Variability in straw composition: methodological considerations

Susmel P., Mills C.R., Stefanon B., Sandoval Neira J.U.

in

Tisserand J.-L. (ed.).
Les pailles dans l'alimentation des ruminants en zone méditerranéenne

Zaragoza : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 6

1994
pages 9-26

Variability in straw composition: methodological considerations

P. SUSMEL
C.R. MILLS
B. STEFANON
J.U. SANDOVAL NEIRA
DIPARTIMENTO DI SCIENZE
DELLA PRODUZIONE ANIMALE
UNIVERSITA DEGLI STUDI DI UDINE
ITALY

SUMMARY - Forty straw samples were received from 8 laboratories situated in Mediterranean countries. The samples were subjected to chemical analyses for fibre components and phenolic compounds and incubated *in sacco* in "Simmental" cows receiving straw based diets in order to estimate the degradability coefficients. Sources of variation of the degradability parameters were also investigated. Degradability coefficients were correlated with chemical analyses and *in vivo* data. A wide range in degradability coefficients was observed for samples of different species, variety, harvest site and rainfall or irrigation received. In general, phenolic compounds were observed to have higher correlation coefficients with the "a+b" fraction and the effective degradability than the fibre fractions. There were no significant correlations between phenolic compounds and *in vivo* OMD.

Key words: Straw, Mediterranean zone, composition, nutritional value.

RESUME - "Variabilité de la composition des pailles : considérations méthodologiques". La dégradabilité ruminale des pailles de céréales (40 échantillons), provenant des 8 laboratoires placés dans des pays méditerranéens, a été mesurée avec la technique du sachet nylon sur deux groupes de 3 sujets chacun, alimenté avec de paille de blé, dans le but d'étudier la variabilité des coefficients de la cinétique de dégradabilité des pailles. On a trouvée des corrélations significatives entre les coefficients de dégradabilité de la composition chimique des pailles. La différence de variabilité des paramètres de la cinétique et de la dégradabilité théorique, non seulement entre les échantillons des différentes zones, mais aussi en considération des espèces, de la variété de la culture et des différents facteurs agronomiques, a été remarquable. En générale, les composées phénoliques ont eu les coefficients de corrélation les plus élevées avec la dégradabilité in sacco. Les corrélation entre les composées phénoliques et la digestibilité de la matière organique n'ont pas été significative.

Mots-clés *: Paille, zone méditerranéenne, composition, valeur alimentaire.*

Introduction

Cereals are produced worldwide because they can grow in different geographical areas and so a huge amount of fibrous by-products are available in most countries. It has been estimated (Kossila, 1984; Sundstøl, 1988) that the amount of straw produced for each unit of grain is 0.6 for wheat, 0.72 for barley, 0.78 for oats and 1.2 for rye.

The prediction of the nutritive value of cereal straws is thus very important as, unlike central and northern European countries, in the arid Mediterranean countries the economic survival of ruminants is based on cereal by-products. Research has shown a high positive relationship between straw degradability, intake and animal performance (Ørskov *et al.*, 1988), supporting the possibility of covering the maintenance energy requirements of ruminants by feeding more degradable straw or increasing its nutritive value with appropriate treatments (urea, NH_3, NaOH).

As part of an international project supported by the European Economic Commission (TS 2A - 0250 - M CD), the University of Udine agreed to receive straw samples from the other participating countries, and determine the *in sacco* degradability in an attempt to predict *in vivo* parameters measured in digestibility trials performed in each country. The survey was performed on 40 straw samples from 8 laboratories in 5 countries: Saint Genes and Montpellier (5 and 7 straw samples) - France; Florence and Udine (6 and 2 straw samples) - Italy; El Harrach (4 straw samples) - Algeria; Fonte Boa (4 straw samples) - Portugal; Zaragoza (6 straw samples) - Spain; Ariana (6 straw samples) - Tunisia.

This paper presents chemical analyses of the straws, the experimental results associated with the degradability trials performed at Udine, and the correlations between chemical and *in sacco* parameters. Furthermore, in this presentation the main specific and agronomic effects and comparisons with other research are discussed.

Material and Methods

In sacco degradability

Samples received unmilled (Tunisia and Zaragoza) were milled through a hammer mill fitted with a 1.0 mm screen. The samples were not sieved to remove dust.

2 g air dry matter was weighed into duplicate polyester bags (10 x 15 cm closed dimensions) giving a weight surface area ratio of approximately 12 mg DM cm^{-2}. Where the quantity of sample was insufficient, single bags were incubated (Florence, El Harrach, sample 33 from Portugal). As a minimum, bags were incubated for 8, 24, 48, 72 and 96 hours. When sample quantity permitted, bags were also incubated for 0, 4 and 16 hours. Each straw sample was incubated in 3 cows, with bags being introduced before the morning meal, except for the 16 hour bags which were normally introduced at 16:00 h.

After incubation, bags were rinsed gently in a bucket of cold water and subjected to a cold rinse and spin cycle in an automatic washing machine. The bags were dried at 65°C for 48 hours, allowed to re-equilibrate to atmospheric humidity overnight and then reweighed.

Six rumen-fistulated, mature "Simmental" cows, divided into 2 groups of 3 animals, were available. Cows were fed twice a day (at 8:00 and 16:00 h) a diet consisting of 3 kg wheat straw, 0.35 kg urea-maize mix (60 g per kg urea), 0.3 kg barley meal, 0.4 kg soya and 30 g mineral vitamin mix, twice a day at 8:00 and 16:30 h. Actual straw intakes were measured over a period of 14 days, with average intakes for group 1 of 3.38, 4.42 and 5.31 kg, and 5.61, 4.15 and 5.08 kg for group 2. The cows were adapted to a straw based diet for a month and then had a 10 day period on the experimental ration before bag incubations began.

For health reasons not associated with the straw diets, 2 animals were removed from the trial after 3 weeks on the experimental ration.

Rumen outflow rate was measured in the three cows with the highest straw intakes. 250 g chromium mordented straw (40 g Cr per kg DM) and 10 g Co-EDTA previously dissolved in a small volume of water were introduced directly into the rumen via the cannula. Faecal grab samples were collected after 0, 2, 6, 10, 14, 18, 24, 28, 32, 36, 48, 56, 72, 80, 96, 120, 144 and 156 hours, dried at 65°C and milled prior to analysis for Cr and Co.

Dry matter degradability was calculated as the proportional loss of dry matter from the individual bags. The degradability values were interpolated with the CNLR subroutine of the SPSSx (1985) package using a first-order model (Ørskov and MacDonald, 1979).

Faecal chromium concentrations were fitted to the double exponential model proposed by Dhanoa *et al.* (1985). For the solid phase (assumed to represent only the straw) an average rumen outflow rate (k_1) of 0.0194 h^{-1} was calculated from the data from two cows, as the data from one animal could not be satisfactorily fitted to the Dhanoa *et al.* (1985) model. The outflow rate for the liquid phase was calculated from the Co kinetics from 3 cows, with a mean value of 0.0706 h^{-1}; this value was used to calculate the effective degradability of the basal diet compound feed.

The effective degradability of the feeds was calculated from the degradability coefficients, modified for the rumen outflow rate using the equation of Ørskov and MacDonald (1979).

The organic matter digestibility of the straw samples was measured in each research unit.

Chemical and statistical analysis

Crude protein, NDF, ADF, ADL (either determined at each unit or at Udine) were performed according to the AOAC (1984) and Goering and Van Soest (1970) methods respectively. Phenolic compounds were determined by oxidising 100 mg NDF residue with nitrobenzene in an oilbath, separating and identifying the products by HPLC. The main phenols determined with this method were vanillic acid, syringic acid, vanaldehyde, syringaldheyde, pcoumaric acid and ferulic acid.

Cr and Co were measured by atomic absorption spectroscopy (Williams *et al.*, 1962) after ashing.

Analysis of variance, correlation and cluster analysis (EML methods) were performed with the SAS (1988) package.

Results and discussion

It can be seen from Tables 1a and 1b that samples 3, 18, 30, 33 and 39 had an "a" of zero, and samples 4 to 8 very low "a" values. This may be due to the absence of "zero hour" bags for these samples. The samples supplied by Tunisia were incubated for a full range of times (0 to 96 hours) and all had "a" values above zero. In fact, the T13 triticale had one of the highest "a" values recorded at 21.46%.

Values for "b" varied from 44.5% for sample 47 to 86.1% for sample 18 and the rate of degradation "c" varied from 0.0163 h^{-1} for sample 48 to 0.0564 h^{-1} for sample 51.

Agronomic factors

Degradability coefficients of straws from Tunisia, France and Spain, harvested from two areas with differing rainfall or with and without irrigation, show that the "a+b" and the effective degradability were generally higher for the straw from the dry area.

The effect of rainfall on straw degradability has also been reported by Capper *et al.* (1989) for barley grown in locations differing in rainfall by 205 to 300 mm. Ørskov *et al.* (1990) summarised the nutritive value of cereal straw varieties (9 varieties of spring barley, 10 winter wheat, 12 winter barley and 6 oat) and observed a generally lower degradability of straw grown in the year with higher rainfall. The authors considered that high rainfall or general water availability causes a loss of the soluble fraction from the straw as well as a more rapid translocation of this fraction into the grain, but changes in the soluble fraction "a" were not always consistent.

Thomson and Ceccarelli (1991) reported an inverse relationship between stem height and rainfall, but the distribution of water during the growth stages must also be considered. Many other factors can interact with rainfall in determining the degradability characteristics, such as ambient temperature, fertiliser application, soil quality and harvesting date. However, it is likely that, particularly under Mediterranean conditions, the effect of rainfall, even if not associated with other factors, has a primary effect on internode differentiation.

Effect of species and their botanical characteristics

According to some authors (Kernan *et al.*, 1979; Tuah *et al.*, 1986), the degradability (a+b or Dg) of barley and oat straw is higher than that of wheat or triticale.

Table 1a. Individual straw degradability values (mean of 3 cows)

Sample	Treatment	R.U.	Ref.	Mean a(%)	Mean b(%)	Mean c(%)	Mean a+b(%)	Mean Dg(%)
Wheat	U	If	1	2.70^{b}	58.99^{B}	0.0298	61.69^{B}	38.17^{BC}
Wheat	NH_3	If	2	7.74^{a}	51.79^{B}	0.0319	59.53^{B}	39.94^{B}
Barley	U	If	3	0.00^{b}	58.83^{B}	0.0302	58.83^{B}	35.50^{BC}
Barley	NH_3	If	4	1.08^{b}	61.82^{B}	0.0336	62.90^{B}	40.15^{B}
Triticale	U	If	5	0.79^{b}	58.08^{B}	0.0340	58.87^{B}	37.69^{C}
Triticale	NH_3	If	6	1.33^{b}	71.20^{A}	0.0413	72.52^{A}	49.58^{A}
s.e.m.				1.72	2.87	0.0050	2.76	2.94
Wheat	U	Fc	7	1.89^{C}	62.23^{B}	0.0387	64.12^{C}	43.02^{B}
Wheat	NH_3 (3 weeks)	Fc	8	1.11^{C}	79.22^{A}	0.0367	80.33^{A}	52.52^{A}
Wheat	NH_3 (8 weeks)	Fc	9	5.60^{B}	77.10^{A}	0.0299	82.70^{A}	52.16^{A}
Wheat	Urea (3 weeks)	Fc	10	9.49^{A}	59.39^{C}	0.0331	68.89^{B}	46.83^{B}
Wheat	Urea (12 weeks)	Fc	11	5.60^{B}	61.13^{B}	0.0322	66.73^{BC}	43.63^{B}
s.e.m.				1.10	1.04	0.0063	1.31	1.87
Wheat		A	20	5.62	61.35^{C}	0.0445	66.97^{B}	47.91^{C}
Wheat	NH_3	A	18	0.00	86.13^{A}	0.0409	86.13^{A}	57.73^{A}
Wheat	Urea	A	19	3.83	77.81^{B}	0.0330	81.64^{A}	52.68^{B}
Wheat	Urea + H_20	A	21	1.73	55.90^{C}	0.0361	57.63^{C}	37.90^{D}
s.e.m.				2.28	3.13	0.0084	3.83	0.84
Soya		P	30	0.00^{C}	60.41^{c}	0.0826^{A}	60.40^{B}	48.76^{A}
Wheat E2		P	33	0.00^{C}	65.06^{a}	0.0316^{B}	65.06^{A}	40.31^{C}
Wheat		P	34	5.21^{B}	63.27^{b}	0.0300^{B}	68.47^{A}	43.61^{B}
Wheat	Urea	P	90	10.46^{A}	57.62^{d}	0.0298^{B}	68.08^{A}	45.34^{B}
s.e.m.				2.75	2.86	0.0076	1.79	0.87
Wheat	(*var.* Centauro)	Iu	101	15.35	48.89	0.0260	64.24	42.98
Barley	(*var.* Jador)	Iu	102	10.36	51.10	0.0265	61.46	39.48

R.U. = Research Unit; If = Florence, Italy; Fc = Clermont-Ferrand, France; A = Algeria; P = Portugal; Iu = Udine, Italy
U = untreated; NH_3, Urea = treatments
^{a,b,c} Means in the same column and within the same R.U. differ at $P<0.05$
^{A,B,C} Means in the same column and within the same R.U. differ at $P<0.01$

Table 1b. Individual straw degradability values (mean of 3 cows)

Sample & *var.*	Treatment or water supply	R.U.	Ref.	Mean a(%)	Mean b(%)	Mean c(%)	Mean a+b(%)	Mean Dg(%)
Barley Rihane	low r	TU	22	3.93^{D}	64.28^{a}	0.0259	68.21^{A}	40.57^{C}
Barley Rihane	high r	TU	24	5.10^{D}	60.60^{a}	0.0257	65.70^{B}	38.23^{C}
Wheat Razzak	low r	TU	23	8.97^{C}	49.86^{c}	0.0316	58.83^{C}	39.79^{C}
Wheat Razzak	high r	TU	27	3.25^{D}	59.84^{b}	0.0233	63.08^{B}	35.18^{D}
Wheat Tanit	high r	TU	26	12.50^{B}	56.72^{b}	0.0244	69.21^{A}	43.66^{B}
Triticale T13	high r	TU	25	21.46^{A}	47.71^{c}	0.0263	69.17^{A}	48.78^{A}
s.e.m.				0.78	5.23	0.0044	3.53	1.00
Barley Alpha		Fm	41	3.55^{C}	59.93^{AB}	0.0322	63.48^{C}	40.96^{C}
Wheat Primadur	NH_3 d	Fm	39	0.00^{D}	75.83^{A}	0.0476	75.83^{B}	53.82^{A}
Wheat Primadur	NH_3 i	Fm	40	4.75^{C}	67.62^{AB}	0.0339	72.36^{BC}	47.77^{B}
Wheat Neo dur	NH_3 d	Fm	44	17.13^{A}	59.53^{AB}	0.0296	76.66^{B}	51.98^{A}
Wheat Neo dur	NH_3 i	Fm	43	9.34^{B}	61.91^{AB}	0.0344	71.24^{BC}	48.77^{B}
Wheat Ardente	NH_3 d	Fm	42	15.41^{A}	63.16^{AB}	0.0296	78.58^{A}	53.04^{A}
Wheat Talent	i	Fm	45	9.32^{B}	57.01^{B}	0.0405	66.34^{C}	47.88^{B}
s.e.m.				6.43	5.61	0.0075	3.81	0.65
Barley Barbarossa	d	S	46	7.89^{E}	54.64^{B}	0.0346^{B}	62.52^{B}	42.73^{C}
Barley Barbarossa	i	S	47	13.43^{D}	44.48^{C}	0.0237^{C}	57.91^{B}	37.89^{D}
Wheat Anza	d	S	48	9.93^{E}	67.43^{A}	0.0163^{C}	77.36^{A}	40.32^{C}
Wheat Anza	i	S	49	19.15^{B}	45.27^{C}	0.0295^{BC}	64.42^{B}	46.46^{B}
Wheat Penafiel	d	S	50	21.60^{A}	55.71^{B}	0.0533^{A}	77.31^{A}	62.41^{A}
Wheat Penafiel	i	S	51	15.83^{C}	62.39^{AB}	0.0564^{A}	78.22^{A}	62.18^{A}
s.e.m.				0.97	3.74	0.0039	3.71	1.36

R.U. = Research Unit; TU = Tunisia; Fm = France, Montpellier; S = Spain
d = dry land, i = irrigated; low r, high r = low and high rain; NH_3 = treatment
$^{a, b, c}$ Means in the same column and within the same R.U. differ at P<0.05
$^{A, B, C}$ Means in the same column and within the same R.U. differ at P<0.01

However, in our survey, it was generally observed that triticale straw was the most degradable (although the number of samples was small), followed by wheat and then barley. There were, of course, exceptions to this trend, such as the very high degradability recorded for the wheat samples received from Spain and it is particularly evident that the variability in potential degradability between varieties can exceed that between species. Indeed, published results (Ørskov *et al.*, 1990; Shand *et al.*, 1988; Tuah *et al.*, 1986; Walli *et al.*, 1988) indicate that the range of within species degradability is very high and the feeding value of wheat or triticale straw can be as high as that of barley or oat.

Differences in degradability of wheat, barley and oat straw have often been considered the result of differences in the relative proportion of leaf and stem (Ramanzin *et al.*, 1986; Shand *et al.*, 1988). Ramanzin *et al.* (1986) observed that barley internodes had the lowest degradability and leaves the highest, while the NDF concentrations had the opposite trend; the authors suggested that the variation in the nutritive value of straw could be due to the different proportions of leaf and stem which have different degradability; in particular, about 20% of the differences in straw degradability were attributed to the distribution of botanical fractions and 80% to their degradability. The different degradation characteristics of stem and leaf have been summarised by Ørskov (1991). These differences can be augmented by selective animals, such as sheep and goats, when the amount of straw offered is higher than their voluntary intake; it is likely that, in this situation, animals prefer leaves to stem.

Data reported by Thomson and Ceccarelli (1991) clearly showed the relationship between leaf to stem ratio and degradability for 4 varieties of barley grown in Syria, the straw with shorter stems had more leaves (55 *vs* 36%) and appeared to be more extensively degraded *in vitro* (80.6 *vs* 68.3%, $P<0.01$). These results are confirmed by the data reported by Ohlde *et al.* (1992), who found that leaves are more degradable than internodes and for this reason barley and oat have mean *in vitro* digestibility values higher than wheat and triticale.

In dry areas, drought stress is associated with a marked reduction of stem height and grain production in durum wheat and barley (Thomson and Ceccarelli, 1991), but the nutritive value of the straw increases (Ceccarelli, 1987; Gland, 1991). For this reason, tall and early maturing varieties, which can escape drought, should be subjected to genetic selection for dry areas. These aspects are in conflict with the increase in straw quality required for arid areas, where straw represents an important feed resource.

Under different agricultural conditions, such as in Scotland, variety selection factors differ considerably from those applied to varieties which must grow in hot, dry conditions and the use of cereal varieties with shorter stems represent an advantage in terms of lodging resistance. Consequently, the increased rainfall can cause a different relationship between stem height, grain yield and straw quality. Tuah *et al.* (1986) reported the loss of straw DM from nylon bags incubated in the rumen for 19 varieties of barley, 14 of wheat, 11 of oat and 1 of triticale, but they did not observe any correlation between straw length, nitrogen concentration or grain yield and degradability.

Chemical composition

In Tables 2a and 2b, the chemical composition (N, fibre and phenolic compounds) of the straws are reported. Unfortunately, we were unable to complete the Table due to lack of information or sample for chemical analysis.

Data on crude protein content was available only for a few samples, and differences between species, geographical area or agronomic factors could not be investigated; as expected, ammonia and urea treated straws had higher CP contents. However, for untreated barley, wheat and oat straws, no relationships between nitrogen content and grain yield have been observed (Tuah *et al.*, 1986). In a review by Antongiovanni and Sargentini (1991) the crude protein content of cereal straws published by different authors were reported. Geographical area of origin had a bigger effect than species in determining crude protein content; it is likely that climatic-agronomic conditions played a major role in this regard. Crude protein in straw is mainly in the form of insoluble nitrogen linked to cell walls, and is largely unavailable. However, Thomson and Ceccarelli (1991) reported a linear relationship between the nitrogen content in straw and voluntary feed intake in sheep, especially for unsupplemented straw.

It was not possible to obtain an NDF value for all the straws, but it varied from 68.3% for wheat (*var.* Penafiel dry land) to 91.8% for barley (*var.* Jador) grown in Italy. A higher within species variability for NDF and fibre fraction contents was also evident. From the results reported by other researchers (Theander and Aman, 1984; Cottyn and de Boever, 1988; Givens *et al.*, 1989) it appears that barley straw, generally considered to have a higher digestibility value, often has a higher NDF and other fibre fractions than wheat straw.

The phenolic compounds detected after nitrobenzene oxidation were vanillic, syringic, p-coumaric and ferulic acid and the aldehydes vanillin and syringaldehyde, the most representative being the latter two (Tables 2a and 2b). The reaction is known to produce high yields of vanillin from guaiacyl units, syringaldehyde from syringyl units and p-hydroxy-benzaldehyde from p-hydroxyphenyl units, all three being typical end-products of graminaceous lignins. Trace amounts of p-hydroxy-benzaldehyde in straw after NDF extraction, high yields of vanillin and syringaldehyde and small quantities of p-coumaric and ferulic acids were reported by Galletti and Piccaglia (1989).

Total phenolic compounds accounted for 2.59 (wheat Penafiel irrigated from Zaragoza) to 5.24% DM (triticale from Florence), representing, for the samples where ADL were measured, an average value of 57.1 + 21.70% of ADL.

Prediction of nutritive value of straw

Correlation coefficients between degradability parameters, *in vivo* digestibility, intake and chemical composition are reported in Table 3. High correlation coefficients ($P<0.01$) were observed for OMD measured *in vivo* with total potential degradability (a+b, 0.800) or effective degradability (Dg, 0.662), but not for OMD measured *in vitro*. NDF, ADF and ADL contents of the straw samples were negatively correlated with "a+b" and Dg values; moreover, negative coefficients were shown between NDF and the constant rate of degradation ("c") and ADF or ADL and potential degradability ("b"). An increase in the correlation coefficients was generally observed when the phenolic compounds or their sum was used as a predictor of degradability; this was particularly noticeable for aldehydes and total phenolics. The small amount of data available for OMD and phenolic compounds did not allow the calculation of the correlation between them; NDF, ADF and ADL were not correlated with OMD.

The prediction of the nutritive value of straw is thus a critical step, especially if a programme to genetically improve straw quality without affecting grain yield is to be planned.

Results obtained in the present survey have shown that degradability characteristics, potentially degradable fractions ("a+b") and effective degradability (Dg) are promising methods to predict OMD, while NDF content was not correlated. Unfortunately, we were unable to perform a complete range of chemical determinations because the small quantity of sample available or the absence of *in vivo* data rendering additional analysis irrelevant. However, the high correlation coefficients found between degradability characteristics and phenolic residues indicated that they can be taken as criteria to screen cereal varieties. Unpublished data (Susmel *et al.*) on shrubs, forbes and forages grown in dry areas have demonstrated a considerable degree of correlation between phenolic compounds, digestibility and intake in sheep, suggesting that the nutritive value of fibrous feed can be predicted from the chemical analysis of phenolic compounds.

The identification of simple predictors for straw quality is a controversial matter and the opinion of the authors cited above are often contrasting.

Organic matter digestibility and voluntary intake are certainly the final objective in the evaluation of straw quality for animal feeding, but their *in vivo* measurement is expensive and time consuming.

In vitro degradability is often considered a parameter of the nutritive value of straw (Thomson and Ceccarelli, 1991; Capper, 1988), but it is not considered to be an accurate predictor of the nutritive value of straw for genetic purposes. Capper (1988) reported a positive correlation between cellulase solubility of NaOH treated and untreated straw with sheaf proportion, even though for untreated straws it was not significant; titrable phenols were also significantly correlated with cellulase solubility. In an attempt to classify sorghum crop residues, Mueller-Harvey *et al.* (1991) used cluster analysis and *in vitro* data of bird resistant and non bird resistant varieties. The data were homogeneous and led to the conclusion that phenolic analysis is a powerful tool to screen plant for genetic selection.

Table 2a. *In vivo* organic matter digestibility and chemical composition of straws from Florence (If), Clermont Ferrand (Fc), El Harrach (A), Santarem (P) and Udine (Iu)

Sample	Treatment	R.U.	Ref.	OMD (%)	CP (% DM)	NDF (% DM)	ADF (% DM)	ADL (% DM)	Phenolic compounds (% DM)						
									VAN	SYR	VANd	SYRd	pCUM	FER	TOT
Wheat	U	If	1	-	4.00	76.60	53.00	7.40	0.33	0.29	1.45	1.49	0.25	0.34	4.15
Wheat	+	If	2	50.78	10.40	80.10	57.60	7.90	-	-	-	-	-	-	-
Barley	U	If	3	-	4.40	79.80	56.70	8.60	-	-	-	-	-	-	-
Barley	+ NH_3	If	4	-	9.20	78.80	57.80	10.00	-	-	-	-	-	-	-
Triticale	U	If	5	-	3.00	83.40	58.40	9.30	0.40	0.36	1.55	1.95	0.48	0.51	5.24
Triticale	+ NH_3	If	6	-	10.20	76.60	53.90	7.40	-	-	-	-	-	-	-
Wheat	U	Fc	7	41.00	2.50	87.30	51.90	-	0.35	0.35	1.37	1.37	0.36	0.44	4.24
Wheat	+ NH_3 (3 weeks)	Fc	8	54.50	6.90	79.00	53.10	-	-	-	-	-	-	-	-
Wheat	+ NH_3 (8 weeks)	Fc	9	58.50	7.40	80.20	53.70	-	0.33	0.28	1.38	1.13	0.26	0.38	3.77
Wheat	+ Urea (3 weeks)	Fc	10	53.60	20.70	79.40	49.70	-	0.31	0.27	1.37	1.34	0.34	0.42	4.05
Wheat	+ Urea (12 weeks)	Fc	11	55.10	17.60	80.90	51.40	-	-	-	-	-	-	-	-
Wheat	U	A	20	58.50	8.30	78.00	49.10	4.20	0.31	0.26	1.41	1.54	0.35	0.45	4.32
Wheat	+ NH_3	A	18	59.90	11.40	75.10	45.20	4.10	-	-	-	-	-	-	-
Wheat	+ Urea	A	19	50.90	3.60	83.10	52.60	5.20	0.27	0.30	1.25	1.33	0.19	0.37	3.70
Wheat	+ Urea + H_2O	A	21	43.80	9.90	83.20	53.40	4.40	-	-	-	-	-	-	-
Soya		P	30	41.20	6.00	74.60	62.10	15.00	0.17	0.09	1.61	0.97	0.00	0.00	2.85
Wheat E2		P	33	41.60	6.00	76.50	50.60	-	-	-	-	-	-	-	-
Wheat		P	34	52.10	5.00	79.00	52.20	6.98	0.36	0.32	1.49	1.33	0.31	0.47	4.29
Wheat	+ Urea	P	90	48.60	14.90	82.10	58.00	7.83	0.41	0.40	1.70	1.64	0.32	0.51	4.98
Barley Jador		Iu	101	-	-	82.70	56.50	9.10	0.16	0.28	1.61	1.84	0.10	0.12	4.12
Wheat Centauro		Iu	102	-	-	91.80	66.90	12.00	0.22	0.35	1.67	1.57	0.43	0.45	4.69

U = Untreated; NH^3, Urea = Treatments
OMD = data measured by each research unit

Table 2b. Chemical composition of straw from Tunisia (TU), Montpellier (Fm) and Zaragoza (S)

Sample and *var.*	Treatment or water supply	R.U.	Ref.	Chemical composition			Phenolic compounds (% DM)						
				NDF	ADF	ADL	VAN	SYR	VANd	SYRd	pCUM	FER	TOTAL
Barley Rihane	low r	TU	22	86.40	-	-	0.19	0.29	1.56	1.52	0.35	0.37	4.27
Barley Rihane	high r	TU	24	82.50	-	-	0.21	0.32	1.75	1.60	0.36	0.39	4.62
Wheat Razzak	low r	TU	23	78.30	-	-	0.16	0.29	1.55	1.91	0.12	0.29	4.31
Wheat Razzak	high r	TU	27	87.00	-	-	0.16	0.30	1.45	1.66	0.34	0.43	4.33
Wheat Tanit	high r	TU	26	79.50	-	-	0.17	0.24	1.65	1.30	0.20	0.44	4.01
Triticale T13	high r	TU	25	70.60	-	-	0.16	0.26	1.40	1.49	0.30	0.42	4.03
Barley alpha		Fm	41	79.56	48.89	4.00	-	-	-	-	-	-	-
Wheat Primadur	NH_3 d	Fm	39	78.94	48.94	3.83	-	-	-	-	-	-	-
Wheat Primadur	NH_3 i	Fm	40	80.22	50.89	4.33	-	-	-	-	-	-	-
Wheat Neo dur	NH_3 i	Fm	43	82.44	52.17	4.83	-	-	-	-	-	-	-
Wheat Neo dur	NH_3 d	Fm	44	78.44	52.11	4.72	-	-	-	-	-	-	-
Wheat Ardente	NH_3 d	Fm	42	80.83	48.17	3.89	-	-	-	-	-	-	-
Wheat Talent	i	Fm	45	78.55	49.00	5.56	-	-	-	-	-	-	-
Barley Barbarossa	d	S	46	82.77	-	-	0.34	0.32	1.46	1.69	0.27	0.48	4.56
Barley Barbarossa	i	S	47	80.87	-	-	0.38	0.36	1.70	1.76	0.31	0.43	4.94
Wheat Anza	d	S	48	75.87	-	-	0.36	0.29	1.45	1.22	0.27	0.41	3.99
Wheat Anza	i	S	49	81.52	-	-	0.35	0.29	1.67	1.23	0.23	0.45	4.21
Wheat Penafiel	d	S	50	68.33	-	-	0.20	0.16	1.00	0.82	0.15	0.35	2.68
Wheat Penafiel	i	S	51	72.23	-	-	0.22	0.16	0.96	0.71	0.18	0.35	2.59

d = dry land, i = irrigated; low, high r = low and high rain; NH_3 = treatment

Ørskov (1991) considers the degradability characteristics, i.e. "a", "b" and "c" a powerful indicator of both nutritive value and voluntary intake.

Thus a cluster analysis was performed in an attempt to classify the straws in relation to (A) degradability characteristics; (B) phenolic profile and (C) chemical and nutritive criteria.

Table 3. Correlation between digestibility, chemical composition and degradability

	Observations	a	b	c	a+b	Dg
OMD	14	-	0.616*	-	0.800**	0.662**
NDF	40	-0.312*	-	-0.428**	-0.340*	-0.582**
ADF	28	-	-0.510**	-	-0.557**	-0.478*
ADL	22	-	-0.465*	-	-0.601**	-0.442*
SYR	24	-	-	-0.748**	-	-0.641**
pCUM	24	-	-	-0.512*	-	-0.455*
FER	24	-	-	-0.555**	-	-
VAND	24	-	-	-	-0.640**	-0.762**
SYRD	24	-	-	-0.557**	-0.660**	-0.789**
TOT	24	-	-	-0.670**	-0.562**	-0.803*

Among the different combinations of the degradability coefficients, the use of "a", "b", "c" and effective degradability (Dg), permitted good clustering of straws (Fig. 1). The identification of 5 clusters classified the straws into: (1) untreated wheat, barley and triticale straw (apart from the treated wheat straw from Florence), mainly grown on irrigated or high rainfall areas; (2) ammonia treated wheat and triticale straw and one urea treated wheat; (3) a mixed population of wheat, soya, barley and triticale straw, treated and untreated; (4) a cluster of wheat straw; and (5) a cluster in which the variety effect seemed to be predominant.

In a second cluster analysis (Fig. 2), phenolic profiles of 24 straws were used. In this analysis, 5 clusters could be identified: (1) untreated barley and wheat straw (hard and soft); (2) 9 wheat (2 urea treated in which the treatment was ineffective and 1 ammonia treated) and 1 triticale straw, generally grown under conditions of high rainfall or irrigation; (3) two wheat straws of the same variety; (4) barley, triticale and urea wheat straw; and (5) soya straw.

In a third analysis (Fig. 3), cluster criteria included effective degradability, total phenol content and the NDF of 24 straws. Four clusters could be identified: (1) untreated wheat, all the barley and triticale; (2) wheat straws, including urea treated and hard wheat; (3) soya, triticale, ammonia treated soft wheat, urea treated hard wheat and untreated wheat straw; and (4) the same wheat variety as clusters 5 and 4 from analyses 1 and 2.

The results obtained from the clusters analyses were not as accurate as those reported by Mueller-Harvey *et al.* (1991) for sorghum crops, but the extreme variability of the samples surveyed needs to be considered.

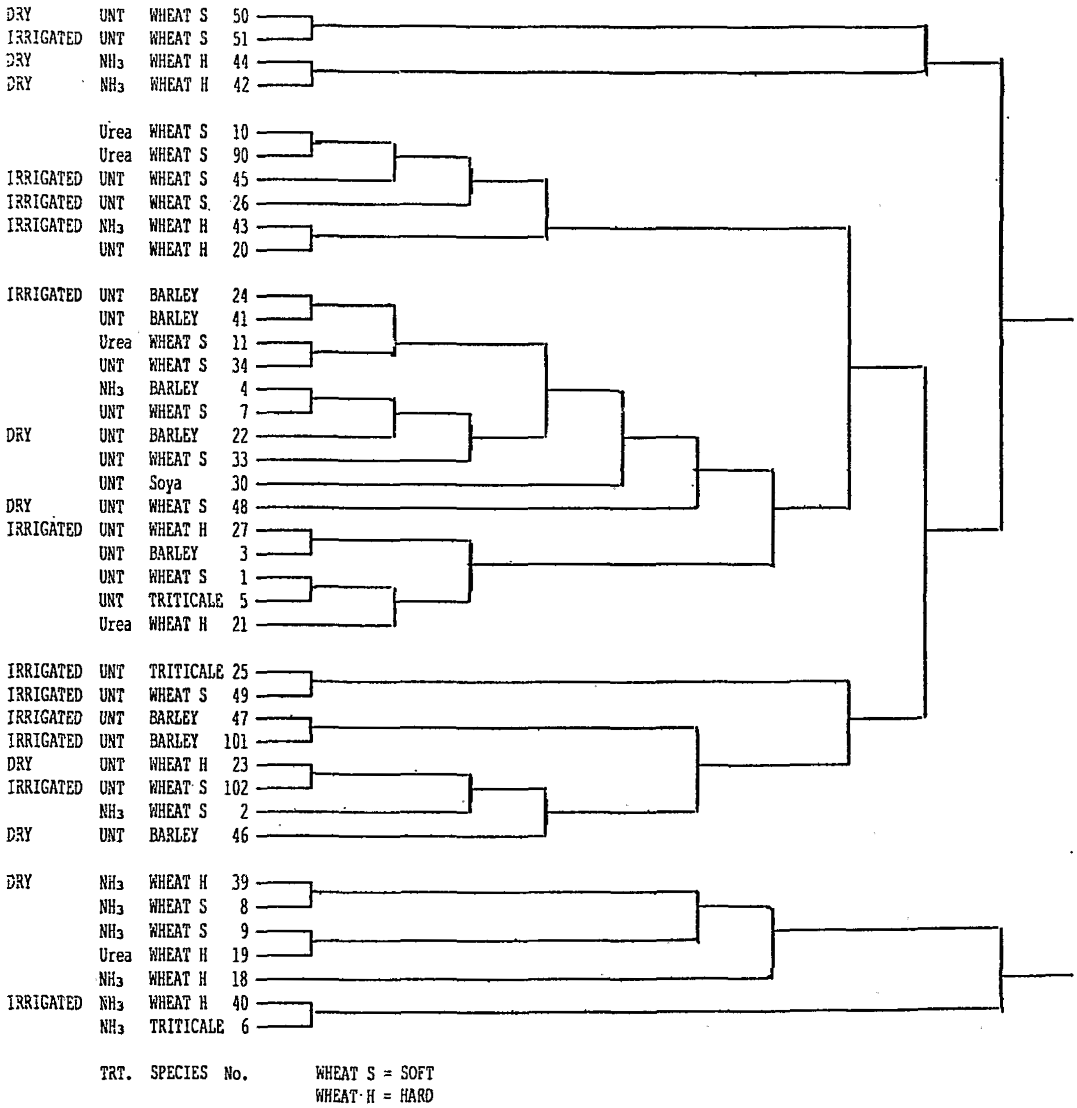

Fig. 1. Clustering of straw by degradability coefficients a, b, and c and Effective Degradability.

Conclusions

In this paper the need for a simple and reliable method to predict the nutritive value of genetically improved cereal varieties has been stressed.

Of the *in vivo* nutritive parameters, the most interesting for the definition of straw quality are the level of voluntary intake and digestibility, but in the present survey the data available were fragmentary and thus a comprehensive investigation to find a good predictor of this parameters, specially DM intake, was not possible.

The rumen degradability measurements and the determination of lignin phenolic profiles led us to the conclusion that species and agronomic factors are important for estimating *in vivo* parameters, but these are not necessarily determining factors. Chemical factors are also useful but simple, physical methods have also been shown to be worthwhile, specially in developing countries where advanced techniques may not be available.

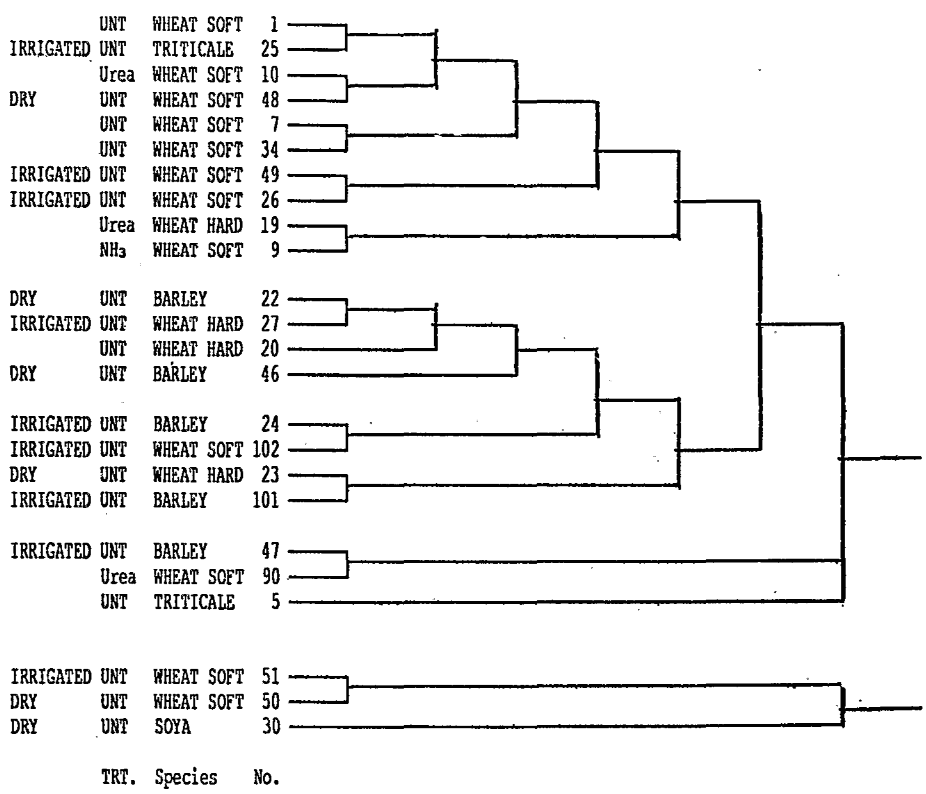

Fig. 2. Clustering of straw by phenolic profiles and total phenolics.

Van der Meer (1989) stressed the need for a structural rather than chemical definition of the lignin-cellulose with reference to intake and digestibility. The most simple methods that can be recommended for use are those that measure leaf to stem ratio, hardness, swelling or other mechanical properties. These methods need to be investigated, implemented and used with chemical methods.

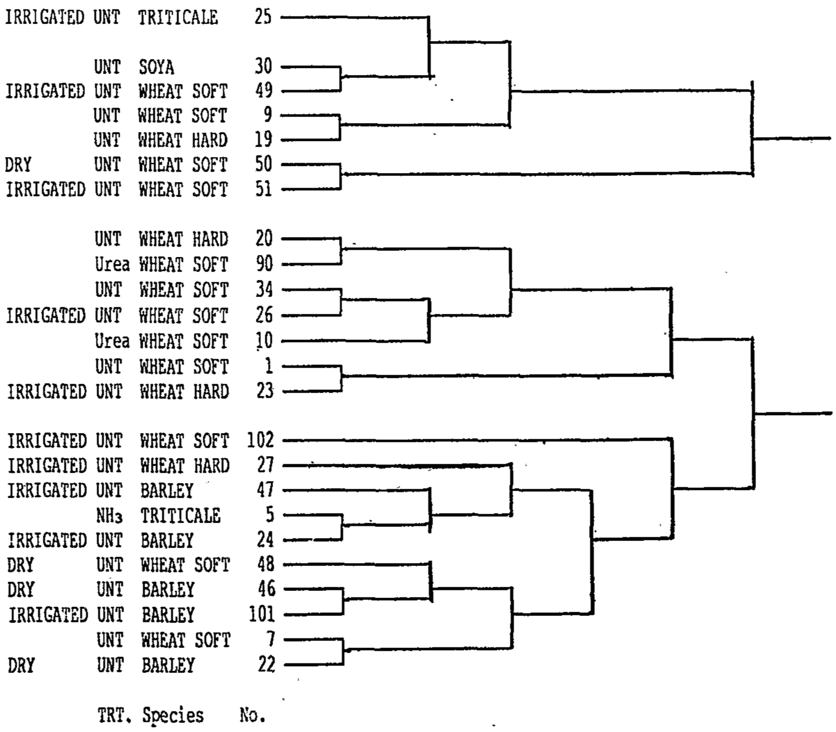

Fig. 3. Clustering of straw by Effective Degradability, total phenol content and NDF.

References

AOAC (1984). Official Methods of Analysis. Association of Official Analytical Chemists, 14th Edn. Washington DC.

ANTONGIOVANNI, M., SARGENTINI, C. (1991). Variability in chemical composition of straws. Options Méditerranéennes, Série A 16: 49-53.

CAPPER, B.S. (1988). Genetic variation in the feeding value of cereal straws. Anim. Feed Sci. Technol. 21: 127-140.

CAPPER, B.S., THOMSON, E.F., RIHAWI, S. (1989). Voluntary intake and digestibility of barley straw as influenced by variety and supplementation with either barley grain or cottonseed cake. Anim. Feed Sci. Technol. 26: 105-116.

CECCARELLI, S. (1987). Tolerance to climate stresses. Barley Genetics V. Proceed. 5th Intern. Barley Genetics Symposium, Okyama, pp. 689-702.

COTTYN, B.G., DE BOEVER, J.L. (1988). Upgrading of straw by ammoniation. Anim. Feed Sci. Technol. 21: 287-294.

DHANOA, M.S., SIDDONS, R.C., FRANCE, J., GALE, D.L. (1985). A multicompartmental model to describe marker excretion patterns in ruminant faeces. Br. J. Nutr. 53: 663-671.

GALLETTI, G.C., PICCAGLIA, R. (1989). Analysis of lignin in straw by HPLC with electrochemical detector. In: Evaluation of straw in ruminant feeding. Eds Chenost M. and Reiniger, P. Elsevier Applied Science, London, pp. 163-172.

GIVENS, D.I., EVERINGTON, M.J., ADAMSON, A.H. (1989). Chemical composition, digestibility *in vitro* and energy value *in vivo* of untreated cereal straw produced on farms throughout England. Anim. Feed Sci. Technol. 26: 323-335.

GLAND, A. (1991). Genetic comparison of different accessions of barley for arid zones. In: Production and Utilisation of lignocellulosics. Ed. Galletti, G.C. Elsevier Applied Science, London and New York, pp. 229-236.

GOERING, H.K., VAN SOEST, P.J. (1970). Forage Fibre analyses (Apparatus, Reagents, Procedures and some Applications). USDA Agricultural Handbook No. 379.

KERNAN, J.A., CROWLE, W.L., SPURR, D.T., COXWORTH, E.C. (1979). Straw quality of cereal cultivars before and after treatment with anhydrous ammonia. Can. J. Anim. Sci. 59: 511-517.

KOSSILA, V. (1984). Location and potential feed use. In: Straw and other fibrous by-products as feeds. Eds Sundstøl, F. and Owen, E. Elsevier, Amsterdam, pp. 4-24.

MEER Van der, J.M. (1989). Physical methods in the study of cell wall structures and cell wall degradation. In: Evaluation of straw in ruminant feeding. Eds Chenost, M. and Reiniger, P. Elsevier Applied Science, London, pp. 108-123.

MULLER-HARVEY, I., DHANOA, M.S., BLACKWELL, P.M.S., REED, J.D. (1991). Cluster analysis of HPLC separations of phenolics and *in vitro* degradability of sorghum crop residues to describe differences amongst varieties and sites. In: Production and Utilisation of lignocellulosics. Ed. Galletti, G.C. Elsevier Applied Science, London and New York, pp. 277-289.

OHLDE, G.W., BECKER, G., AKIN, D.E., RIGSBY, L.L., LYON, C.E. (1992). Differences in rumen bacterial degradation of morphological fractions in eight cereal straws and the effect of digestion on different types of tissue and mechanical properties of straw stalks. Anim. Feed Sci. Technol. 36: 173-186.

ØRSKOV, E.R. (1991). Possibility of manipulating resource quality by genetic selection. In: Production and Utilisation of lignocellulosics. Ed. Galletti, G.C. Elsevier Applied Science, London and New York, pp. 219-228.

ØRSKOV, E.R., McDONALD, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. Cambs. 92: 499-503.

ØRSKOV, E.R., REID, G.W., KAY, M. (1988). Prediction of intake by cattle from degradation characteristics of roughages. Anim. Prod. 46: 29-34.

ØRSKOV, E.R., SHAND, W.J, TEDESCO, D., MORRICE, L.A. (1990). Rumen degradation of straw. 10. Consistency of differences in nutritive value between varieties of cereal straw. Anim. Prod. 51: 155-162.

RAMANZIN, M., ØRSKOV, E.R., TUAH, A.K. (1986). Rumen degradation of straw. 2. Botanical fraction of straw from two barley cultivars. Anim. Prod. 43: 271-278.

SAS. SAS-STAT Users Guide. Release 6.03 Edition. SAS Institute Inc., Cary, NC.

SPSSx (1985). SPSSx User Guide. McGraw-Hill, New York.

SHAND, W.J., ØRSKOV, E.R., MORRICE, L.A.F. (1988). Rumen degradation of straw. 5. Botanical fractions and degradability of different varieties of oat and wheat straw. Anim. Prod. 47: 387-392.

SUNDSTØL, F. (1988). Straw and other fibrous by-products. Livestock Production Science 19: 137-158.

THEANDER, O., AMAN, P. (1984). Anatomical and chemical characteristics. In: Straw and other fibrous by-products as feed. Eds Sundstøl, F. and Owen, E. Elsevier, Amsterdam, pp. 45-78.

THOMSON, E.F., CECCARELLI, S. (1991). Progress and future directions of applied research on cereal straw quality at ICARDA. In: Production and Utilisation of lignocellulosics Ed. Galletti, G.C. Elsevier Applied Science, London and New York, pp. 249-263.

TUAH, A.K, LUFADEJU, E., ØRSKOV, E.R. (1986). Rumen degradation of straw. 1. Untreated and ammonia treated barley, oat and wheat straw varieties and triticale straw. Anim. Prod. 43: 261-269.

WALLI, T.K., ØRSKOV, E.R., BHARGAVA, P.K. (1988). Rumen degradation of straw.

3. Botanical fractions of two rice straw varieties and effects of ammonia treatment. Anim. Prod. 46: 347-352.

WILLIAMS, C.H., DAVID, D.J., IISMAA, O. (1962). The determination of chromic oxide in faeces samples by atomic adsorption spectroscopy. J. Agric. Sci. 59: 381-385.