zero time washing loss of DM ranged from 242 to 415 g/kg DM. The insoluble but fermentable matter (*B*) varied from 331 to 515 g/kg DM, potential DM degradation from 728 to 815 g/kg DM and *c* values from 0·024 to 0·053.

The mean DM intake of the maize silages was 57·2 (s.e. 2·5) g DM per kg $M^{0.75}$ per day and ranged from 41·1 to 68·6 g DM per kg $M^{0.75}$ per day (Table 5). OM

Table 3 *Chemical composition and fermentative characteristics of the maize silages*

Silages	Chemical constituents (g/kg dry matter (DM))						Fermentative characteristics				
	Ash	Crude protein	Neutral-detergent fibre	Acid-detergent fibre	Acid-detergent lignin	Ether extract	pH	Acetic acid (g/kg DM)	Volatile fatty acid (mmol/kg DM)	Ammonia nitrogen (% total N)	Water-soluble nitrogen (% total N)
S1	49	77	359	193	26	31	3·75	22	399	6·3	46·4
S2	77	93	449	254	37	31	3·56	25	437	6·9	60·2
S3	60	82	449	241	28	31	3·68	15	259	6·1	67·8
S4	51	77	420	234	28	29	3·71	25	437	5·4	51·6
S5	62	87	542	321	45	27	3·50	41	723	6·9	63·3
S6	55	84	436	246	37	32	3·83	18	984	8·4	56·3
S7	67	89	457	268	44	29	3·69	41	785	7·4	66·7
S8	66	85	464	273	43	27	3·59	23	403	6·5	65·1
S9	54	84	363	209	30	34	3·77	26	462	8·4	47·6
S10	72	78	507	249	40	25	3·73	13	237	4·7	49·7
S11	61	82	487	243	37	30	3·56	29	510	6·0	63·8
Mean	61	84	448	248	36	30	3·67	25	512	6·6	58·0
s.e.	2·6	1·5	16·6	10·1	2·1	0·7	0·03	2·7	65·5	0·3	2·4

Table 4 *Dry matter (DM) degradability (g/kg DM) of silages after 12, 24 and 48 h and their degradation characteristics obtained by fitting data of DM degradation over 72 h incubation to the equation* $y = a + b(1 - e^{-ct})$†

	DM degradation after:							
Silages	12 h	24 h	48 h	*A*	*B*	*a* + *b*	*c*	Residual s.d.
S1	476	536	660	415	331	745	0·025	2·4
S2	443	492	659	320	471	791	0·026	2·3
S3	456	527	621	321	439	759	0·027	1·3
S4	428	561	654	324	455	779	0·027	1·6
S5	490	614	674	320	419	739	0·053	2·3
S6	449	547	680	242	516	759	0·037	4·0
S7	441	557	658	304	511	816	0·026	1·6
S8	492	573	625	356	388	744	0·030	2·5
S10	427	515	616	248	480	728	0·034	2·0
S11	363	500	624	279	485	764	0·024	2·0
Mean	447	542	647	313	449	762	0·031	
s.d.	38	36	23	51	58	27	0·009	

† *A* is the washing loss (water soluble fraction) and $B = (a + b) - A$ is the insoluble but fermentable matter; *a*, *b* and *c* are the constants in the exponential equation $y = a + b(1 - e^{-ct})$; $a + b$ is the potential DM degradation and *c* is the rate of DM degradation. S9 was not measured.

digestibility and NDF apparent digestibility varied from 0·622 to 0·757 and from 0·377 to 0·605 respectively. The mean values were 0·678 (s.e. 0·012) and 0·491 (s.e. 0·021) for OM digestibility and NDF apparent digestibility, respectively.

Significant differences between adapted and semiexotic cultivars were only found in stover fibre components, whereas the silage chemical composition of the adapted and semiexotic materials was similar. The adapted and semiexotic materials

Table 5 *Dry matter (DM intake in g DM per kg* $M^{0.75}$ *per day),* in vivo *apparent digestibility of organic matter (OM digestibility),* in vivo *apparent digestibility of cell walls (NDF digestibility) and* in vitro *digestibility of dry matter* (in vitro *DM digestibility) of the maize silages*

	DM intake	s.e.	*In vivo* OM digestibility	s.e.	*In vivo* NDF digestibility	s.e.	*In vitro* DM digestibility
Silages							
S1	$60·1^{ab}$	4·48	$0·757^{a}$	0·011	$0·437^{de}$	0·023	0·736
S2	$54·8^{bc}$	3·32	$0·652^{cde}$	0·010	$0·485^{bcd}$	0·028	0·681
S3	$46·2^{cd}$	1·98	$0·695^{bc}$	0·005	$0·552^{ab}$	0·008	0·663
S4	$62·5^{ab}$	1·71	$0·722^{ab}$	0·013	$0·538^{abc}$	0·023	0·685
S5	$41·1^{d}$	0·85	$0·680^{bcd}$	0·016	$0·605^{a}$	0·024	0·669
S6	$68·4^{a}$	5·14	$0·679^{bcd}$	0·008	$0·475^{cd}$	0·014	0·690
S7	$68·6^{a}$	4·25	$0·622^{e}$	0·015	$0·446^{de}$	0·030	0·668
S8	$51·4^{bcd}$	2·56	†		†		0·635
S9	†		$0·680^{bcd}$	0·023	$0·377^{e}$	0·043	0·692
S10	$57·2^{bc}$	3·36	$0·648^{de}$	0·018	$0·497^{bcd}$	0·005	0·639
S11	$56·9^{bc}$	3·63	$0·672^{cd}$	0·007	$0·536^{abc}$	0·006	0·619
Mean	57·2		0·678		0·491		0·671
s.d.	7·9		0·039		0·065		0·031
Adapted cultivars							
Mean	52·9		0·701		0·524		0·687
s.d.	9·1		0·040		0·066		0·029
Semiexotic cultivars							
Mean	60·5		0·660		0·467		0·657
s.d.	7·7		0·025		0·060		0·030

^{a,b,c,d,e} Means in the same column with different superscripts differ significantly ($P < 0·05$).
† Not measured.

Table 6 *Correlation matrix (r) between ear content, fibre components, ruminal degradation constants and* in vivo *and* in vitro *measures*†

	Ear content	Stover fibre components			Silage fibre components			Fermentative characteristics					Ruminal degradation constants			*In vivo* digestibility of			*In vitro* DM digestibility
		NDF	ADF	ADL	NDF	ADF	ADL	pH	Acetic acid	VFA	NH_3-N	Nsol	*a*	*b*	*c*	DM intake	OM	NDF	
Ear content	1·00																		
Stover:																			
NDF	0·27	1·00																	
ADF	0·69*	0·63*	1·00																
ADL	0·60	0·60	0·83**	1·00															
Silage:																			
NDF	–0·77**	–0·14	–0·47	–0·41	1·00														
ADF	–0·55	–0·32	–0·21	–0·32	0·87***	1·00													
ADL	–0·58	0·07	–0·08	–0·18	0·77**	0·84***	1·00												
pH	0·42	0·64*	0·63*	0·53	–0·64*	–0·67*	–0·51	1·00											
Acetic acid	–0·25	–0·38	–0·13	–0·09	0·26	0·52	0·51	–0·49	1·00										
VFA	–0·04	0·10	0·40	0·35	0·12	0·36	0·42	0·11	0·52	1·00									
NH_3-N	0·09	–0·10	0·38	0·28	–0·35	–0·01	0·08	0·25	0·31	0·69*	1·00								
Nsol	–0·31	–0·42	–0·14	0·08	0·58	0·66*	0·51	–0·61*	0·35	0·21	0·06	1·00							
a	0·87***	0·12	0·55	0·42	–0·78**	–0·50	–0·44	0·28	–0·10	–0·15	0·09	–0·16	1·00						
b	–0·84**	–0·22	–0·44	–0·26	0·61	0·46	0·41	–0·26	0·29	0·28	0·08	0·30	–0·90***	1·00					
c	–0·32	–0·15	–0·14	–0·39	0·63*	0·73**	0·52	–0·25	0·30	0·41	0·22	0·05	–0·45	0·20	1·00				
DM intake	0·25	0·63*	0·62*	0·64*	–0·51	–0·49	–0·13	0·70*	–0·04	0·41	0·27	–0·37	–0·37	0·19	0·05	1·00			
OM apparent digestibility	0·85**	–0·04	0·19	0·13	–0·54	–0·53	–0·77**	0·24	–0·29	–0·26	–0·18	–0·49	0·69*	–0·86**	–0·10	–0·11	1·00		
NDF apparent digestibility	–0·29	–0·46	–0·47	–0·31	0·76**	0·67*	0·29	–0·64*	0·11	–0·03	–0·49	0·54	–0·52	0·33	0·56	–0·77**	0·04	1·00	
In vitro DM digestibility	0·49	–0·17	0·25	–0·02	–0·72**	–0·50	–0·56	0·50	–0·01	0·19	0·36	–0·57	0·50	–0·40	–0·03	0·28	0·62*	–0·46	1·00

† NDF = neutral-detergent fibre; ADF = acid-detergent fibre; ADL = acid-detergent lignin; VFA = volatile fatty acid; NH_3-N = ammonia nitrogen; Nsol = water-soluble nitrogen; OM = organic matter; DM = dry matter; for ruminal degradation constants see Table 4 footnote.

were no different for DM intake (52·9 *v.* 60·5, $P > 0·05$), or OM digestibility (0·701 *v.* 0·660, $P > 0·05$) (Table 5).

The simple correlation coefficients between the most relevant variables and a series of DM intake and OM digestibility prediction equations are given in Tables 6 and 7, respectively. The correlation matrix shows the negative correlation between NDF of silage and ear content ($r = -0·77$, $P < 0·01$). The constants *a* and *b* were significantly correlated with the ear content ($r = 0·87$; $P < 0·001$, and $r = -0·84$; $P < 0·01$, respectively) and with silage NDF concentration ($r = -0·78$; $P < 0·01$ and $r = 0·61$; $P < 0·10$, respectively). The correlations between the constant *c* and the NDF and ADF concentration were positive and significant ($r = 0·63$; $P < 0·05$ and $r = 0·73$; $P < 0·01$, respectively), as were those between *c* and the amount of digestible cell walls (NDF × NDF digestibility) ($r = 0·70$; $P < 0·05$; not tabulated).

There was no correlation between DM intake and *in vivo* OM digestibility, but DM intake was correlated ($P < 0·01$) with the amount of digestible cell wall ($r = -0·73$; not tabulated). On the other hand, DM intake was positively and significantly ($P < 0·05$) correlated with the stover fibre components ($r = 0·63$, $r = 0·62$ and $r = 0·64$ for NDF, ADF and ADL, respectively) and with the pH of the silage ($r = 0·70$; $P < 0·05$). When the acetic acid concentration was added to the silage pH the equation accounted for 0·64 of the variability in DM intake (Table 7). The correlations between DM intake and the potential DM degradation ($a + b$) and the constant *c* were $r = 0·50$ and $r = -0·45$, respectively and neither were significant ($P > 0·05$).

OM digestibility was correlated positively with the ear content ($r = 0·85$; $P < 0·01$) and negatively with silage ADL concentration ($r = -0·77$; $P < 0·01$). *In vitro* DM digestibility was also significantly correlated with *in vivo* OM digestibility ($r = 0·62$; $P < 0·05$). The constants *a* and *b* accounted for proportionately 0·48 and 0·74 of the variability in OM digestibility respectively when considered individually.

Discussion

Ear content was a good predictor of OM digestibility. This variable accounted for proportionately 0·72 of the variability in OM digestibility, in agreement with Andrieu (1984) who found a good correlation between both OM digestibility and energy value of maize silages, and the grain content. The high positive correlation ($r = 0·87$; $P < 0·001$) between ear content and the constant *a* can be attributed to the high level of non-structural carbohydrates linked to a high grain content. On the other hand, the similar potential DM degradation of the silages could explain the high and negative correlation between ear content and the constant *b* ($r = -0·84$; $P < 0·01$) and the negative and significant correlation between *a* and *b* ($r = -0·90$; $P < 0·001$).

The DM intake predictive value of the chemical composition of the silage has been reported by several authors. Laforest *et al.* (1986), working with legume and grass silages, found that the intake of DM was correlated positively with CP ($r = 0·92$) and negatively with NDF ($r = -0·87$). Jones *et al.* (1980), with maize silages, hay crop silages and mixtures of both, also found the same kind of relationships. In

Table 7 *Multiple stepwise regressions between DM intake (g DM per kg $M^{0·75}$ per day) or OM digestibility and ear content, fibre components, fermentative characteristics,* in vitro *DM digestibility and* in situ *DM degradation*†

Y	Technique	Equation	*r*	Significance	Residual s.d.
DM intake					
	Stover fibre components	28·09 + 0·60 (ADL)	0·641	0·046	7·2
	Silage fibre components	70·50 – 0·13 (NDF) + 329·2 (ADL/ADF)	0·757	0·051	6·6
	Fermentative characteristics	–249·34 + 80·74 (pH) + 0·42 (acetic)	0·802	0·027	6·0
	In situ DM degradation	–81·21 + 0·12 (*a*) + 0·22 (*B*)‡	0·932	0·002	3·9
	All four techniques	–188·66 + 0·12 stover NDF + 1·98 NH_3-N –0·51 Nsol + 0·24 ($a + b$)	0·990	0·001	1·7
OM digestibility					
	Ear content	0·4163 + 0·0006 (ear content)	0·849	0·004	0·023
	Silage fibre components	0·8305 – 0·0043 (ADL)	0·769	0·009	0·025
	In vitro DM digestibility	0·1728 + 0·75 (*in vitro* DM digestibility)	0·624	0·054	0·032
	In situ DM degradation	0·9828 – 0·0007 (*b*)	0·862	0·003	0·022
	All four techniques	0·9828 – 0·0007 (*b*)	0·862	0·003	0·022

† For abbreviations see Table 6.
‡ Equation obtained removing the silage S1.

our case, the DM intake was significantly correlated with the stover fibre components ($P < 0.05$). The stover NDF, ADF and ADL accounted for proportionately 0·40, 0·38 and 0·41 of the variability in DM intake respectively when considered individually. The best predictive equation using only the stover fibre components is shown in Table 7 and it was through the stover ADL. In relation to the fibre components of the silages, when an index of lignification (ADL/ADF) was added to the cell wall concentration (NDF), the DM intake predictive value of the multiple regression equation was improved significantly ($P < 0.05$) and the equation then accounted for 0·57 of the variability. On the other hand, the silage ADL concentration was a good predictor of OM digestibility whereas the other fibre components did not increase significantly the predictive value.

DM intake increased as pH of the silage increased. The linear equation obtained to predict DM intake was: $y = -164.2 + 60.4$ (pH) ($r = 0.703$: $P < 0.023$; residual s.d. = 6·7). Shaver *et al.* (1984) found that the silage pH was a factor that affects voluntary consumption of maize silage. They developed a quadratic equation to predict OM intake, that is to say, that intake increases if silage pH rises from 3·6 to 5·6 but falls after this point. In our case, the quadratic equation did not improve the prediction, probably because of the short range of pH values. On the other hand, the silage pH was positively related to the DM percentage of the silage ($r = 0.73$; $P < 0.01$; not tabulated) in accordance with the stability criterion proposed by Dulphy and Demarquilly (1981).

There was no correlation between DM intake and *in vivo* OM digestibility. Our results confirm what has been indicated by Ørskov *et al.* (1988); that is, when intake is voluntary, *in vivo* apparent digestibility of forages given to ruminants at maintenance is an inadequate measure of nutritive value. On the other hand, many regression equations have been published relating *in vivo* to *in vitro* digestibility. With the two-stage fermentation procedure of Tilley and Terry (1963), Aerts *et al.* (1977) found, with silages of different species, that the *in vitro* OM digestibility could explain 0·73 of the variability of *in vivo* OM digestibility. We also found a positive and significant correlation ($r = 0.62$, $P < 0.05$) between OM digestibility and *in vitro* DM digestibility.

The insoluble but potentially degradable fraction (b) allowed us to predict the OM digestibility. Potential DM degradation ($a + b$) provided an inaccurate DM intake ($r = 0.50$; $P > 0.05$) in agreement with Carro *et al.* (1991). In the same way, Khazaal *et al.* (1995) obtained a low and non-significant coefficient of correlation with grass and legume hays. In our case, some silages differing in DM intake had similar degradabilities. When S1, with a practically linear DM degradation was removed, the accuracy of DM intake, through the degradation components, increased and the correlation between DM intake and the insoluble but fermentable matter (B) was significant ($r = 0.79$; $P < 0.01$). In fact, when constant a from the exponential equation and B were employed together we obtained an acceptable prediction of DM intake when a single technique was used. The precision of the equation to predict DM intake was improved using ruminal degradation characteristics (residual s.d. = 3·9) compared with chemical composition (residual s.d. = 6·6) or fermentative traits (residual s.d. = 6·0). Nevertheless, the best DM intake equation was obtained when all four techniques were employed together ($r = 0.99$; $P < 0.001$; residual s.d. = 1·7). On the other hand, the insoluble but potentially degradable fraction (b) allowed us to predict *in vivo* OM digestibility, though with a similar precision to ear content. The use of the four techniques together did not improve the OM digestibility prediction given by the *in situ* DM degradation technique (Table 7).

In conclusion, prediction of DM intake and OM digestibility of maize silages was slightly more accurate using degradability characteristics than the other single techniques used, although the best predictive DM intake equation was obtained using stover NDF, NH_3-N and water-soluble N and the potential DM degradation. However, given the complexity of using the four techniques together, and with the aim of striking a balance between accuracy and simplicity, reliability and inexpensiveness, it is possible to propose ear content as a predictor of OM digestibility, and fermentative traits, pH and acetic acid concentration, as a DM intake predictor.

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