Utilization

Stover Fodder Quality Traits for Dual-purpose Sorghum Genetic Improvement

M Blümmel[1]* and **Belum VS Reddy**[2]
[1. International Livestock Research Institute (ILRI), c/o ICRISAT, Patancheru 502 324, Andhra Pradesh, India;
2. ICRISAT, Patancheru 502 324, Andhra Pradesh, India]
*Corresponding author: m.blummel@cgiar.org

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] stover plays an important part in the feed budget of Indian farmers who often demand dual-purpose sorghums. Farmer preferences therefore have resulted in the exploration of ways of including stover fodder assessment in sorghum genetic improvement research at ICRISAT-Patancheru, India, as well as Indian sorghum programs. This requires simple yet meaningful and easily measurable laboratory fodder quality traits to reliably rank cultivars for stover quality. Livestock nutritionists have proposed many laboratory traits for fodder quality assessment, but validation of these indicators through actual livestock productivity trials has been limited, and often applied only to higher-quality feed stuffs used in the manufacture of industrialized livestock feed. Basing dual-purpose sorghum genetic improvement work on untested laboratory traits could clearly present uncertain results for the breeding objective. In that context, this study compares a wide range of chemical (nitrogen, fiber constituents neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) and sugar) and *in vitro* (rate and extent of *in vitro* gas production, apparent and true digestibility) measurements to assess organic matter digestibility, organic matter intake, nitrogen balance and digestible organic matter intake of 22 sorghum stover samples fed to sheep.

Materials and Methods

The materials consisted of 22 sorghum stover samples obtained from 13 genotypes (CSH 16, CSH 18, ICSR 93034, CSV 15, ICSV 700, ICSV 93046, PSV 16, S 35, ICSV 745, SPH 1148, Andhra, Telangana and Raichur). The total number of 22 was arrived at because 4 cultivars were grown in consecutive years and compared to sorghum grown continuously (4) and intercropped (4) with pigeonpea. In addition, stover from one local cultivar (Telangana) was purchased from two different fodder traders and fed separately to sheep.

Sheep feeding trials. Growing male sheep of the 'Deccani' breed with a mean live weight of about 20 kg were fed with stover samples of different cultivars to measure stover quality traits in *in vivo* experiments. The sheep were housed in metabolic cages enabling the measurement of feed intake, feed digestibility and nitrogen balance. Stover samples from each cultivar/source were fed to six sheep randomly allocated according to body weight (sheep groups were balanced according to live weight). The sheep were made accustomed to a stover type for a minimum of two weeks, followed by a 10-day fecal and urine collection period for estimation of stover digestibility and nitrogen balance, respectively. All stover samples were offered chopped and as sole feed (ie, no supplement given) about 15% more than appetite. In other words, sheep were allowed to refuse about 15% of the stover offered, which is the norm for investigating voluntary (*ad libitum*) feed intake.

Laboratory stover quality analysis. Stover samples were analyzed for nitrogen (N × 6.25 = crude protein), NDF, which is an estimate of the cell wall fraction, ADF, which is an estimate of cellulose content, ADL and sugar content by routine chemical analytical procedures. Biological fodder quality traits of the stover samples were analyzed for apparent *in vitro* digestibility using *in vitro* gas production procedures (Menke and Steingass 1988) and for true *in vitro* digestibility using the gravimetric procedure (Goering and van Soest 1970). The extent, rate and lag phase of *in vitro* fermentation kinetics were determined using *in vitro* gas production as described by Blümmel and Ørskov (1993).

Statistical analysis. The statistical package of SAS (1988) was used for analysis of variance (SAS GLM procedure) for estimation of simple correlations between laboratory quality traits and *in vivo* measurements and for stepwise multiple regressions between laboratory traits and *in vivo* measurements.

Results and Discussion

Significant differences were observed in organic matter digestibility (OMD), and intake (OMI), nitrogen balance and digestible organic matter intake (DOMI) of the various sorghum stover treatments (Table 1). [When these *in vivo* measurements were calculated for only one stover per cultivar (the one fed first) of the 13 studied, the statistical differences were of the same order; data not shown]. The ranges observed in the *in vivo* measurements were substantial from a livestock productivity viewpoint. A difference of 4–5 percentage units in *in vivo* digestibility can result in a 17–24% difference in livestock productivity (Vogel and Sleper 1994). In our study, the difference in *in vivo* digestibility observed in the sorghum stover samples was about 15% (Table 1). Similarly, digestible organic matter intake, which is directly related to the performance of livestock fed on cereal crop residues (Blümmel et al. 2003), varied more than 1.6-fold. Differences of this magnitude will have huge implications for livestock productivity.

Correlations indicated significant association of laboratory traits with OMD, OMI and DOMI (Table 2). However, only stover nitrogen content was significantly related to N balance. The latter finding is not surprising since stover (or generally feed) nitrogen content is one of the measurements used to calculate nitrogen balance, and the two measurements are therefore not really independent. Also nitrogen balances in the kind of feeds used in our study should be considered with some caution. The overall levels of nitrogen input and output were relatively small, and the potential for analytical errors is considerable as feed nitrogen, feed-refusal nitrogen, urinary nitrogen and fecal nitrogen are all input variables into the balance. Also animal hair growth is an alternative sink for nitrogen, which was not considered in the present work, and which could have effects on the nitrogen balance when established from overall small nitrogen inputs and outputs.

Most relations between laboratory traits and *in vivo* measurements were as expected in that nitrogen content and *in vitro* digestibility measurements were positively associated with OMD, OMI and DOMI while fiber constituents (NDF, ADF and ADL) were significantly negatively associated with OMD, OMI and DOMI. The time and analytical inputs required for the various traits

Table 1. Mean values and ranges of organic matter digestibility (OMD) and intake (OMI), nitrogen balance (N balance) and digestible organic matter intake (DOMI) of 22 sorghum stovers fed *ad libitum* to sheep.

Measurement	Mean	Range	Probability	LSD[1]
OMD (%)	57.1	50.9–65.1	<0.0001	3.24
OMI (g/kgLW$^{0.75}$/d)[2]	44.9	37.2–56.8	<0.0001	5.67
N balance (g/kgLW$^{0.75}$/d)	–0.007	–0.25–0.21	<0.0001	0.08
DOMI (g/kgLW$^{0.75}$/d)	25.7	20.4–33.0	<0.0001	3.2

1. LSD = Least significant difference.
2. LW$^{0.75}$ is live weight to the power of 0.75, which is equivalent to the metabolic live weight.

Table 2. Estimates of correlations between laboratory sorghum stover quality traits organic matter digestibility (OMD) and intake (OMI), nitrogen balance, and digestible organic matter intake (DOMI) and *in vivo* measurements.

Trait	OMD	OMI	N balance	DOMI
Nitrogen	0.47 (0.03)[1]	0.63 (0.002)	0.67 (0.0007)	0.72 (0.0002)
NDF[2]	–0.58 (0.005)	–0.51 (0.01)	0.15	–0.65 (0.001)
ADF[3]	–0.58 (0.005)	–0.71 (0.0002)	0.11	–0.82 (0.0001)
ADL[4]	–0.61 (0.003)	–0.67 (0.0006)	–0.17	–0.79 (0.0001)
Sugar	0.52 (0.01)	0.39 (0.07)	–0.32	0.53 (0.01)
Apparent *in vitro* digestibility	0.48 (0.02)	0.60 (0.003)	–0.02	0.69 (0.0003)
True *in vitro* digestibility	0.47 (0.03)	0.70 (0.0003)	0.12	0.77 (0.0001)
In vitro fermentation kinetics				
Extent	0.40	0.70 (0.0003)	–0.15	0.75 (0.0001)
Rate	0.36	0.34	0.04	0.43 (0.04)
Lag	–0.32	–0.42 (0.05)	0.11	–0.46 (0.03)

1. Values in parentheses are statistical probability values.
2. NDF = Neutral detergent fiber.
3. ADF = Acid detergent fiber.
4. ADL = Acid detergent lignin.

Table 3. Stepwise multiple regressions (R^2) between sorghum stover laboratory quality traits and *in vivo* measurements (as in Table 1).

X-Variables	Y-Variable	R^2	Probability
Model: Extent + Nitrogen	OMI[1]	0.67	0.0001
Step 1: Extent		0.51	0.0002
Step 2: Nitrogen		0.16	0.007
Model: Nitrogen + ADF[2] + Rate	N balance	0.83	0.0001
Step 1: Nitrogen		0.45	0.0007
Step 2: ADF		0.19	0.005
Step 3: Rate		0.18	0.004
Model: ADF + Nitrogen	DOMI[3]	0.84	0.0001
Step 1: ADF		0.68	0.0001
Step 2: Nitrogen		0.16	0.0003

1. OMI = Organic matter digestibility.
2. ADF = Acid detergent fiber.
3. DOMI = Digestible organic matter intake.

listed in Table 2 are quite different. For example, nitrogen, NDF and ADF are quite convenient analyses while ADL (lignin) analysis demands first the ADF preparation which then has to be treated with 72% sulphuric acid, washed, filtered, dried and ashed. Similarly measurements of *in vitro* apparent and true digestibility are much easier obtained than *in vitro* fermentation kinetics (extent, rate and lag time measurements). In other words, the ease of measurement and predictive power of laboratory traits need to be balanced. From this point of view, nitrogen, ADF and true *in vitro* digestibility measurements seem to be recommendable laboratory traits for sorghum stover analysis (Table 2). These laboratory traits each accounted for more than 50% of the variation in DOMI, the most pertinent of the *in vivo* measurements listed in Table 2. For example, ADF accounted for 67% of the variation in DOMI.

Still substantially improved prediction of *in vivo* measurements by laboratory traits of sorghum stover can be achieved through a combination of traits in multiple regressions. For example, 67% of the variation in OMI was accounted for by the extent of *in vitro* fermentation when combined with the measurement of the nitrogen content (Table 3). Nitrogen content, acid detergent fiber and the rate of *in vitro* fermentation together accounted for 83% of the variation in N balance while the combination of ADF and nitrogen accounted for 84% of the variation in DOMI. The last model of the stepwise multiple regressions seems to be particularly suitable for reliably ranking sorghum stover for fodder quality for two reasons: (1) DOMI is a very pertinent *in vivo* measurement which is very closely related to milk and meat production; and (2) nitrogen and ADF are simple and very convenient to measure.

Conclusions

The study confirmed substantial variation in the fodder value of sorghum stovers, thus supporting the concept of genetic enhancement to improve dual-purpose sorghum cultivars. Simple laboratory traits such as nitrogen, ADF and true *in vitro* digestibility were identified to predict pertinent livestock responses such as digestible organic matter intake with very high accuracy.

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