Effect of Stage of Maturity and Cultivars on the Digestibility of Whole Maize Plant and its Morphological Fractions

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ABSTRACT : A study was conducted on four maize cultivars to determine the dry matter and fibre digestibility as influenced by advancing plant age. Samples of maize cultivars Akbar, Neelum, UM-81 and IZ-31 were harvested at weekly intervals/ growth stages. The samples of morphological fractions such as leaf and stem were also collected at various growth stages. Whole mixed fodder and different fractions of maize plant were analysed for their chemical composition and *in vitro* digestibility. The results showed that *in vitro* dry matter digestibility (IVDMD) of whole maize plant, leaf and stem decreased significantly with advancing stage of maturity. Digestibility of NDF, ADF, hemicellulose and cellulose decreased significantly in all plant parts with advancing plant age/growth stages. Maximum values for the digestibility of dry matter and various cell wall constituents were observed in leaf, followed by whole plant and stem fractions. Cultivars were observed to have significant effect on IVDMD and digestibility of NDF, ADF and cellulose in all plant fractions. The results indicated that digestibility of maize fodder was affected by stage of maturity and cultivars. However, maturity had a greater effect on digestibility in all plant fractions than did cultivars. Dry matter contents were found to be significantly and negatively correlated with IVDMD of whole plant and its leaf and stem fractions. Based on correlations, regression equations were computed to predict IVDMD. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1228-1233*)

Key Words : Maize, Stage of Maturity, Cultivars, Morphological Fractions, IVDMD, Prediction Equations for IVDMD

INTRODUCTION

The value of a good quality fodder for animal production depends upon the nutrient concentration as well as fodder intake by animals. The quality of fodder is evaluated in terms of palatability, voluntary intake, digestibility and utilization of various nutrients. Poor digestibility and lower voluntary intake are always associated with relatively higher lignin contents. Lignin is a chemical fraction of the cell wall most frequently associated with digestibility of forages by ruminants (Van Soest, 1987). Various mechanisms have been suggested by which lignin inhibits cell wall digestion e.g. encrustation, toxicity to digesting microbes and lignin-polysaccharide complexes. Plant polysaccharides are not simply encrusted by lignin but are probably covalently bonded to it (Bolker, 1963).

Maize has for centuries been used as a forage crop in Pakistan. Generally, the maize fodder along with cobs at milking stage is cut and fed to animals. It provides adequate energy and protein for growth and milk production (Choudhry, 1983). Maize has always higher *in vitro* dry matter digestibility as compared to other fodder crops and is considered as the most suitable summer fodder crop (Lloveras, 1990).

Most of the work conducted on forage evaluation is on forages grown in temperate regions and this information as such may not be applicable to fodders grown in tropical or sub-tropical climate. The tropical forages are generally higher in lignin contents than those in the temperate regions. Animal production in tropical countries is, therefore, handicapped by the low quality of the forages (Van Soest, 1987). Comprehensive nutritional evaluation of maize fodder has not been undertaken in Pakistan. An attempt was, therefore, made to determine the nutritive value of local maize fodder with particular reference to morphological fractions, cultivar differences and the effect of advancing harvest stages.

MATERIALS AND METHODS

The study was conducted on four approved maize cultivars, Akbar, Neelum, UM-81 and IZ-31. All the maize cultivars were sown from March to June, 1991 in the experimental fields of the University of Agriculture, Faisalabad. The crop was sown in 3 replicates using randomized complete block design. Urea at the rate of 125 kg/hectare was applied as fertilizer. Six irrigations of canal water were given during the 14 weeks experimental period. The fodder was harvested for drawing samples at weekly intervals. The morphological fractions of the plant such as leaf and stem were also collected at various growth stages. The leaves (blade + sheath) were separated manually from the stem. The whole maize plant and its leaf and stem fractions were chopped into 2 to 3 cm pieces and dried at 60℃ (AOAC, 1984). Dried samples were ground, passed through 1mm screen and saved in labeled airtight containers for analysis. The structural components such as neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose,

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Table 1. *In vitro* digestibility coefficients of DM, NDF, ADF, hemicellulose and cellulose of whole maize plant and its morphological fractions at different growth stages (Mean±SE)

Description	Growth stages (age in weeks)				
	Seedling (1st week)	Early growth (5th week)	Flowering (9th week)	Milk/dough (11th week)	Mature (14th week)
			Whole plant		
IVDMD	75.82 ± 0.39^a	72.34 ± 0.31^b	70.30 ± 0.33^c	67.35 ± 0.35^d	65.69 ± 0.40^e
NDF	72.45 ± 0.43^a	70.82 ± 0.38^b	69.01 ± 0.36^c	66.72 ± 0.52^d	65.54 ± 0.31^e
ADF	67.93 ± 0.76^a	64.11 ± 0.77^b	63.06 ± 0.62^c	58.18 ± 0.48^d	57.40 ± 0.54^d
Hemicellulose	86.27 ± 0.33^a	81.64 ± 0.54^b	77.21 ± 0.44^c	75.93 ± 0.43^c	73.26 ± 0.49^d
Cellulose	83.47 ± 0.46^a	79.12 ± 0.50^b	72.94 ± 0.48^c	65.77 ± 0.46^d	63.01 ± 0.48^e
			Leaf		
IVDMD	77.04 ± 0.33^a	75.75 ± 0.27^b	73.98 ± 0.32^c	69.94 ± 0.40^d	68.21 ± 0.39^e
NDF	76.70 ± 0.54^a	76.29 ± 0.45^a	74.49 ± 0.45^b	71.83 ± 0.49^c	70.24 ± 0.62^d
ADF	69.71 ± 0.26^a	69.06 ± 0.24^a	67.63 ± 0.36^b	62.78 ± 0.70^c	61.86 ± 0.64^c
Hemicellulose	88.42 ± 0.49^a	86.34 ± 0.39^b	86.18 ± 0.31^b	85.13 ± 0.17^b	82.27 ± 0.63^c
Cellulose	87.74 ± 0.31^a	85.88 ± 0.37^b	83.81 ± 0.54^c	78.11 ± 0.62^d	75.12 ± 0.47^e
			Stem		
IVDMD	69.35 ± 0.27^a	66.82 ± 0.29^b	62.02 ± 0.33^c	59.45 ± 0.39^d	58.52 ± 0.24^d
NDF	62.34 ± 0.63^a	59.48 ± 0.82^b	58.67 ± 0.69^b	54.98 ± 0.52^c	54.40 ± 0.46^c
ADF	54.11 ± 1.65^a	50.91 ± 2.05^{ab}	49.61 ± 1.62^b	43.84 ± 0.93^c	42.72 ± 0.94^c
Hemicellulose	76.03 ± 0.38^a	73.11 ± 0.87^b	70.48 ± 0.49^c	68.81 ± 0.25^{cd}	67.71 ± 0.22^d
Cellulose	74.44 ± 0.36^a	67.61 ± 1.12^b	60.11 ± 1.39^c	51.35 ± 0.80^d	49.39 ± 0.90^d

[a,b,c,d,e] Different superscripts on means in a row show significant ($p<0.01$) differences.

cellulose, lignin, cutin and silica (Firdous, 1997) were determined by using detergent system (Van Soest and Robertson, 1985).

The *in vitro* digestion technique developed by Troelsen (1971) was used for measuring the digestibility of dry matter and various fibrous fractions such as NDF, ADF, hemicellulose and cellulose of the fodder samples. Fodder samples (3 g) were weighed in 250 ml Erlenmeyer flasks fitted with rubber stoppers. The flasks and samples were placed in an incubator at 39±10℃ and 120 ml inoculum was added to each flask. The inoculum was prepared by mixing the strained rumen fluid with artificial sheep saliva (McDougall, 1947) as modified by Baumgardt et al. (1962). The artificial sheep saliva was heated and held at 39℃ and charged with stream of carbon dioxide before the rumen fluid was added. The digestion time was 48±1 hours. The digested samples were filtered and washed with boiling water. The residue was dried at 105℃ and weighed. The above mentioned procedure was followed up to stage one only.

Statistical analysis

The data on various parameters were subjected to statistical analysis using analysis of variance technique and Duncan's multiple range test was applied to compare treatment means (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

In vitro digestibility

The data on *in vitro* digestibility coefficients of various structural components of different fractions of maize plant at various growth stages have been presented in table 1. Table 2 shows the average digestibility coefficients of DM and various cell wall components of different cultivars of maize plant and its morphological fractions.

A. *In vitro* dry matter digestibility (IVDMD)

The DM digestibility declined significantly with advancing age in whole maize plant and its leaf and stem fractions. The highest DM digestibility coefficients were recorded in case of leaf fraction (68.21±0.39 to 77.04±0.33). The DM digestibility of whole plant ranged from 65.69±0.40 to 75.82±0.39, being higher than that of stem fraction of the plant (58.52±0.24 to 69.35±0.27). Azim et al. (1989) also reported a decline in dry matter digestibility (DMD) of whole maize plant and its fractions at two vegetative stages. They further reported that maximum DMD was found in leaves followed by whole mixed plant, middle and bottom portions of the stem. However, the values reported by them were lower than those observed in the present study.

Table 2. Digestibility coefficient of DM, NDF, ADF, hemicellulose and cellulose of different cultivars of whole maize plant and its morphological fractions (all stages combined) Mean±SE

Cultivars	Structural components				
	DM	NDF	ADF	Hemicellulose	Cellulose
			Whole plant		
Akbar	70.84±1.01[b]	69.08±1.10[b]	62.29±1.21[b]	79.15±1.79	72.86±2.62[b]
Neelum	71.39±1.21[a]	69.95±0.95[a]	64.51±1.33[a]	80.02±1.49	74.55±2.66[a]
UM-81	69.13±0.98[d]	67.38±0.89[c]	60.23±1.09[c]	78.01±1.48	71.69±2.61[b]
IZ-31	69.85±0.98[c]	68.44±1.08[c]	61.57±1.38[bc]	78.26±1.43	72.35±2.66[b]
			Leaf		
Akbar	73.45±0.85[b]	74.03±0.89[b]	66.53±1.15[ab]	85.72±0.62[ab]	81.85±1.68[b]
Neelum	74.22±0.91[a]	75.88±0.77[a]	67.71±0.76[a]	86.82±0.59[a]	83.69±1.45[a]
UM-81	71.96±0.98[c]	72.40±0.83[c]	65.15±1.20[b]	84.37±0.84[b]	80.63±1.57[c]
IZ-31	72.29±0.95[c]	73.32±0.93[b]	65.44±1.27[b]	85.76±0.84[ab]	82.35±1.70[b]
			Stem		
Akbar	63.22±1.20[ab]	57.71±1.24[b]	48.44±1.84[b]	71.55±1.27	59.42±3.21[bc]
Neelum	63.86±1.27[a]	60.50±1.06[a]	53.75±1.88[a]	70.51±0.75	63.10±2.87[a]
UM-81	62.48±1.16[b]	56.86±0.88[b]	45.66±1.54[b]	70.98±1.12	58.07±3.42[c]
IZ-31	63.39±1.06[ab]	56.83±0.83[b]	45.11±0.17[b]	70.80±1.16	61.73±3.34[ab]

[a,b,c] Different superscripts on means in a row/column show significant ($p<0.01$) differences.

Variations in DM digestibility due to cultivars were significant in whole plant and its leaf and stem fractions. Neelum cultivar had significantly higher DM digestibility in whole plant, leaf and stem fractions when compared to other cultivars, whereas significantly lower digestibility was observed in case of UM-81 cultivar. The higher DM digestibility of Neelum, as compared to other cultivars could be due to lower NDF, ADF and lignin concentrations in it. Hunt et al. (1993) also reported that rumen in situ (24 hr) and 2 - stage in vitro DM digestibility of whole maize plant and stover samples was greater ($p<0.01$) for maize hybrid 3377 than for 3389.

B. Cell wall constituents

NDF

Significant differences ($p<0.01$) existed among *in vitro* NDF digestibility coefficient of whole maize plant and its morphological fractions with advancing growth stages. NDF digestibility coefficients of leaf fraction ranged from 70.24±0.62 to 76.70±0.54, being higher than those of whole plant (64.54±0.31 to 72.45 ±0.43). However, the stem fraction had the lowest NDF digestibility (54.40±0.46 to 62.34±0.63). A similar trend was reported by Vona et al. (1984). They observed that digestibility of NDF by cattle and sheep declined ($p<0.05$) with advancing maturity of the grasses. Cultivar effects on NDF digestibility varied in whole plant and its leaf and stem fractions. Neelum cultivar had significantly higher NDF digestibility in all plant fractions, whereas it was the lowest in UM-81. It was probably due to the higher structural components of UM-81 than that of Neelum cultivar. Hunt et al. (1993) also reported significant differences in the digestibility of NDF between maize hybrids.

ADF

In vitro ADF digestibility declined significantly in whole maize plant and its leaf and stem fractions with advancing stages of growth. The leaf fraction of the plant was found to have the highest ADF digestibility (61.86±0.64 to 69.71±0.26) followed by whole plant (57.40±0.54 to 67.93±0.76). However, the lowest ADF digestibility (42.72±0.94 to 54.11±0.65) was observed in case of stem fraction. This variation was probably due to higher hemicellulose and cell contents and lower lignin concentration in the leaf fraction of the plant. Hemicellulose contents of whole plant, leaf and stem fractions were 22.98, 24.23 and 21.57 percent, respectively. Whereas the lignin concentration was 3.71, 3.09 and 4.88 percent, respectively (Firdous, 1997).

Significant variations also existed in the *in vitro* ADF digestibility of whole maize plant and its leaf and stem fractions with respect to various cultivars. ADF digestibility was found to be higher for Neelum cultivar in whole plant, leaf and stem fractions (table 2). However, ADF digestibility was almost similar for Akbar, UM-81 and IZ-31 cultivars. It may be due to lower lignin concentration in Neelum, as compared to other cultivars. Digestibility of ADF was reported to be higher in maize hybrid pioneer 3377 than in 3389 (Hunt et al., 1993).

Table 3. Prediction equations for IVDMD (Y) from DM contents of various cultivars of maize (whole plant) and its morphological fractions

Varieties	Regression equations	Correlation (r)	SE
		Whole plant	
Akbar	Y = 79.9 - 0.415 DM	-0.930**	±0.38
Neelum	Y = 80.3 - 0.421 DM	-0.906**	±0.43
UM-81	Y = 78.0 - 0.426 DM	-0.940**	±0.36
IZ-31	Y = 82.9 - 0.463 DM	-0.946**	±0.33
		Leaf	
Akbar	Y = 82.9 - 0.356 DM	-0.972**	±0.21
Neelum	Y = 83.5 - 0.359 DM	-0.966**	±0.24
UM-81	Y = 82.1 - 0.406 DM	-0.964**	±0.27
IZ-31	Y = 82.5 - 0.406 DM	-0.959**	±0.28
		Stem	
Akbar	Y = 73.6 - 0.576 DM	-0.940**	±0.43
Neelum	Y = 76.3 - 0.751 DM	-0.939**	±0.42
UM-81	Y = 71.7 - 0.524 DM	-0.862**	±0.61
IZ-31	Y = 72.4 - 0.525 DM	0.863**	±0.56

** = Significant ($p<0.01$).

Hemicellulose

In vitro hemicellulose digestibility declined significantly with advancing plant maturity in whole maize plant and its morphological fractions. *In vitro* hemicellulose digestibility coefficients were higher in leaves (82.27±0.63 to 88.42±0.49) than those in whole plant (73.26±0.49 to 86.27±0.33). Hemicellulose digestibility coefficients ranged from 67.71±0.22 to 76.03±0.38, being the lowest in the stem fraction of the plant. The digestibility of hemicellulose has been reported to decline non-linearly with advancing maturity stage (Sanderson et al., 1989). Hemicellulose was digested 80 percent faster than cellulose. Singh and Narang (1990) also noted a slightly higher hemicellulose digestibility than that of cellulose in different forages. Findings of this study are in line with those of the above reported work.

Variations in hemicellulose digestibility due to various cultivars were observed only in case of leaf fraction of the plant. Neelum cultivar had higher hemicellulose digestibility, whereas the lowest digestibility was observed in leaves of UM-81. The higher hemicellulose digestibility of leaves of Neelum could be due to its lower indigestible fibre fractions such as NDF, ADF and lignin. Neelum and UM-81 cultivars had 54.33 vs. 55.87 NDF, 31.70 vs. 32.43 ADF and 3.42 vs. 3.69 percent lignin (Firdous, 1997).

Cellulose

In vitro cellulose digestibility of whole plant and its leaf and stem fractions continued to decrease significantly with advancing stages of growth. Cellulose digestibility coefficients of the leaf fraction of the plant ranged from 75.12±0.47 to 87.74±0.31, being higher than that of whole plant (63.01±0.48 to 83.47±0.46), whereas the stem fraction had the lowest (49.39±0.90 to 74.44±0.36) cellulose digestibility. It was probably due to lower cell wall (NDF) and lignin concentration in leaves than stem. The leaf and stem fractions of maize plant had 54.03 vs. 58.54 percent NDF and 3.09 vs. 4.88 percent lignin, respectively (Firdous, 1997). Rocha and Vera (1981) reported a decrease in cellulose digestibility by 0.39±14 percent daily in some tropical grasses.

Cellulose digestibility was also affected by different cultivars in whole maize plant, leaf and stem. Cellulose digestibility of Neelum cultivar was found to be significantly higher in all cases. However, UM-81 cultivar had the lowest digestibility in various plant fractions. Neelum cultivar had lower concentration of indigestible fibre fractions, whereas UM-81 cultivar had higher lignin concentration, which may be related to lower cellulose digestibility in this variety i.e. 3.42 vs. 3.69 percent (Firdous, 1997).

Relationship between DM contents and *in vitro* IVDMD

Correlation was computed between dry matter (DM) contents and IVDMD of different plant fractions. Correlation coefficients were observed among DM contents and IVDMD of different plant fractions. Correlation values (r) were -0.897, -0.918 and -0.892 for whole plant, leaf and stem, respectively. Based on the correlations, regression / prediction equations were computed to work out percent IVDMD (y) of whole plant, leaf and stem. The prediction equations are given below.

Whole plant: Y = 79.3 - 0.423 DM (SE, 0.22)
Leaf: Y = 82.6 - 0.375 DM (SE, 0.37)

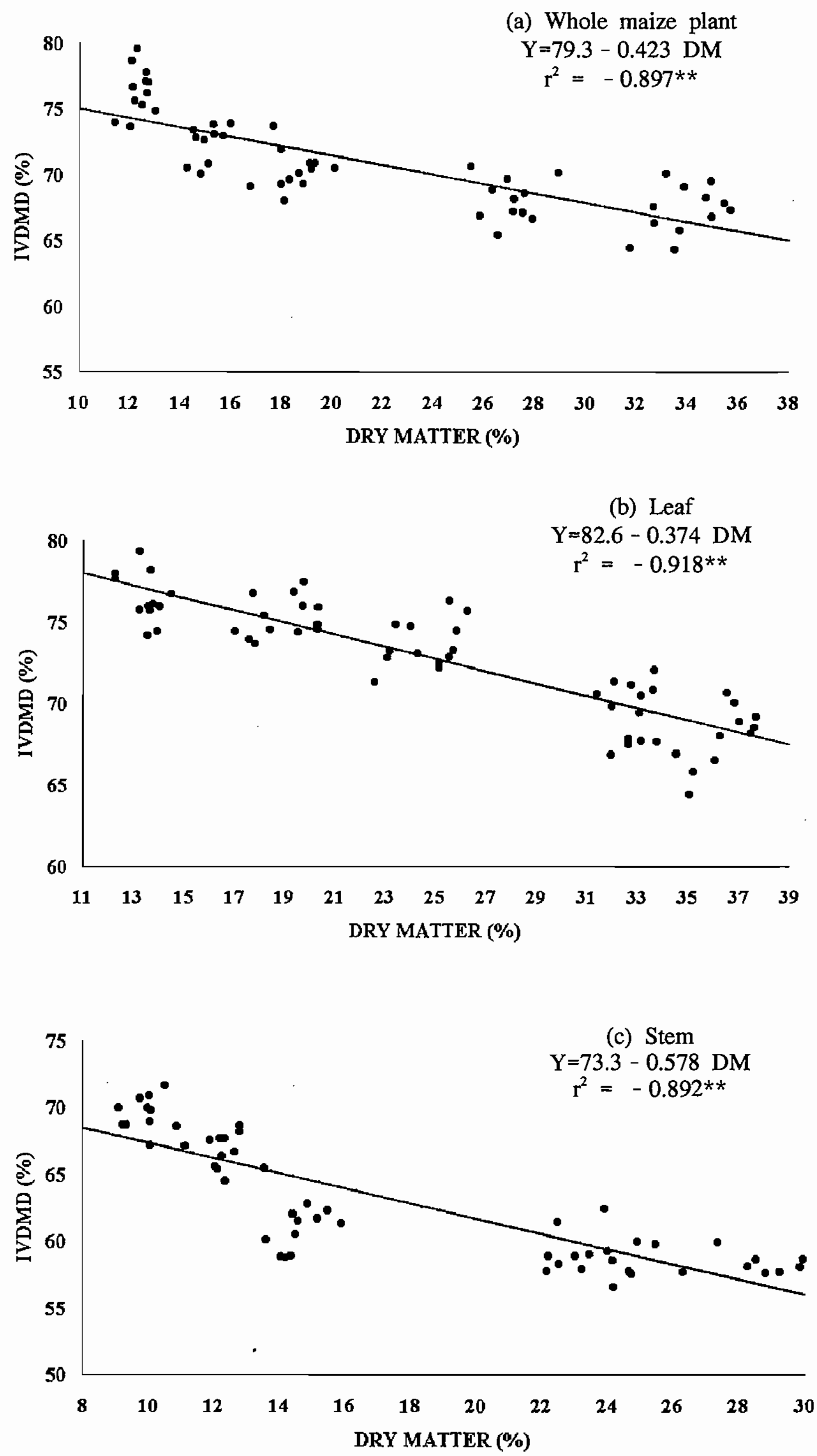

Figure 1. Relationship between *in vitro* IVDMD and dry matter contents of whole maize plant (a), leaf (b) and stem (c)

Stem: Y = 73.3 - 0.578 DM (SE, 0.51)

Regression lines showing the relationship between DM contents and IVDMD of whole plant (a), leaf (b), and stem (c), are presented in figure 1.

Correlation coefficients were also calculated between DM contents and IVDMD of different cultivars of whole maize plant and its morphological fractions. DM contents were found to be significantly ($p<0.01$) and negatively correlated with IVDMD of various cultivars of whole plant, leaf and stem. Regression equations along with correlation coefficients (r) and standard error (SE) of different varieties of maize plant and its morphological fractions are given in table 3.

The results showed that as the DM concentration increased there was a decrease in IVDMD of maize (whole plant) and its morphological fractions. This might have negative effect on the palatability and digestibility. It is therefore apparent that the plant maturity has adverse effect on the quality of fodder.

Recommendations

On the basis of the results of the present study, the following recommendations are made.

1. Maize fodder may be cut preferably between 8th-9th week of age (flowering stage) to obtain fodder having more nutrients and better digestibility for livestock feeding. However, the harvest time can be further assessed on the basis of total digestible nutrients and dry matter yield of a particular cultivar.
2. Among the maize cultivars, Neelum proved to be the best. This cultivar had higher digestibility and DM contents and lower concentration of indigestible fibre fractions. In addition yield and other agronomic characteristics may also be considered.
3. Regression equations could be helpful for quick estimation of nutritive value of maize fodder by scientists working in the field of forage evaluation.

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