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Chemical Composition of *Melia volkensii* Gurke: an Unrealised Browse Potential for Semi-arid Agroforestry Systems

Patrick B Milimo*

Kenya Forestry Research Institute (KEFRI), PO Box 20412, Nairobi, Kenya

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Abstract: Results of chemical analyses of some nutritional characteristics of *Melia volkensii* browse, important for large wild and domestic herbivores in East Africa, are presented. Seeds, fruit pulp, leaves and twigs had high levels of crude protein, crude fat, minerals and fibre. Newly coppiced shoots (leaves and twigs), old shoots, fruit pulp and seed contained 230, 190, 130 and 320 g kg^{-1} dry weight crude protein, respectively. The essential amino acid profile compared well with the FAO scoring pattern. Tyrosine was the first limiting amino acid in the coppice leaves and twigs, lysine in the cotyledons, and threonine and lysine in the endosperm. The concentrations of crude fat in the seed, fruit pulp, coppice shoots and old shoots were 480, 100, 80 and 50 g kg^{-1}, respectively. The fatty acids in the cotyledon and endosperm were mainly palmitic (110 and 109 g kg^{-1}, respectively), oleic (327 and 252 g kg^{-1}, respectively) and linoleic (487 and 573 g kg^{-1}, respectively). The levels of P, Na, K, Ca, Mg and the Ca/P ratio per kg dry weight were on average higher than the optimum recommended for ruminants. These results demonstrate that *M volkensii* browse, especially coppice leaves and twigs, have a high index for nutrient content, and the planting of this species should be promoted in the semi-arid areas to supplement senescent grasses and cereal crop residues.

Key words: *Melia volkensii*, browse yield estimates, crude protein, crude fat, amino acids, fatty acids, mineral elements, digestibility, agroforestry and semi-arid regions.

INTRODUCTION

A lack of reliable dietary protein sources is one of the biggest problems facing inhabitants of semi-arid areas of Africa. Production of protein from animal sources is inadequate, prohibitive in cost and generally beyond the reach of the average income earner. This is partly due to the fact that livestock are grossly undernourished. To a large extent, livestock feed in these areas is based on grazing senescent grasses and cereal crop residues (Van Soest 1988), which are deficient in proteins but have high fibre contents that limit intake and digestibility of cell wall carbohydrates (Rittner and Reed 1992).

The problem of poor livestock nutrition is magnified by the fact that most studies attempting to address Africa's browse shortage problems usually ignore traditional tree and shrub species (Bayer 1990; Sands *et al* 1970). Such information is crucial in determining the availability and productivity of traditional browse species that will play a more prominent role in the strategy to increase livestock production and, hence, protein self-sufficiency by the inhabitants of semi-arid regions of Africa. Indigenous tree and shrub species have advantages over exotic ones, since less extension inputs may be needed and higher survival rates and growth are expected as the species are already adapted to the local environmental conditions. One such tree species occurring in the dry areas of East Africa is *Melia volkensii* Gurke (Meliaceae).

The natural range of *M volkensii* is small (about 750 000 km^2) compared to the broad pantropical distribution of *M azedarach* (L) in southeastern Asia and northern Australia. The range for *M volkensii* extends from the southern slopes of the Pare mountains

* Present address: The Australian National University, Department of Forestry, GPO Box 4, ACT 2601, Canberra, Australia.

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(04° 05′ S, 37° 43′ E) in Tanzania to El Wak (03° 56′ N, 41° 52′ E) in Kenya. The eastern limit of the range is Lug Ganane (03° 45′ N, 42° 35′ E) in Somalia, while the western limit is Isiolo (00° 21′ N, 37° 35′ E) in Kenya. Diversity in ecology within the range implies the existence of genetic variation and, hence, the potential for cultivation outside its natural range. The ability in adaptation has been demonstrated by the successful establishment of trial plots on different sites in Kenya and northern Queensland, Australia (Milimo P B unpublished).

M volkensii is browsed by giraffe, orix (Leuthold and Leuthold 1972), goats and cattle (Milimo 1990). According to a study by Leuthold and Leuthold (1972), *M volkensii* contributes about 2 and 9% of the dry and wet season browse, respectively, of the giraffe in Tsavo National Park, Kenya. Despite the usefulness of the species (Milimo and Hellum 1989a, b), its seedlings are not routinely propagated in tree nurseries for planting in semi-arid agroforestry systems. The omission of *M volkensii* from lists of tree and shrub species in tree nurseries is explained by seed dormancy, which has prevented its propagation (Dale and Greenway 1961). However, this problem has been addressed, and the prospects of propagating seedlings from seed (Milimo 1989a; Milimo and Hellum 1989a, b) and rooted cuttings (Milimo 1989b) are good.

The present chemical analyses of leaves, twigs and fruits (browse; Bergstrom 1992) of *M volkensii* were undertaken to define the potential of the species as a browse tree (for cattle and goats) and emphasise the need for its planting and cultivation in semi-arid agroforestry systems.

MATERIALS AND METHODS

Source of materials

Materials for these studies were sampled at different times from Kibwezi (2° 20′ S, 37° 57′ E), an area representative of sites where *M volkensii* occurs naturally in Kenya. In this study, browse refers to leaves, twigs and fruits of *M volkensii*. Two categories of leaves and twigs were distinguished, coppice and mature leaves and twigs. Mature leaves and twigs were sampled in August 1987 and coppiced leaves and twigs in December 1987 from stumps of trees felled 4 weeks prior to the November 1987 rains.

Morphologically mature fruits were collected from 18 trees in August 1985. The fruit of *M volkensii* (a mature fruit weighs about 50 g fresh) is comprised of the following three distinct parts: the fruit pulp (outer fleshy part, composed of the pericarp, mesocarp and exocarp; Esau 1977), the stony endocarp, and seeds (1–5 seeds each weighing about 2 g, embedded in locules within the endocarp; Milimo and Hellum 1989b). Therefore, the first step in preparing samples was to separate pulp from endocarps using a wooden pestle and mortar; the second was to extract seeds from the endocarps (after air drying for 2 weeks); and the third involved the separation of different seed tissues (cotyledons and endosperm, hereafter simply referred to as seed parts).

Sample preparation

The cotyledons, endosperm and the integuments make up 74, 13 and 13% of the *M volkensii* whole seed dry weight, respectively (Milimo 1986). To separate the different seed parts, seeds were first soaked in cold water at ambient temperature for 24 h. The separated seed parts, leaves and twigs were then dried in a Napko oven (Model 240 Gibbco, Melbourne) at 60°C for 24 h and ground in a mortar to pass through a 60-mm mesh.

Chemical composition

Analyses were performed in duplicate and relative proportions of the different components determined. Crude protein (CP) was determined by the Kjeldahl digestion method ($CP = N \times 6{\cdot}25$). Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin that also included cutin (ADL), dry matter (DM), crude fat (CF), cell wall constituent ash (CWCA), cellulose, hemicellulose, and total ash were determined according to the methods of Goering and Van Soest (1970). P was determined separately in duplicates by the molybdate blue colorimetric reaction; Ca, Na and Mg by atomic absorption spectrophotometry; and K by the flame photometry method. The amino acids and fatty acids were determined according to the methods of Williams (1984).

The content of each amino acid (mg 16 g^{-1} N) was expressed as a percentage of the content of the same amino acid in the same quantity of whole hen's egg, i.e. the chemical score (FAO 1970).

Browse yield estimates

Fruits were collected from five mature trees (diameter and height greater than 40 cm and 15 m, respectively) at Kibwezi in August 1991. Fruits from each tree were weighed separately, bulked and $2 \times 1{\cdot}0$ kg samples drawn for the estimation of dry weight. Pulp and endocarps were separated, and the latter were dried in an oven at 60°C to a constant weight.

RESULTS AND DISCUSSION

Crude protein

Yield estimates for CP and CF in the fruit parts are presented in Table 1. A single mature *M volkensii* tree

TABLE 1
Yield estimates (kg per tree) of crude protein and fat content of fruit pulp and seed of *Melia volkensii*[a]

Fruit part	*Fresh weight*	*Dry weight*	*Crude protein*	*Crude fat*
Fruit pulp	80·5	15·6	2·0	1·6
Endocarp	33·7	20·9	ND	ND
Seed	5·8	1·8	0·6	0·9
Total	120·0	38·3	2·6	2·5

[a] Yield per tree is estimated from collections during one fruiting season. Fruits used in this study were unripe but morphologically mature or described as 'fruit hard' (Milimo and Hellum 1989b).

yielded an average total of 38 kg of dry fruit and 17·4 kg when endocarps are excluded. The fruit pulp and the seed contributed about 41 and 5% of the total fruit dry weight, respectively (the seeds are not naturally accessible to browsing animals because they are embedded in locules within unpalatable thick stony endocarps; Milimo and Hellum 1989b).

The 325 g kg^{-1} dry weight CP concentration for the seed was comparable to that reported for the cucurbit seed kernels (312 g kg^{-1}) by Kanwar *et al* (1991). The CP content of the other parts of the tree were 126 g kg^{-1} dry weight for the fruit pulp, 229 g kg^{-1} dry weight for coppice shoots and 191 g kg^{-1} dry weight for the old leaves and twigs combined. Coppice shoots had higher average CP levels than all of the 30 semi-arid West African tree species reported by Bayer (1990). Only *Mucuna poggei* (228 g kg^{-1}) had a comparable concentration. The CP levels for the West African study ranged from 67 to 228 g kg^{-1}. Further, in the West African study, a distinction was not made between juvenile and mature browse, and it is probable that the results reported represent samples of mixed-age browse. In another study involving 48 subspecies of *Acacia nilotica*, Carter (1970) observed a crude protein range of 81–216 g kg^{-1}, confirming that browse from *M volkensii* is potentially a superior source of protein for ruminants.

Amino acids

Amino acid content of coppice leaves, coppice twigs, cotyledons, and endosperm, and their amino acid scores are presented in Table 2. These clearly show that leaves, twigs and seed protein were generally rich in the make-up of essential amino acids. When compared to the whole hen's egg, coppice leaves were higher in lysine, phenylalanine, and leucine, while coppice twigs were higher in leucine only. Cotyledon and endosperm essential amino acid concentrations were generally lower than in the whole hen's egg (FAO 1970) but on average higher than those reported for cucumber and bottle gourd seeds (Kanwar *et al* 1991). The first limiting essential amino acid in mature leaves, twigs, coppice

TABLE 2
Amino acid content (mg g^{-1} protein) and amino acid scores (values in parenthesis) of fractions of *Melia volkensii*

Amino acid	*Whole hen's egg*[a]	*Coppice leaves*	*Coppice twigs*	*Cotyledons*	*Endosperm*
Aspartic	96·2	124·2 (129)	121·4 (126)	80·4 (84)	77·3 (80)
Glutamic	127·4	148·3 (116)	207·9 (163)	250·8 (200)	250·8 (197)
Lysine[b]	69·8	73·5 (105)	57·1 (82)	27·1 (39)	33·2 (46)
Arginine	61·0	50·7 (83)	26·9 (44)	125·5 (206)	110·8 (182)
Histidine	24·3	27·1 (112)	28·6 (118)	23·2 (96)	20·9 (86)
Phenylalanine[b]	57·3	65·8 (115)	50·2 (88)	49·8 (87)	43·4 (76)
Leucine[b]	88·2	107·0 (121)	111·4 (126)	69·5 (79)	60·2 (68)
Isoleucine[b]	62·9	47·0 (75)	61·8 (98)	38·4 (61)	36·2 (58)
Methionine[b]	33·6	21·2 (63)	25·3 (75)	21·4 (64)	21·4 (64)
Valine[b]	68·5	49·0 (72)	39·5 (58)	47·0 (68)	41·2 (60)
Proline	41·6	57·9 (139)	58·5 (141)	23·4 (55)	29·8 (72)
Threonine[b]	51·2	40·1 (78)	29·0 (57)	24·3 (47)	23·4 (46)
Serine	76·5	45·4 (59)	49·6 (65)	48·6 (64)	44·1 (58)
Alanine	59·2	65·3 (110)	62·6 (106)	27·0 (46)	20·2 (34)
Glycine	33·1	59·4 (178)	57·8 (175)	45·2 (136)	81·6 (247)
Tyrosine[b]	41·6	18·1 (44)	12·7 (31)	24·5 (60)	27·4 (66)
Cysteine[b]	24·3	ND	ND	ND	ND
Tryptophan[b]	ND	ND	ND	ND	ND
Ammonia	ND	ND	ND	18·4	18·0
% recovery (protein)	ND	ND	ND	96·3	91·0

[a] FAO (1970).
[b] Essential amino acids.

leaves, cotyledons and endosperm were tyrosine, methionine, lysine, and threonine, respectively (Table 2). These results are in general agreement with those observed for cucumber and bottle gourd seeds (Kanwar *et al* 1991) and soya bean (Oyenuga and Fetuga 1975). Present results suggest that coppice leaves and twigs are a superior browse than seed parts, provided that they can be supplemented with other feeds high in tyrosine. Since seed parts had higher chemical scores for tyrosine than shoots, these could be used as a supplement for the former.

Crude fat

The content of CF was highest in the seed (481 g kg^{-1}) and lowest in the old shoots (54 g kg^{-1}). CF ranking in the different browse parts may be presented thus: seed > fruit pulp > coppice shoots > old shoots. The concentration of CF in the seed was higher than those reported by Kanwar *et al* (1991) for cucumber (444 g kg^{-1}) and bottle gourd seed kernels (463 g kg^{-1}). The average value observed for combined old and coppice leaves and twigs in the current study (65 g kg^{-1}) was within the range of values observed (about 70 g kg^{-1}) by other workers (Gurr 1984), which again also confirms the biological value of *M volkensii* browse as a potentially important source of CF. The energy yield of fats is not only about twice that of other food components but is also high in digestibility, a factor that make its contribution to animal metabolism valuable (Gurr 1984; Garton 1959).

Fatty acids

Seven fatty acids were identified and quantified from seed parts (Table 3); of these, oleic, linoleic and gadoleic are unsaturated fatty acids, while palmitic, stearic and arachidic are saturated. High concentration values can be observed for oleic and linoleic acids.

TABLE 3
Fatty acid (mg g^{-1} fat) composition of fractions of *Melia volkensii* seeds

Fatty acid	*Cotyledon*	*Endosperm*
Palmitic	110·2	108·7
Steric	63·0	54·8
Oleic	327·3	252·3
Linoleic	487·1	572·8
Linolenic	2·3	3·0
Arachidic	3·9	3·3
Gadoleic	5·2	5·0

Mineral elements

The results of mineral element analyses (Table 4) show that P, Na, K, Ca and Mg concentrations and the Ca/P ratio were, on average, higher than the minimum recommended for ruminants (Underwood 1981), although P and K values for fruit pulp and whole seed were lower, respectively. However, these could be corrected by supplementing with the leaves and twigs that had higher values. Bayer (1990) reported an average value for P of 2·2 g kg^{-1} and a range of 0·9–3·7 g kg^{-1} for West African browse species. The Ca/P ratio for coppice leaves was slightly higher than the recommended optimum. On average, the mineral element results observed for *M volkensii* in this study were higher than those for *M azedarach* reported by Vercoe (1989) and *A nilotica* varieties by Carter (1970).

TABLE 4
Mineral element composition, the Ca/P ratio, ADF (acid detergent fibre), NDF (neutral detergent fibre), ADL (acid detergent lignin) and CWCA (cell wall constituent ash) (g kg^{-1} DM) of *Melia volkensii* whole seed, fruit pulp, coppice and old leaves (*M azedarach* values are given for comparison).

	Optimum value for ruminants[a]	*Whole seed*	*Fruit pulp*	*Coppice leaves and twigs*	*Old leaves and twigs*	*Mature leaves*[b]
P	>1·5	4·7	1·1	2·8	ND	1·1
Na	>1·8	ND	ND	ND	ND	0·3
K	>7·0	3·8	27·5	33·8	ND	4·9
Ca	>0·8	1·3	8·3	32·0	ND	53·9
Mg	>0·7	13·5	5·5	18·4	ND	6·0
Ca/P ratio	<10	0·3	7·5	11·4	ND	49·0
NDF	—	92·4	266·0	378·3	390·4	—
ADF	—	62·6	230·0	309·0	297·3	—
ADL	—	90·2	64·0	51·7	170·3	—
CWCA	—	ND	260·0	359·2	376·5	—

[a] Underwood (1981).
[b] Data for *M azedarach* (Vercoe 1989).

Digestibility

The results of NDF, ADF, ADL and CWCA are also presented in Table 4. CWCA content was highest in the old leaves and twigs, followed by that of coppice leaves and twigs, and lowest in the fruit pulp. These values are higher than those reported by Carter (1970) for green pods and old leaves of *A nilotica*.

The NDF and ADF contents of the whole seed were lower than those of the fruit pulp, coppice leaves and twigs combined, and old leaves and twigs combined. Thus, the range observed for *M volkensii* is consistent with those observed by other workers. For example, Carter (1970) observed an ADF range of 204–443 g kg^{-1} for different parts of *A nilotica*, and Bayer (1990) an average of 448 and 351 g kg^{-1} for NDF and ADF, respectively, for 29 West African species.

The whole seed, fruit pulp, coppice leaves and twigs were lower in lignin content than the old leaves and twigs. These results are also consistent with those reported by Bayer (1990) for West African browse species whose range was 47–192 g kg^{-1}. The presence of secondary compounds like tannins and lignins affect DM digestibility values. Their presence in high concentration lowers the availability of protein for livestock (Wilson and Harrington 1980).

Production potential

M volkensii crops can be either left to mature for fruit production or may be continuously hedged to sustain a vegetative state. The production of leaf and twigs can be increased at the expense of fruits by pollarding and hedging to produce vegetative parts. The hedging and carrying (or 'cut and carry') of fodder, if managed well, will lead to increased production of farm organic matter (manure) and, hence, reduce dependence on chemical fertilisers while having a minimum effect on light penetration and, therefore, competition between browse trees and food crops. Thus, the practice is recommended for mixed farming systems to increase the income of subsistence farmers in the semi-arid areas. However, data on timing and intensity of pollarding of *M volkensii* crops are currently unavailable and require investigation.

Though the seed parts of *M volkensii* have high levels of CP and CF, these are not naturally accessible because they are embedded in locules within thick stony endocarps (Milimo and Hellum 1989b). However, as human and livestock populations in arid and semi-arid regions of Africa increase, browse supplements under circumstances of intensive production will become necessary, thereby justifying resource investment in developing better and more practical methods of extracting the seed from the stony endocarp for its high CP and CF contents to supplement *M volkensii* leaves and twigs and other food crop residues used by farmers as livestock feed.

Fruits of *M azedarach* are classified as toxic, especially to pigs (Everist 1969), and milk produced from dairy stock fed on *M azedarach* leaves is tainted slightly. However, no accounts of poisoning and/or milk tainting by *M volkensii* browse have been reported.

CONCLUSION

The high nutritional value of *M volkensii* browse observed in the current study clearly shows that the species has a lot of potential for browse production and increasing the nutritional status of livestock in the semi-arid regions of Africa. This potential could be increased by (a) further studies that lead to identification of possible ecotype differences in chemical composition and phenology; (b) studies that determine the relationship between pollarding frequency and intensity, yield information and browse digestibility; and (c) cattle and goat feeding experiments that include characterisation and quantification of phenolics and their effect on nutritional quality.

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REFERENCES

Bayer W 1990 Use of native browse by Fulani cattle in central Nigeria. *Agroforestry Syst* **12** 217–228.

Bergstrom R 1992 Browse characteristics and impact of browsing on trees and shrubs in African savannas. *J Veg Sci* **3** 315–324.

Carter J 1970 *Feed Value of Prickly Acacias.* Arid Zone Research Institute, Longreach, Australia, pp 7–17.

Dale I R, Greenway P J 1961 *Kenya Trees and Shrubs.* Buchanan's Kenya Estate Ltd, London, UK.

Esau K 1977 *Anatomy of Seed Plants.* John Wiley, New York, USA.

Everist S L 1969 *Use of Fodder Trees and Shrubs* (Advisory Leaflet No 1024). Queensland Department of Primary Industries, Division of Plant Industry, Brisbane, Australia, pp 1–31.

FAO 1970 *Amino-Acid Content of Foods and Biological Data on Proteins* (Nutritional studies No 24). FAO, Rome, Italy.

Garton G A 1959 Lipids in relation to rumen function. *Proc Nut Soc* **18** 112–117.

Goering H K, Van Soest P J 1970 *Forage and Fibre Analysis* (Agricultural Handbook No 379). USDA, Washington, DC, USA.

Gurr M I 1984 The chemistry and biochemistry of plant fats and their nutritional importance. In: *Fats in Animal Nutrition*, ed Wiseman J. Butterworths, London, UK, pp 3–22.

Kanwar J R, Sharma P B, Manwar S S 1991 Biochemical and nutritional characteristics of non-conventional protein sources. *J Sci Food Agric* **55** 141–151.

Leuthold B M. Leuthold W 1972 Food habits of giraffe in Tsavo National Park, Kenya. *E African Wildlife J* **10** 129–141.

Milimo P B 1986 The control of germination in *Melia volkensii* seeds. MSc thesis, Department of Forest Science, University of Alberta, Canada.

Milimo P B 1989a *Collection, Processing and Germination of* Melia volkensii Seeds (Tech Note No 1). Kenya Forestry Research Institute, Nairobi, pp 1–8.

Milimo P B 1989b Preliminary studies on vegetative propagation of *Melia volkensii* by cuttings. In: *Trees for Development in Sub-Saharan Africa*, ed Wolk J N. ICRAF, Nairobi, pp 298–301.

Milimo P B 1990 *New Uses for* Melia azedarach *var* australasica *and* M. volkensii Gurke (Forestry Newsletter 10). ACIAR, Canberra, pp 2–3.

Milimo P B, Hellum A K 1989a Dormancy in seeds of *Melia volkensii* Gurke. *E African Agric For J* **54**(3) 111–122.

Milimo P B, Hellum A K 1989b Studies of the structure and development of seeds of *Melia volkensii* Gurke. *E African Agric For J* **55**(1) 27–36.

Oyenuga V A, Fetuga B L 1975 Some aspects of the biochemistry and nutritive value of watermelon seed (*Citrullus vulgaris* Schrad). *J Sci Food Agric* **26** 843–854.

Rittner U, Reed J D 1992 Phenolics and in-vitro degradability of protein and fibre in west African browse. *J Sci Food Agric* **58** 21–28.

Sands E B, Thomas D B, Knight J, Pratt D J 1970 Preliminary selection of pasture plants for the semi-arid areas of Kenya. *E African Agric For J* **XXXVI**(1) 49–57.

Underwood E J 1981 *The Mineral Nutrition of Livestock* (2nd edn). Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Van Soest P J 1988 Effect of environment and quality of fibre on the nutritive value of crop residues. In: *Plant Breeding and Nutritive Value of Crop Residues*, ed Reed J D, Capper B S & Neate P J H. ILCA, Addis Ababa, Ethiopia, pp 71–94.

Vercoe T K 1989 Fodder values of selected Australian tree and shrub species. In: *Trees for the Tropics* (Monograph 10), ed Boland D J. ACIAR, Canberra, pp 187–192.

Williams S 1984 *Official Methods of Analysis* (14th edn). AOAC, Arlington, VA, USA.

Wilson A D, Harrington G N 1980 Nutritive value of Australian browse plants. In: *Browse in Africa: the Current State of Knowledge*, ed Le Houerou H N. ILCA, Addis Ababa, Ethiopia, pp 291–297.