

Variability of digestibility criteria in maize elite hybrids submitted for registration in the French official catalogue

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Abstract – Since 1995, a methodological study has been conducted to determine the feasibility and accuracy of various in vitro digestibility criteria used to estimate genotypic variation in silage maize elite hybrids in the framework of French registration official trials. The study dealt with eighteen early hybrids, amongst which seven official control hybrids and eleven new hybrids submitted for French registration in 1995. Experiments were conducted at seven locations in 1995 and ten locations in 1996. The biochemical components and in vitro digestibility of whole-plant and cell-walls were predicted by near infra-red reflectance spectroscopy. Genotypic variation was significant for all criteria studied. In vitro whole-plant and cell-wall digestibility assessments and the predicted net energy value (UFL) were all notably accurate, discriminant and relevant, with some differences according to the method of assessment. Ranges observed between hybrids tested within the official French registration network were similar to those obtained with control genotypes known for their low or high digestibility values, from previous experiments. Data suggested that, in addition to the usual agronomic characteristics, digestibility or net energy value criteria should also be considered in the silage maize registration process. (© Inra/Elsevier, Paris.)

Zea mays / digestibility / energy value / hybrids / registration / silage maize

Résumé – Variabilité pour les critères de digestibilité au sein d'hybrides de maïs proposés à l'inscription au catalogue français. Depuis 1995, une étude méthodologique a été entreprise dans le but d'étudier la faisabilité et la précision de différents critères liés à la digestibilité in vitro pour estimer la variabilité génotypique au sein d'hybrides élites de maïs ensilage testés dans le cadre des essais officiels pour l'inscription au catalogue français. Cette étude porte sur 18 hybrides précoces incluant sept témoins d'inscription et onze nouveaux hybrides proposés à l'inscription en France en 1995, expérimentés dans sept lieux en 1995 et dix lieux en 1996. Par spectroscopie de réflectance dans le proche infrarouge, les composants biochimiques et les digestibilité in vitro de plantes entières et de parois ont été prédits. Tous les critères étudiés étaient variables génotypiquement. Les estimations de digestibilités de plantes entières et de parois, ainsi que la prédiction de la valeur énergétique nette (UFL), étaient précises, discriminantes et pertinentes, avec

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quelques différences selon les méthodes utilisées. Les écarts de digestibilité et de valeur énergétique nette observés entre ces hybrides élites testés dans le réseau officiel d'inscription sont équivalents à ceux obtenus pour des génotypes témoins déjà connus pour leur faible ou forte digestibilité. L'intérêt d'introduire un critère de digestibilité ou de valeur énergétique nette, en plus des critères agronomiques habituels, pour l'inscription des variétés de maïs ensilage en France a clairement été montrée. (© Inra/Elsevier, Paris.)

***Zea mays* / digestibilité / hybrides / inscription / maïs ensilage / valeur énergétique**

1. INTRODUCTION

Because of its high energy content, forage maize is a major component of ruminant diets. In the European Union, more than 3 300 000 ha are cropped for silage making. Genetic variation in digestibility and energy value of silage maize was clearly established through *in vitro*, *in situ* and *in vivo* experiments (see especially [2, 6, 11–13, 16, 19, 23, 24, 27, 32]). Maize hybrids of good digestibility could therefore contribute to giving consumers high quality bovine products (milk or meat) whilst lowering production costs, thus providing a higher income for cattle breeders.

Digestibility measurements are already taken into account for registration on official lists in other European countries – the Netherlands, Belgium and Switzerland – and for recommendation in the United Kingdom [8, 33]. In Germany, research into the characterisation of the digestibility of cultivars is currently under way. The tests and assessment methods chosen vary from country to country. Until recently, registration on the French official list of maize cultivars with a silage specificity was based on early maturity, biomass productivity and lodging resistance subject to satisfactory results in grain trials. In 1995, at the initiative of GEVES (*Groupe d'étude des variétés et des semences*) and in collaboration with SEPROMA (*Chambre syndicale des entreprises françaises de semences de maïs*), INRA (*Institut national de la recherche agronomique*) and AGPM (*Association générale des producteurs de maïs*), work was undertaken to study the feasibility, accuracy and relevance of various *in vitro* digestibility criteria to estimate genotype variability in maize elite hybrids in CTPS (*Comité technique permanent de la sélection*) official trials. Another objective of the study was to specify exper-

imental protocols and measurement procedures for establishing reliable data on the energy value of silage maize cultivars. Furthermore, at the initiative of SEPROMA and AGPM, and in collaboration with the *Institut de l'élevage*, the reliability of *in vitro* criteria in predicting genotype variation in silage maize when fed to cattle is also being currently investigated through tests on dairy cows or bulls. Studies using dairy cows are also conducted at INRA Lusignan to test the relevancy of *in vitro* criteria to animal performances.

Taking into account digestibility criteria for silage maize registration on the official list has become all the more important since research conducted by Deinum and Struik [23] in the Netherlands and Barrière and Argillier [14] in France, indicated that there was a drift towards low digestibility hybrids, when digestibility traits were not considered during maize selection and evaluation programmes.

The objective of this work is therefore threefold: to study the variability of *in vitro* digestibility criteria in a set of maize elite hybrids submitted for French official registration and tested in the CTPS multilocal network; to investigate the genetic and statistic advantages of those criteria; and to examine the relationship between digestibility criteria and biomass productivity.

2. MATERIALS AND METHODS

2.1. Genetic material

This study was conducted on a sub-network of CTPS maize French official trials. This work was carried out on 18 early-maturity elite hybrids (S1 group, around FAO

220-280), amongst which were 11 new hybrids submitted for registration in 1995 and 7 already registered control hybrids (official control hybrids). Three hybrids (INRA258, DK265, Lu2003), well-known for their *in vivo* digestibility values from INRA Lusignan results, were added to serve as digestibility control hybrids.

2.2. Experimental design and measurements

All hybrids were grown within the CTPS network at 7 locations in 1995 and 10 locations in 1996. The trials were randomised block designs with three replicates. Each plot consisted of four rows, 5 m long, with a row spacing of 0.80 m and a density of ten plants m^{-2} . At the silage stage, the two middle rows of each plot were machine-harvested as forage trials with a chopper. The biomass yield and the dry matter content of the whole plant were measured in each environment. A representative sample of 1–1.5 kg chopped material per plot was taken.

Whole-plant samples were dried in an oven (70 °C) and then ground with a hammer mill so as to pass through a 1-mm screen. Samples were analysed by AGPM, using near infra-red reflectance spectroscopy (NIRS). NIRS values were collected, using a NIRS System 5500, between 1 100 and 2 500 nm, every 2 nm. The calibration equations used were provided by the Station de Haute Belgique, Libramont (Belgium). The following characteristics were determined: *in vitro* digestibility of dry matter investigated by enzymatic digestion, according to either De Boever et al. [20] (hereafter referred to as IVDDM.db) or Aufrère and Michalet-Doreau [5] (hereafter referred to as IVDDM.auf); and *in vitro* digestibility of cell walls (IVDCW) investigated by enzymatic degradation of NDF samples [1]. The following biochemical components were also determined by NIRS: contents of neutral detergent fiber (NDF); acid detergent lignin (ADL) [28]; starch (Ewers method); soluble carbohydrates [30]; crude protein (nitrogen \times 6.25, Kjeldahl); and ash (12 h in an oven at 470 °C).

The *in vitro* digestibility of the non-starch and non-soluble carbohydrate part of the plant (IVDN_{SC}) was then computed, assuming that starch and soluble carbohydrates were potentially completely digestible [6]:

$$IVDN_{SC} = \frac{100 \times (IVDDM - \text{starch}\% - \text{soluble carbohydrate}\%)}{(100 - \text{starch}\% - \text{soluble carbohydrate}\%)}$$

Two separate IVDN_{SC} estimates were computed using De Boever's and Aufrère's IVDDM methods: IVDN_{SC}.db, IVDN_{SC}.auf.

The *in vitro* digestibility of the NDF part of the plant (IVDNDF) was also computed, assuming that the non-NDF part was completely digestible [10]:

$$IVDNDF = \frac{100 \times (IVDDM - (100 - NDF\%))}{NDF\%}$$

Two separate IVDNDF estimates were computed using De Boever's and Aufrère's IVDDM methods: IVDNDF.db, IVDNDF.auf.

A prediction equation of the net energy value (UFL, unité fourragère lait) was proposed by Andrieu [4]: $UFL = 11.38 + 0.1390 \times \text{crude protein} + 1.0609 \times IVDDM.auf$, with UFL expressed per 100 kg of organic matter (OM), crude protein content in g/kg OM, and IVDDM.auf by enzymatic digestion of DM [5]. Using NIRS prediction of crude protein content and IVDDM.auf, we computed an UFL value expressed per kg DM.

2.3. Statistical analyses

Analyses of variance were performed on data from the 18 elite hybrids observed in 17 environments with 3 replicates. They were carried out following standard procedures for the fixed model:

$$Y_{ijk} = \mu + E_j + (B:E)_{kj} + G_i + (GE)_{ij} + R_{ijk}$$

where Y_{ijk} is the phenotypic value of genotype i in environment j in the block k , μ the general mean, E_j the main effect of environment j , $(B:E)_{kj}$ the effect of block k nested in environment j , G_i the main effect of genotype i , $(GE)_{ij}$ the interaction effect between genotype i and environment j , and R_{ijk} the error term.

In the absence of a random model and therefore being unable to estimate true variances, we used the components of the expected mean squares (see Dagnélie [18]) to derive a measure of the amount of variability accounted for by a given effect of the model. In a fixed effect model, the expectation of the mean square of factor q can be equated as follows:

$$E(MS_q) = \sigma^2 + k_q \times \phi_q \quad (1)$$

where σ^2 is the residual variance, k_q a function of the size of the experiment; the term ϕ_q was considered as a measure of the variation due to factor q . It will be denoted 'variance'.

For the factor genotype, equation (1) is:

$$E(MS_G) = \sigma^2 + n_b \times n_e \times \phi_G = \sigma^2 + n_b \times n_e \times \sum_i G_i^2 / (n_g - 1)$$

where n_g , n_b , n_e are the number of genotypes, blocks and environments, respectively. The expected mean squares of the other factors were calculated similarly (see Dagnélie [18]).

Genotypic correlations among traits were computed across hybrid means ($n = 18$).

3. RESULTS AND DISCUSSION

Environmental and genotypic effects, and genotype \times environment interaction effects were highly significant for all traits (*table I*). ‘Variances’ due to environment were always higher than those due to other factors, both in terms of agronomic and digestibility traits (*table I*). ‘Variance’ due to the main genotypic effect was generally preponderant compared to that caused by the genotype \times environment interactions, except in the case of dry matter, starch, NDF and ADL contents (*table I*). The various cell-wall digestibility assessments (IVDNDF, IVDNSC and IVDCW) were the traits which displayed the highest ratio of genotypic ‘variance’ on genotype \times environment interaction ‘variance’

(*table I*). Therefore, we highlighted with this experimental design the lesser importance of genotype \times environment interactions for cell-wall digestibility traits compared with whole-plant digestibility traits and, even more significantly, with biochemical composition traits. This confirmed the generally low variations attributed to genotype \times environment interactions for feeding value traits tested in vivo or in vitro, and particularly those concerned with cell-wall digestibility traits, as seen in studies using different genetic materials (experimental hybrids and registered hybrids from different eras of breeding) tested in smaller multilocal networks [9, 10, 17, 21, 22, 24, 34].

The F ratios for each source of variation were almost identical, whether using Aufrère’s or De Boever’s IVDDM assessment method and, consequently, IVDNSC and IVDNDF (*table I*). However, the residual variance of IVDDM.db was 1.5 times larger than that of IVDDM.auf, and residual variances of IVDNSC.db and IVDNDF.db were about twice as large as those of IVDNSC.auf and IVDNDF.auf (*table I*). The calculated ϕ ‘variances’ were also larger for all criteria using IVDDM.db

Table I. Analysis of variance for agronomic characteristics, biochemical component contents (expressed in % of dry matter), digestibility traits (expressed in %), and for the predicted UFL value (expressed per kg of dry matter).

Characteristic	F _E	F _G	F _{G\timesE}	Φ _E	Φ _G	Φ _{G\timesE}	RV
Dry matter content (%)	367.2**	49.3**	3.9**	8.52	1.19	1.21	1.26
Biomass yield (t DM ha ⁻¹)	464.3**	28.2**	1.4**	8.32	0.52	0.13	0.97
Crude proteins	211.3**	57.0**	2.1**	0.42	0.12	0.04	0.11
Starch	146.9**	23.4**	2.7**	13.57	2.20	2.91	5.02
Soluble carbohydrates	133.0**	22.8**	1.6**	4.55	0.75	0.35	1.76
NDF	38.2**	11.8**	1.8**	2.33	0.72	0.89	3.39
ADL	90.4**	20.1**	1.9**	0.064	0.015	0.011	0.039
IVDDM.db	84.6**	31.1**	1.9**	3.50	1.34	0.69	2.26
IVDDM.auf	76.3**	31.8**	1.9**	2.05	0.89	0.47	1.47
IVDNSC.db	195.6**	41.8**	1.7**	7.65	1.70	0.49	2.12
IVDNSC.auf	274.1**	50.7**	1.4**	4.78	0.92	0.13	0.95
IVDNDF.db	177.4**	46.5**	1.6**	13.48	3.68	0.86	4.13
IVDNDF.auf	203.6**	48.5**	1.4**	7.95	1.97	0.25	2.12
IVDCW	186.6**	28.6**	1.5**	5.07	0.80	0.27	1.47
UFL	84.4**	35.7**	1.9**	0.00030	0.00013	0.00006	0.00020

F_E, F_G, F_{G \times E} are F ratios referring to environments ($n = 17$), genotypes ($n = 18$) and genotype \times environment interactions, respectively (**: $P < 0.01$). Φ _G, Φ _E, and Φ _{G \times E} are the Φ ‘variances’ referring to environments ($n = 17$), genotypes ($n = 18$) and genotype \times environment interactions, respectively, and RV is the residual variance.

than for those using IVDDM.auf. The range between the minimal and maximal values of hybrids was 3.7 points for IVDDM.db and 2.9 points for IVDDM.auf. Therefore, IVDDM estimated through the Aufrère method displayed lower genotypic discrimination than that estimated with the De Boever method, but compensated by a greater accuracy. IVDMD.auf also showed a lower general mean: the average value of IVDDM.auf was around four points lower than that of IVDDM.db (*table II*). These differences became larger with the calculation of IVDNSC and, to an even greater extent, IVDNDF. The very low average of IVDNDF.auf (around 28 %) was particularly unexpected since *in vivo* NDF digestibility values were found to be around 40–50 % ([4]; unpublished INRA Lusignan data).

The comparison of mean, 'variance' and residual variance between the different cell-wall digestibility assessments revealed a genotypic 'variance' approximately 2-fold larger for IVDNDF than for IVDNSC with, nevertheless, a residual variance also twice as large. IVDCW displayed a slightly smaller genotypic 'variance' than IVDNSC and an

intermediate value for residual variance. The general mean for IVDCW was unexpectedly very large (*table II*). According to Agneessens (*pers comm*), this could be explained by the fact that the measurement procedure requires a first step which uses a neutral detergent to produce cell-wall residue, before enzymatic degradation can occur. The cell-wall obtained in this manner could, therefore, be far more accessible to enzymes.

The hybrids were all 'early-maturity' ones. The genotypic range in dry matter content and biomass productivity, within this group, was around four points and 3 t DM ha⁻¹, respectively (*table II*). Averaged over environments and replicates, the level of net energy content ranged from 0.92 to 0.97 UFL/kg DM among hybrids ($n = 18$). The values of official control hybrids ($n = 7$) were located on the same UFL variation scale as hybrids submitted for registration in 1995 ($n = 11$), but extreme UFL values were mostly displayed by official control hybrids.

Agronomic and digestibility values for the three digestibility control hybrids (experimental hybrids

Table II. Means, ranges among elite hybrids tested in the CTPS network ($n = 18$), and values of the three digestibility control hybrids (INRA258, DK265, Lu2003), for agronomic characteristics, biochemical component contents (expressed in % of dry matter), digestibility traits (expressed in %), and predicted UFL value (expressed per kg of dry matter).

Characteristic	Mean	Min–Max hybrid	INRA258	DK265	Lu2003
Dry matter content (%)	32.30	31.13 – 35.44	30.84	31.23	34.23
Biomass yield (t DM ha ⁻¹)	15.95	14.79 – 17.85	12.78	14.73	15.19
Crude proteins	7.67	7.09 – 8.23	8.37	8.18	7.53
Starch	30.42	28.29 – 33.18	26.61	28.09	28.33
Soluble carbohydrates	5.42	3.92 – 7.20	6.68	6.58	4.89
NDF	39.65	38.41 – 41.46	40.72	39.96	41.04
ADL	2.85	2.69 – 3.12	2.74	2.71	3.18
IVDDM.db	75.71	73.46 – 77.05	76.71	76.92	73.14
IVDDM.auf	71.55	69.76 – 72.68	71.82	72.28	69.43
IVDNSC.db	62.18	59.84 – 63.80	65.07	64.64	59.79
IVDNSC.auf	55.65	54.07 – 57.11	57.71	57.54	54.20
IVDNDF.db	38.84	35.10 – 41.33	42.81	42.23	34.58
IVDNDF.auf	28.22	24.92 – 30.08	30.73	30.56	25.43
IVDCW	82.38	80.54–83.48	83.44	83.42	79.80
UFL	0.95	0.92 – 0.97	0.97	0.97	0.92

or old varieties) were compared to values of today's elite hybrids tested in the CTPS network (hybrids submitted for registration in 1995, and official control hybrids). The three digestibility control hybrids displayed a lower biomass yield than today's hybrids, particularly for hybrids INRA258 and DK265 (hybrids registered in France in 1958 and 1987, respectively) (*table II*). This was to be expected in view of the important genetic progress accomplished in productivity: Lorgeou and Barrière [31] showed that since 1986, a whole-plant improvement nearing $0.17 \text{ t DM ha}^{-1} \text{ year}^{-1}$ has been obtained. The three digestibility control hybrids had rather lower starch content compared to today's elite hybrids (*table II*). For whole-plant or cell-wall digestibility criteria and UFL energy values, the ranges observed in hybrids tested within the official French registration network were similar to those obtained with the digestibility control hybrids (*table II*). Therefore, amongst the elite maize hybrids currently submitted for registration, there were i) hybrids with a digestibility or an energy value as low as those of Lu2003, especially bred at INRA Lusignan for its low feeding value, and ii) hybrids with a digestibility or an energy value as high as those of two older hybrids which were shown, through INRA Lusignan and SEPROMA experiments, to have a high energy value. This is consistent with Barrière and Argillier's findings [14] which showed, through in vivo sheep experiments, that there was a regular decrease in the average energy value, depending on the year of registration in France, which coincided with the emergence of particularly low digestibility hybrids, although some hybrids with a good digestibility remained. This would therefore suggest that it is important to add a digestibility criterion in the official maize registration process.

The genotypic correlation coefficient between IVDDM.auf and IVDMD.db was equal to 0.99 (*table III*). The genotypic correlations between IVDNSC.auf and IVDNSC.db, and IVDNDF.auf and IVDNDF.db were slightly lower (*table III*). The various cell-wall digestibility assessments (IVDCW, IVDNSC, IVDNDF) were all highly significantly correlated amongst each other (*table III*). In vitro dry matter digestibility, whether

IVDDM.auf or IVDDM.db, was negatively and highly significantly correlated with NDF content and lignin content, whereas only a positive trend was observed between starch and IVDMD (*table III*). In fact, the limiting factor of plant digestibility is the cell-wall, especially the lignin constituent. IVDDM was also positively and highly significantly correlated with various cell-wall digestibilities, with higher correlation coefficients when cell-wall digestibility values were based on De Boever's method rather than Aufrère's method. This probably needs to be related to higher and significant genotypic correlations between cell-wall (NDF) content and cell-wall digestibilities when using De Boever's method (IVDNSC.db, IVDNDF.db). In contrast, when assessed through other methods (IVDNSC.auf, IVDNDF.auf, IVDCW), the correlation between cell-wall digestibility and cell-wall (NDF) content was not, or hardly, significant (*table III*). A priori, cell-wall content and cell-wall digestibility are potentially independent [3, 6, 25].

The only significant genotypic correlation with biomass yield was between biomass yield and crude protein content (*table III*). A higher whole-plant productivity was associated with a lower crude protein content. Biomass yield and digestibility (or energy value) were not significantly correlated (*table III, figure 1*). It is therefore possible to find amongst hybrids of a same maturity group, varieties with a high productivity and a satisfactory energy value. This reflects the findings of Dhillon et al. [24], Ferret et al. [26], Barrière et al. [11], and Argillier et al. [7]: their research into experimental genotypes or hybrids from various breeding eras, but with an almost identical maturity, highlighted no significant relationship between biomass yield and feeding value.

4. CONCLUSION

The digestibility and net energy value of silage maize was affected both by environmental and genotype effects. Environmental effects came out predominant but the genotype \times environment inter-

Table III. Coefficients of genotypic correlation between biomass yield (t DM ha⁻¹), biochemical component contents (expressed in % of dry matter), digestibility traits (expressed in %), and the predicted UFL value (expressed per kg of dry matter). *, **: $P < 0.05$ and $P < 0.01$, respectively.

	Biomass yield	Crude proteins	Starch	NDF	ADL	IVDDM. db	IVDDM. auf	IVDNSC. db	IVDNSC. auf	IVDNDF. db	IVDNDF. auf	IVDCW	UFL
Biomass yield	—	-0.55*	-0.35	0.21	0.16	-0.14	-0.11	-0.13	-0.08	-0.08	0.03	0.00	-0.30
Crude proteins		—	0.00	-0.29	-0.17	0.18	0.13	0.33	0.34	0.07	-0.10	0.10	0.49
Starch			—	-0.65**	-0.52*	0.42	0.38	0.15	-0.11	0.18	-0.09	-0.06	0.33
NDF				—	0.81**	-0.83**	-0.82**	-0.70**	-0.54*	-0.55*	-0.25	-0.42	-0.82**
ADL					—	-0.95**	-0.93**	-0.88**	-0.74**	-0.86**	-0.64**	-0.72**	-0.88**
IVDDM.db						—	0.99**	0.95**	0.83**	0.92**	0.73**	0.81**	0.94**
IVDDM.auf							—	0.94**	0.85**	0.92**	0.76**	0.84**	0.93**
IVDNSC.db								—	0.95**	0.93**	0.79**	0.89**	0.95**
IVDNSC.auf									—	0.87**	0.82**	0.93**	0.88**
IVDNDF.db										—	0.92**	0.92**	0.84**
IVDNDF.auf											—	0.94**	0.64**
IVDCW												—	0.78**

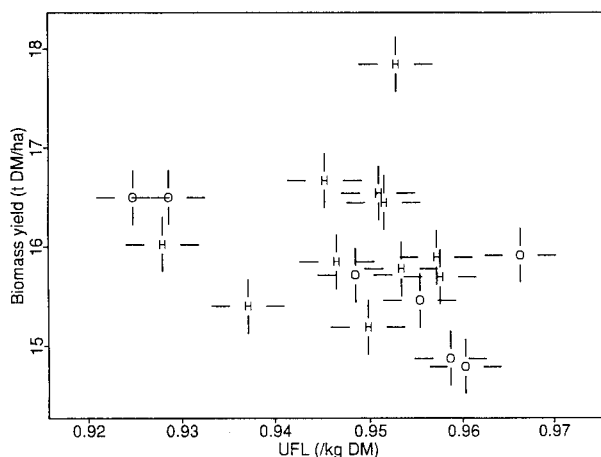


Figure 1. Average values of hybrids' biomass yield (t DM ha⁻¹) plotted against those for net energy value (UFL/kg DM) (O = official control hybrid, H = hybrid submitted for registration): a confidence limit is associated to each hybrid mean ($P < 0.05$).

actions were found to be generally low. Therefore, in a given environment, it is the hybrid that will determine the energy value of the silage maize and, by extension to the farmer, the performance of cattle (all other things being equal).

Genotypic variation amongst early-maturity maize elite hybrids, tested in French official registration trials in 1995, existed for in vitro digestibility criteria and biochemical composition traits predicted by NIRS. Hybrids were found with similar low and high digestibility values as the control hybrids already known to INRA Lusignan for their low and high digestibility (proved through in vivo and in vitro tests). This proves that it is worthwhile to add a digestibility test to French registration rules.

Each of the various potential digestibility criteria displayed its own genetic and statistical advantages and drawbacks. In vitro whole-plant digestibility is a global criterion, which allows to discriminate between genotypes with great accuracy. In order to improve the energy value of silage maize in a ruminant's diet, it is advisable to partition whole-plant digestibility into cell-wall content and cell-wall digestibility. The various cell-wall digestibility criteria used in this study were tightly correlated with

each other, but their average values, their genotypic and residual variations may have been different. Besides good accuracy and genotypic discrimination, cell-wall digestibility values also had the advantage of showing low genotype \times environment interactions.

The use of in vitro tests for the assessment of digestibility or net energy value would only be relevant if those tests turned out to be good predictors of hybrid behaviour when fed to animals. The relationship between in vitro digestibility traits and in vivo digestibility (or UFL value) tested on sheep was studied by various European teams. In France, official authorities suggest using the equation of Andrieu [4], which allows the prediction of UFL values from in vitro whole-plant digestibility and crude protein content. That equation accounts for around 55 % of the variation in UFL values. Yet, although it easily allows to discard low digestibility genotypes, the distinction between intermediate or good value hybrids is more difficult. The predicted UFL value was proved in this study to be both an accurate and discriminate criterion. Moreover, the first experimental tests of hybrids on dairy cows and young bulls showed that cattle performances were generally in accordance with the hybrid digestibility value expected from in vitro or in vivo (with sheep) tests [12, 15, 29].

On the basis of the results currently available, the UFL value (prediction equation of Andrieu [4]) was the test selected for digestibility evaluation of hybrids submitted for French registration, in addition to the usual agronomic criteria. For the first time, in 1998, the UFL criteria will be taken into account for silage maize French registration. In the future, registration regulations could be updated as more information becomes available. Furthermore, the feeding value of silage maize is as much conditioned by digestibility as it is by intake effects. A capital challenge for maize breeders and users is now likely to be the adjustment of a criterion for maize hybrid intake prediction, which will allow the identification of hybrids combining both high digestibility and good ingestibility.

Finally, it would appear reasonable to expect that silage maize hybrids with high feeding and agro-

onomic values will soon be available to cattle breeders. Nevertheless, the question remains as to whether the improvement of agronomic characteristics can be achieved with due attention paid to the preservation of feeding value traits, or whether it may be possible to progress simultaneously on both counts: agronomic as well as feeding value traits.

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