

Voluntary intake and digestibility of mulberry (*Morus alba*) diets by growing goats

S.S. OMAR¹, C.M. SHAYO² AND P. UDÉN¹

¹Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden

²Zonal Research and Training Centre, Livestock Production Research Institute, Mpwapwa, Tanzania

Abstract

Mulberry (*Morus alba*) was examined as a potential source of fodder for goats in the semi-arid region of central Tanzania in an intake and digestibility study. Four diets [dry mulberry leaf and maize bran in a 1:1 ratio (T₁), fresh leaf (T₂), dry leaf (T₃) and whole mulberry branches (T₄)] were fed *ad libitum* to eight animals in a 4 × 4 Latin square design. Mean dry matter (DM) intakes and digestibilities for T₁, T₂ and T₃ were 42.6, 51.7 and 45.8 g DM /kg W^{0.75} and 55.7, 65.6 and 63.0 %, respectively. Daily gains were 26, 92, 86 and 86 g/d for animals on treatments T₁–T₄. Results of dry matter intake, digestibility and daily weight gain were significantly different (P<0.05). Dry matter intake and digestibility, crude protein concentration and *in vitro* dry matter digestibility decreased with age of the leaf. It is concluded that *Morus alba* could be used as a sole feed to support growth in small ruminants because of the high DM intake and digestibility.

Introduction

The disputed role of trees and shrubs in supplying dietary nitrogen, energy, minerals and

vitamins in arid and semi-arid regions has been discussed (Le Houerou 1980; Devendra 1990; Speedy and Pugliese 1991; Gutteridge and Shelton 1994; Dzewela *et al.* 1997). With the increasing role of trees and shrubs in small-scale farming systems, a substantial effort has been devoted to the identification, collection, multiplication, preservation and evaluation of multipurpose trees for adaptation (Larbi *et al.* 1992; Msangi and Hardesty 1993) and suitability as animal feed (Reed *et al.* 1990; Larbi *et al.* 1993; Kibria *et al.* 1994; Richards *et al.* 1994a, 1994 b).

Although the majority of native trees in semi-arid regions are deciduous, shedding their leaves during the dry season, evergreen trees are protected against herbivory during the same period by anti-nutritional factors such as tannins (Coley *et al.* 1985). In recent years, there has been a growing trend in many regions throughout the developing world to identify potentially important feed sources among shrub and tree leaves and to explore possibilities for including them in ruminants' diets (Devendra 1990).

Mulberry (*Morus alba*) trees are found in most parts of Tanzania including the semi-arid zone. The trees are incorporated in intensive farming systems in northern Tanzania and are used to feed zero-grazed sheep and goats in cut-and-carry systems (Shayo 1997). Information about the feeding value of mulberry in relation to livestock production is scarce. Only limited data are available on chemical composition and digestibility of mulberry leaves (Le Houerou 1980; Casoli *et al.* 1986; Prasad and Reddy 1991; Deshmukh *et al.* 1993; Shayo 1997). The present experiment was conducted to study the chemical composition and nutritive value of the morphological parts of mulberry (leaf, bark and stem) and the intake and *in vivo* dry matter digestibility of the leaves as the sole diet for goats.

Correspondence: Mr S.S. Omar, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, P O Box 7024, S-750 07, Uppsala, Sweden.
e-mail x5saisaa@ulmo.stud.slu.se

Materials and methods

Experimental material

This experiment was carried out between May–July 1997 at the Zonal Research and Training Institute, Mpwapwa (36° 32' E, 6° 21' S) in the semi-arid zone of central Tanzania. Mulberry (*Morus alba*) trees were established in March 1994 when 1 ha was planted with mulberry cuttings. Before the start of the rainy season in November 1996, all trees were cut back (first cut) at a height of 15–30 cm above ground to study yield and nutritive value of mulberry (see Shayo 1997). After plants had regrown, they were harvested for fresh and dry leaves. Leaves for drying were harvested in mid-April whereas fresh material was collected in the experimental periods during May–July 1997. There was a 3-week time difference between periods.

Experimental animals and design

Eight male goats with an average liveweight of 16.6 kg (SD=2.16) were used. Each animal was fed individually in a metabolism crate after being drenched against endo-parasites and sprayed against ecto-parasites. They were weighed before the start and at the end of each 14-day experimental period after a 17-h fast from feed and water. The animals were provided with water and a mineral lick containing: NaCl — 96%; Mn — 340 mg/kg; Zn — 460 mg/kg; Fe — 1%; Co — 80 mg/kg; I — 98 mg/kg; and Se — 10 mg/kg throughout the experiment. The animals were allotted randomly in a double 4 × 4 Latin square design after having balanced the groups for age and weight. The treatments used were as follows: T₁ — dry mulberry leaves and maize bran in a 1:1 ratio; T₂ — fresh mulberry leaves; T₃ — dry mulberry leaves; and T₄ — whole mulberry branches. Treatment T₁ was selected to test if maize bran could improve total intake and T₂ and T₃ to see if drying could increase intake by reducing the potential effect of antinutritional compounds in the mulberry. Treatment T₄ attempted to simulate the situation where animals would consume some bark as well as leaf.

Feeding and sampling

The dry leaves used in T₁ and T₃ were obtained from mulberry branches harvested in mid-April

and included the petioles. The leaves were air-dried for 15 days in a well ventilated barn at an ambient temperature of approximately 25°C. The dry leaves and maize bran in T₁ were fed at the same time in a 1:1 ratio in separate troughs. The fresh material used in T₂ and T₄ was harvested randomly each morning at 07.00 h. Fresh leaves for T₂ were separated from the stems before feeding. Fresh mulberry branches (6–8 mm diameter, 60–80 cm long and from the ends of the branches) were fed to goats in T₄. All diets were fed at 08.00 h and 14.00 h. Refusals were collected daily at 07.30 h before feeding. The dry matter offered per treatment was adjusted from time to time during the preliminary and measurement periods to give not less than 15% refusal from the amount offered in Treatments T₁–T₃ and not less than 40% in Treatment T₄.

Samples were taken from fresh leaf, bark, stems, whole branches, dry leaves and maize bran.

Data collection

During each experimental period, there was a preliminary period of 7 days followed by 7 days of data collection. Between the experimental periods there was a 7-day transition period, in which the animals were removed from the cages and allowed to browse in the pastures. During the data collection period, refusals from each animal were weighed and sub-sampled. All samples were dried at 65°C and stored for further analyses. Faeces were collected daily at 10.00 h, weighed, sampled and frozen. At the end of the experiment, faeces were pooled by period and animal, and dried at 65°C for chemical analyses.

Laboratory analyses

DM, ash and CP concentrations of mulberry leaves, bark, stems and whole branches and maize bran, were determined according to procedures of AOAC (1985). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations were determined according to the procedure of Van Soest *et al.* (1991). The true *in vitro* organic matter digestibility (IVOMD) was estimated according to Goering and Van Soest (1970) as modified by Mbwire and Udén (1991).

Statistical analysis

The design used was a 4×4 Latin square design where each of the 4 treatments was tested in 4 groups of 2 animals per group in 4 periods in the following sequences (2, 4, 1, 3; 4, 2, 3, 1; 3, 1, 4, 2; and 1, 3, 2, 4). All data were analysed using SAS (1993). To test the interaction for the variables, the following model was used:

$Y_{ijkl} = \mu + \alpha_i + \pi_k + \alpha \pi_{ik} + d_{j(l)} + e_{ijkl}$, where: μ = overall mean; α_i = treatment; π_k = period; $\alpha \pi_{ik}$ = interaction between treatment and period; $d_{j(l)}$ = animal within sequences; and e_{ijkl} = residual.

For the test of variables without interactions the following model was used:

$Y_{ijkl} = \mu + \alpha_i + \pi_k + d_{j(l)} + e_{ijkl}$, where: μ = overall mean.; α_i = treatment; π_k = period; $d_{j(l)}$ = animal within sequences; and e_{ijkl} = residual.

Results and discussion

Chemical composition and true *in vitro* OM digestibility

Table 1 shows the chemical composition of leaves, stems, bark and whole branches of mulberry used for feeding. Leaf had higher CP, ash and IVOMD than other plant fractions. In all plant fractions, the CP and IVOMD decreased from Period 1 to Period 4 while NDF and ADF tended to increase. Hirano (1982) and Mandal (1997) also observed that CP concentration in mulberry leaf tended to decrease with maturity. In the present study, the nutritive value of mulberry decreased only moderately with increasing age. A possible explanation is that, although the age of the leaves generally was increasing, emergence of new leaves and loss of old leaves reduced the overall effect. In comparison with the study of Shayo (1997), our CP and ash values were lower and NDF and ADF were higher.

IVOMD of bark was similar to that of leaf only at the early harvests and during this stage the goats were seen to strip and consume the bark from whole branches. The same trend was also observed by Shayo (1997) when comparing *in sacco* DM degradabilities of young and old leaf and bark. Singh *et al* (1989) observed that mulberry leaves had higher potential degradability (77.6%) and higher amounts of neutral detergent solubles than leaves of *Albizia stipulata*, *Quercus incana* and *Robinia pseudoacacia*, though the age of the leaf was not given.

Table 1. Chemical composition and *in vitro* organic matter digestibility (IVOMD) of fresh leaf, bark, stem and whole branches of mulberry plus maize bran.

	Period ¹	Ash	CP ²	NDF ² (%)	ADF ²	IVOMD
Leaf	P1	13.9	15.9	26.5	25.1	91.5
	P2	13.5	14.3	27.2	25.2	90.9
	P3	12.9	13.0	27.7	24.9	86.3
	P4	12.7	12.9	28.9	25.2	85.7
Bark	P1	7.1	8.9	43.4	36.1	89.9
	P2	5.7	8.5	43.4	36.1	88.2
	P3	6.3	8.5	44.3	38.6	83.5
	P4	5.9	8.9	46.9	42.2	78.6
Stem	P1	2.2	3.8	75.1	51.6	37.7
	P2	1.8	3.4	75.2	51.5	34.7
	P3	2.2	3.2	76.4	52.7	34.7
	P4	2.2	3.2	78.4	56.3	33.2
Whole branches	P1	11.4	13.2	34.8	47.3	80.3
	P2	11.1	12.4	46.2	47.8	77.9
	P3	10.5	12.2	47.5	48.0	73.6
	P4	10.1	11.8	48.0	48.6	71.1
Maize bran		4.6	10.2	20.9	7.2	89.1

¹Time difference between periods was 3 weeks.

²CP= crude protein; NDF= neutral detergent fibre; and ADF= acid detergent fibre.

Intake and *in vivo* DM digestibility

Dry matter intakes varied from 42.6 g/kg LW^{0.75} on the dry leaf and bran diet to 51.7 g/kg LW^{0.75} on the fresh leaf diet. Carryover effects were not significant ($P > 0.05$) and were ignored. The values obtained for dry (45.8 g/kg LW^{0.75}) and fresh (51.7 g/kg LW^{0.75}) leaf are somewhat lower than other reported intakes on mulberry leaves (56.3 \pm 3.94 g/kg LW^{0.75}, Prasad and Reddy 1991; 62.7 \pm 3.19 g/kg LW^{0.75}, Nageswara Rao *et al.* 1996).

Intake of dry leaves was lower than that of fresh leaves but differences were not significant ($P > 0.05$) (Table 2). Some loss of nutritive value and hence lower voluntary intake are normally expected when fodder is dried. It appears that mulberry leaves do not contain volatile compounds which are lost in the drying process and could have a detrimental effect on intake. The similarity in DMI and liveweight gains of animals fed fresh and dry leaves supports this argument. However, as liveweight gains were measured over only 2-week periods, they should be taken as indicators only of the level of animal performance these diets might support. Both fresh and dry leaves seem equally suitable for feeding to goats allowing considerable flexibility in approaches to management.

Intake of the mixed diet of dry leaves and maize bran was significantly (< 0.05) lower than

Table 2. Voluntary dry matter intake (DMI), *in vivo* dry matter digestibility (DMD) and liveweight gain in animals on mulberry-based diets.

Parameters	Diets ¹			
	T ₁	T ₂	T ₃	T ₄
DMD (%)	55.7 ± 3.99a	65.6 ± 1.99b	63.0 ± 1.33b	ND ³
DMI (g/kg LW ^{0.75})	42.6 ± 2.21a	51.7 ± 2.85b	45.8 ± 2.12b	ND
Daily gain (g)	25.9 ± 0.81a	92.0 ± 0.33b	85.7 ± 0.80b	85.7 ± 0.49b

¹T₁ = dry leaf and maize bran 1:1 ratio; T₂ = fresh leaf; T₃ = dry leaf; and T₄ = whole mulberry branches.

²Means (±s.e.) in the same row followed by different letters are significantly different (P<0.05).

³Not determined.

those of both fresh and dry leaf fed as the sole diet (Table 2). This low intake combined with low dry matter digestibility (55.7%) resulted in much lower animal performance than on the other treatments (P<0.05; Table 2). As IVOMD of maize bran was 89.1%, we have no ready explanation for the poor results on this treatment. However, the results suggest that it would be unwise to feed a mixed ration of dry leaf and bran to goats in preference to a diet of dry leaf only. Further investigations on these mixed diets seem warranted.

There was a significant interaction between DMI and period (P<0.05) but not between digestibility and period. Increasing leaf age with increasing period was reflected in reduced DMI and digestibility of fresh mulberry leaves. This reflects the declining crude protein concentrations and increasing NDF and ADF concentrations in leaf from Period 1 to Period 4. We did not measure tannin concentrations in the leaves but Makkar *et al.* (1989) studied leaves of *Morus alba* and other tree species and classified mulberry as a low-tannin fodder.

Ruminants select leaves in preference to stems when given sufficient feed to allow choice to be expressed (Forbes 1995; Mero and Udén 1997a, 1997 b), as was evident in this study. Goats consumed leaves and totally rejected the stems when offered whole branches with a 40% refusal. In addition, goats selected younger rather than older leaves on the same branch and even selected within the older leaves. In these leaves, only half of the leaf from the leaf tip inwards was consumed with the base of the leaf and the leaf petiole being rejected. To some extent, maize bran was rejected in favour of leaves.

We omitted the results for DMI and DMD of whole branches. As plants became older, the average number of leaves per stem decreased

from 33 to 8 leaves with a decreased nutritive value due to senescence and leaf drop. This resulted in a higher percent of stems and a higher fibre concentration in the feed offered and made intake and digestibility calculations imprecise. Shayo (1997), studying the proportion of plant parts of mulberry, confirmed the above phenological development throughout the growing season. Average stem percentage (bark excluded) increased from 57.4% at the first cutting to 74.4% at the second cutting, while leaf percent dropped from 31.2% to 6.4%. The same trend was observed in the regrowth after 120 and 190 days. In our study, the decreases in IVOMD and CP concentrations were from 80.3% and 13.2% in Period 1 to 71.1% and 11.8% in Period 4 (Table 1).

Conclusion

This study has indicated that foliage of mulberry trees has a high potential as fodder for goats despite a moderate reduction in its nutritive value during the season. The ability of the mulberry tree to tolerate a moderate drought, its high biomass production, fast growth, high nutritive value and ease of establishment make it an attractive fodder source in the semi-arid region of Tanzania. The multipurpose nature of mulberry needs to be considered and its other uses exploited.

Acknowledgement

Financial assistance of the Swedish International Development Authority (SIDA/SARCEC) and the International Foundation of Science (IFS) are greatly acknowledged.

References

- AOAC (1985) ASSOCIATION OF ANALYTICAL CHEMISTS. *Official Methods of Analysis*. 12th Edn. (AOAC: Washington, DC).
- CASOLI, C., DURANTI, E., DAMIANI, P. and RONGONI, V. (1986). Chemical composition and nutritive value of *Morus alba* leaves. *Zootecnica e Nutrizione Animale*, **12**, 47–53.
- COLEY, P.D., BRYANT, J.P. and CHAPIN, F.S. (1985) Resource availability and plant anti-herbivore defence. *Science*, **230**, 895–899.
- DESHMUKH, S.V., PATHAK, N.N., TAKALIKAR, D.A. and DIGRASKAR, S.U. (1993) Nutritional effect of mulberry (*Morus alba*) leaves as sole ration of adult rabbits. *World Rabbit Science*, **1**, 67–69.
- DEVENDRA, C. (1990) Shrubs and tree fodders for farm animals. *Proceedings of a workshop in Denpasar, Indonesia, 24–29 July, 1989*. IDRC, Ottawa, Canada.
- DZOWELA, B.H., HOVE, L., MAASDORP, B.V. and MAFONGOYA, P.L. (1997) Recent work on the establishment, production and utilization of multipurpose trees as a feed resource in Zimbabwe. *Animal Feed Science and Technology*, **69**, 1–15.
- FORBES, J.M. (1995) *Voluntary food intake and diet selection in farm animals*. 2nd Edn. (CAB International: UK).
- GOERING, H.K. and VAN SOEST, P.J. (1970) Forage fibre analysis. *U.S.D.A. Agricultural Handbook No. 379*. pp. 1–20.
- GUTTERIDGE, R.C. and SHELTON, H.M. (1994) *Forage Tree Legumes in Tropical Agriculture*. (CAB International: UK).
- HIRANO, H. (1982) Varietal differences of leaf protein profiles in mulberry. *Phytochemistry*, **21**, 1513–1518.
- KIBRIA, S.S., NAHAR, T.N. and MAI, M.M. (1994) Tree leaves as alternative feed resource for Black Bengal goats under stall-fed conditions. *Small Ruminant Research*, **13**, 217–222.
- LARBI, A., OCHANG, J., HANSON, J. and LAZIER, J.R. (1992) Agronomic evaluation of *Neonotonia wightii*, *Stylosanthes scabra* and *S. guianensis* accessions in Ethiopia. *Tropical Grasslands*, **26**, 115–119.
- LARBI, A., THOMAS, D. and HANSON, J. (1993) Forage potential of *Erythrina abyssinica*: intake, digestibility and growth rates for stall-fed sheep and goats in Southern Ethiopia. *Agroforestry Systems*, **21**, 263–270.
- LE HOUEIROU, H.N. (1980) Planting and management methods for browse trees and shrubs. In: Le Houerou, H.N. (ed.) *Browse in Africa. The Current State of Knowledge*. (ILCA: Addis Ababa, Ethiopia).
- MAKKAR, H.P.S., SINGH, B. and NEGI, S.S. (1989) Relationship of rumen degradability with microbial colonisation, cell wall constituents and tannin level in some tree leaves. *British Society of Animal Production*, **49**, 299–303.
- MANDAL, L. (1997) Nutritive value of tree leaves of some tropical species for goats. *Small Ruminant Research*, **24**, 95–105.
- MBWILE, R.P. and UDÉN, P. (1991) Comparison of laboratory methods on precision and accuracy of predicting forage organic matter digestibility. *Animal Feed Science and Technology*, **32**, 243–251.
- MERO, R.N. and UDÉN, P. (1997a) Promising tropical grasses and legumes as feed resources in Central Tanzania. I. Effect of applying different cutting patterns on dry matter production and nutritive value of outstanding grasses and legumes in Central Tanzania. *Tropical Grasslands*, **31**, 549–555.
- MERO, R.N. and UDÉN, P. (1997b) Promising tropical grasses and legumes as feed resources in Central Tanzania. II. *In sacco* rumen degradation characteristics of promising grasses and legumes in Central Tanzania. *Animal Feed Science and Technology*, **69**, 341–352.
- MSANGI, R.B.R. and HARDESTY, L.H. (1993) Forage value of native and introduced browse species in Tanzania. *Journal of Range Management*, **46**, 410–415.
- NAGESWARA RAO, S.B., NAWAB SINGH and OGRA, J.L. (1996) Tree leaves based pelleted feeds and their utilisation in goats. *Indian Journal of Animal Nutrition*, **13**, 174–177.
- PRASAD, P.E. and REDDY, M.R. (1991) Nutritive value of mulberry (*Morus alba*) leaves in goats and sheep. *Indian Journal of Animal Nutrition*, **8**, 295–296.
- REED, J.D., SOLLER, H. and WOODWARD, A. (1990) Fodder tree and straw diets for sheep: intake, growth, digestibility and the effects of the phenolics on nitrogen utilisation. *Animal Feed Science and Technology*, **30**, 39–50.
- RICHARDS, D.E., BROWN, W.F., RUEGSEGGER, G. and BATES, D.B. (1994a) Replacement value of tree legumes for concentrates in forage-based diets. I. Replacement value of *Gliricidia sepium* for growing goats. *Animal Feed Science and Technology*, **46**, 37–51.
- RICHARDS, D.E., BROWN, W.F., RUEGSEGGER, G. and BATES, D.B. (1994b) Replacement value of tree legumes for concentrates in forage-based diets. II. Replacement value of *Leucaena leucocephala* and *Gliricidia sepium* for lactating goats. *Animal Feed Science and Technology*, **46**, 53–65.
- SAS (1993) *Statistical Analysis System*. (SAS Institute: Cary, NC, USA).
- SHAYO, C.M. (1997) Uses, yield and nutritive value of mulberry (*Morus alba*) trees for ruminants in the semi-arid areas of central Tanzania. *Tropical Grasslands*, **31**, 599–604.
- SINGH, B., MAKKAR, H.P.S. and NEGI, S.S. (1989) Rate of digestion and potentially digestible dry matter and cell wall of various tree leaves. *Journal of Dairy Science*, **72**, 3233–3239.
- SPEEDY, A. and PUGLIESE, P.L. (1991) Legume trees and other fodder trees as protein sources for livestock. *Proceedings of the FAO expert consultation, MARDI, Kuala Lumpur, Malaysia, 14–18 October, 1991. Animal Production & Health Paper, No. 102*. (FAO: Rome).
- VAN SOEST, P.J., ROBERTSON, J.B. and LEWIS, B.A. (1991). Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, **74**, 3583–3597.

(Received for publication August 5, 1998; accepted August 16, 1999)