Food Chemistry **45** (1992) 5–10

Hydrocyanic acid contents of tropical browse and their influence on performance of goats

Christopher F. I. Onwuka*

Division of Nutritional Biochemistry, Department of Animal Science, University of Ibadan, Ibadan, Nigeria

(Received 7 December 1990; revised version received and accepted 21 August 1991)

The levels of hydrocyanic acid (HCN) in the dried leaves of 38 browse species comprising shrubs, herbs, grasses and trees found in the tropics were determined. They ranged from 6·04 to 65·1 mg kg^{-1}; trace to 39·9 mg kg^{-1} and trace to 73·6 mg kg^{-1} respectively in the trees, shrubs and herbs'/grass leaves. The highest HCN values were recorded for the trees and herbs' leaves. Feeding experiments were conducted to investigate the influence of the HCN contents of *Manihot utilissima*, *Spondias mombin* and *Gliricidia sepium* leaves on the performance of goats. The HCN intake was between 0·94 ± 0·21 and 9·10 ± 0·64 mg $day^{-1}\ w_{kg}^{-0.734}$ while the weights lost ranged from 30 to 130 g $day^{-1}\ w_{kg}^{-0.734}$ in the sole browse leaves and *Manihot sp.* peels treatments. N balance and N digestibilities were also depressed by HCN. Dry matter and energy intakes were significantly ($p < 0.001$) influenced by HCN intake while urinary-N was negatively correlated with HCN intake ($p < 0.05$).

INTRODUCTION

Browse plants abound in various parts of the world. A vast array of trees and shrubs serve as animal fodder in the tropics and sub-tropics. They are often browsed or casually lopped and fed (Skerman, 1977; Le Houérou, 1980). These browse supply feed to cover the bridging period and drought times for livestock feeding. Browse is more important in the diet of goats than in that of cattle especially in the dry season (Reynolds & Adeoye, 1989).

Several toxic substances have been identified in some browse species. These include cyanogenic glucosides (Brewbaker, 1989). These contents of anti-nutritional factors (Onwuka, 1983) could limit the feeding potentials of browse plants. Hydrocyanic acid is poisonous and goats fed browse composed of cut and immediately wilted cassava (*Manihot utilissima*) leaves were reported to have died immediately (Obioha, 1972) although no ill-effects were observed in cattle and sheep fed cassava in various forms (Hill, 1973).

Devendra (1977) showed that fresh cassava leaves are commonly fed directly to ruminants after sun-drying which is believed to reduce the hydrocyanic acid content and hence the toxic effects on the ruminants. Cyanide-containing diets were responsible for weight losses observed in goats (Onwuka *et al.*, 1991).

This study was carried out with the objective of quantifying the hydrocyanic acid levels in some dried browse leaves commonly eaten by ruminants, especially goats.

The effects of the hydrocyanic acid contents of three of the browse leaves (with graded levels of cassava peels supplementation) on some performance characteristics of goats were also monitored.

MATERIALS AND METHODS

Sampling and preparation of browse leaves and peels

The leaves of 38 browse species collected from the humid and sub-humid areas of Nigeria were oven-dried at 50–60°C for 3 days and thereafter ground with an Achtung milling machine to 2 mm sieve size. These leaves were later assayed for their hydrocyanic acid contents. The leaves of the three browse plants used in the feeding trials (*Manihot utilissima*; *Spondias mombin* and *Gliricidia sepium*) and the *Manihot sp.* peels were sun-dried, without grinding, on the flat concrete floor for 3 days.

*Present address: Department of Animal Nutrition, College of Animal Science and Livestock Production, University of Agriculture, P.M.B. 2240, Abeokuta, Ogun State, Nigeria.

Animals and their management

Twenty uniformly healthy and well-fed West African dwarf (*Fouta djallon*) goats, averaging 1·5 years old, were arranged in a randomized block design, using four replicates, into five groups each of four goats (two does and two bucks). They were balanced for live-weights to reduce variations arising from body weights. Fifteen feeding trials were carried out in 45 weeks. Each trial lasted 3 weeks made up of 2 weeks of preliminary feeding and 1 week for the collection of faeces and urine. The animals were housed in metabolism cages described earlier (Onwuka & Akinsoyinu, 1989). Harness bags were used for the collection of faeces from the bucks. The faeces from the does were collected by separating them from the urine with a removable tray made of closely-knit wire mesh. All the goats had access to mineralized salt licks and daily fresh clean water supply. They were routinely dewormed and records of their weekly weight gains taken.

The goats were obtained from the International Livestock Centre for Africa (ILCA) in Ibadan, Nigeria and the Teaching and Research farm of the University of Ibadan, Nigeria.

Diets

Leaves of the three dried browse species, i.e. *Manihot sp.* leaves, MAL; *Spondias sp.* leaves, SPL and *Gliricidia sp.* leaves, GLL, were fed to the groups of goats at 0, 25, 50, 75 and 100% levels supplemented with graded levels of *Manihot sp.* peels, MAP. The 100% *Manihot sp.* peels trial was used as the control treatment. The animals were randomly allotted the diets and were allowed 800 g browse leaves daily. Animals were fed twice daily at 0800 and 1600 hours. The refusals were collected and weighed daily to assess feed intake.

Analytical procedure

The hydrocyanic acid contents of the leaves were determined using the modification of an earlier established method (Tewe, 1975). Crude linamarase was used for determination of the bound HCN. Proximate chemical composition was assayed using standard methods of analyses (AOAC, 1980). Data were statistically analysed using the randomized complete block design. The means were separated using Fisher's Least significant difference test (Steel & Torrie, 1980).

RESULTS

The values obtained for the concentrations of hydrocyanic acid (HCN) in the analysed shrubs leaves are presented in Table 1. They range from a low value of 14·8 mg to a high value of 39.9 mg kg^{-1}. These values are comparable to the HCN levels in the analysed herbs' leaves shown in Table 2. *Manihot sp.* leaves and peels had the highest HCN concentrations of all the herbs and grasses analysed and shown in Table 2. Leaves of the browse species in the *Euphorbiaceae* family, which comprise about 50% of the analysed herbs, grasses and shrubs (Tables 1 and 2) or 27% of all the browse leaves analysed, had comparatively much higher HCN concentrations. Table 3 shows the hydrocyanic acid concentrations in the leaves of tree species analysed. Some of the leaves belonging to plants in the *Chrysobalanaceae* and *Mimosaceae* families had the highest HCN concentrations. Low HCN concentrations of about 6 mg kg^{-1} were also found in some *Mimosaceae* family plant/species.

The proximate chemical composition of the browse leaves and peels used in the feeding trials is presented in Table 4. The three leaves' species fed to the goats were high in their nitrogen contents but the *Manihot sp.* peels had low nitrogen content. Their crude fibre levels were also high. The gross energy contents of the leaves were about the same. Table 5 shows some performance characteristics of goats fed three browse species. Weight losses were observed in the goats used in the sole *Manihot sp.* peels and browse treatments. These negative weights improved as the peels were combined with leaves, though less so with 100% leaves. Negative N-digestibility and N-balance values were also observed in some treatments. Urinary nitrogen

Table 1. Hydrocyanic acid concentration in some dried shrubs' leaves found in Nigeria (mg kg^{-1})

Browse names	Authorities	Family	Hydrocyanic acid values
Alchornea cordifolia	(Schum & Thorn) mill	*Euphorbiaceae*	26·9
Alchornea sp.	(Raffn)	*Euphorbiaceae*	39·9
Bridelia ferruginea	(Benth)	*Euphorbiaceae*	14·8
Cnestis ferruginea	(DC)	*Connaraceae*	39·3
Codiaeum variegatum	(Linn) Blume	*Euphorbiaceae*	37·3
Cola milenii	(K. Schum)	*Sterculiaceae*	Trace
Combretum paniculatum	(Vent)	*Combretaceae*	37·4
Corpolobia lutea	(G. Don)	*Polygalataceae*	20·2
Microsdesmis puberula	(Hook F. & M. Zenkei)	*Euphorbiaceae*	33·4

Table 2. Hydrocyanic acid contents of some herbs and grass leaves (mg kg⁻¹)

Names of browse species	Authorities	Family	Hydrocyanic acid values
Herbs			
Aframomum melequeta	(K. Schum)	*Zingiberaceae*	25·9
Costus afer	(Ker-Gawl)	*Zingiberaceae*	Not detected
Manihot utilissima (clone no. 30211)	(Pohl)	*Euphorbiaceae*	44.0
Manihot utilissima (clone no. 30337)	(Pohl)	*Euphorbiaceae*	49·9
Manihot sp. (clone no. 40764)	(Pohl)	*Euphorbiaceae*	73·6
Manihot sp. (clone no. 51077)	(Pohl)	*Euphorbiaceae*	31·0
Manihot sp. (clone no. 60506)	(Pohl)	*Euphorbiaceae*	24·2
Manihot sp. (peels)	(Pohl)	*Euphorbiaceae*	117·0
Maratochloa leucantha	K. Schum	*Marantaceae*	25·0
Musa paradisica	Linn	*Musaceae*	15·4
Palisota hirsuta	K. Schum	*Comelinaceae*	6·2
Grasses			
Bambusa vulgaris	Wendel	*Gramineae*	26·2
Cynodon nlemfuensis		*Gramineae*	Trace

Table 3. Hydrocyanic acid levels in some Nigerian tree leaves fed to livestock (mg kg⁻¹)

Names of the browse species	Authorities	Family	Hydrocyanic acid values
Acioa barterii	Hook F. & Olive Engl.	*Rosaceae*	44·5
Albizia adianthifolia	(Schum) W. F. Wight	*Mimosaceae*	12·3
Albizia zygia	(DC) J. F. Macabr	*Mimosaceae*	6·04
Baphia nitida	Lodd.	*Papilionaceae*	19·1
Cassia siamea	Lam	*Caesalpineaceae*	14·8
Ceiba pentadra	Gaertn	*Bombacaceae*	37·5
Crysophyllum albidium	G. Don	*Sapotaceae*	26·6
Dialium guineensis	Willd.	*Ceasalpineaceae*	19·5
Elaeis guineensis	Jacq.	*Palmaceae*	27·2
Gliricidia sepium	(Jacq.) Staud	*Papilionaceae*	42·6
Musanga cecropoidea	R. Br.	*Moraceae*	26·1
Naudea diderrichii	(L) De Willd	*Rubiaceae*	15·9
Parinari kerstingii	(Engl.)	*Chrysobalanaceae*	65·1
Parkia clappertoniana	Kaey	*Mimosaceae*	6·14
Samanea saman	Merill	*Mimosaceae*	50·8
Spondias mombin	Linn.	*Anarcadiaceae*	41·1
Terminalia catappa	Linn.	*Combretaceae*	12·2

values did not follow a persistent pattern. On the average, they increased as the amount of browse in the diets increased. The dry matter and digestible energy intakes were low for the animals on the sole peels and browse treatments. The quantities of HCN consumed by the experimental goats are shown in Table 6. The HCN intake levels were different ($p < 0{\cdot}05$). The highest amount of HCN was consumed in treatment 2 although this is not reflected in the weights shown in Table 5.

The effects of the hydrocyanic acid were observed to be more on the animals used in the sole *Manihot sp.* leaves treatment (Table 7). It depressed body weight gain, and N-digestibility coefficients as well as digestible energy intake. This is better assessed when the regression (prediction) equations obtained for the three browse species fed are compared for any of the parameters. Generally, however, the effects of HCN on body weights and urinary nitrogen were not significant ($p > 0{\cdot}05$), hence their correspondingly low coefficients of determination, R^2. Low negative correlations exist between hydrocyanic acid intake and urinary nitrogen.

DISCUSSION

The low hydrocyanic acid contents of the analysed browse leaves may have arisen from drying the samples as was observed earlier (Charavanapavan, 1944; Adegbola & Asaolu, 1986). Values obtained in this study are, however, comparable to those of Devendra (1977) after sun-drying. The higher values of hydrocyanic acid in *Manihot sp.* peels, as relative to the leaves, agree with the values of Oyenuga (1978). Although some leaves of browse in the *Euphorbiaceae* family had high HCN values, this is not necessarily characteristic of all

Table 4. Chemical composition of the browse leaves and peels fed to West African dwarf goats (g 100 g^{-1} dry matter)

Browse type		Nitrogen	Crude fibre	Fresh dry matter	Residual dry matter	Ether extract	Nitrogen free extractives	Gross energy (kcal g^{-1})	Iron (ppm)
Manihot utilissima	leaves	4·42	29·32	31·23	95·5	6·81	27·34	4·85	220
Spondias mombin	leaves	2·70	29·19	49·78	92·5	6·50	39·32	4·36	2100
Gliricidia sepium	leaves	3·31	23·08	34·50	91·0	4·95	43·59	4·35	300
Manihot utilissima	peels	0·95	31·75	27·90	94·5	4·10	49·21	3·90	n/d

n/d: not detected.

Table 5. Mean values of the performance characteristics of West African dwarf goats fed browse leaves with *Manihot sp.* peels as supplement

Characteristics	Browse type	Diets: 100% MAP	25% Br ± 75% MAP	50% Br ± 50% MAP	75% Br ± 25% MAP	100% Br
		Mean + SD	Means ± SD	Means ± SD	Means ± SD	Means ± SD
Dry matter intake (g day^{-1} $W_{kg}^{0.734}$)	MAL	$42{\cdot}20^{a}$ ± 5·60	$84{\cdot}31^{b}$ ± 3·74	$75{\cdot}44^{b}$ ± 5·44	$82{\cdot}19^{b}$ ± 6·36	$85{\cdot}36^{b}$ ± 3·78
	SPL	$42{\cdot}20^{a}$ ± 5·60	$59{\cdot}72^{bcd}$ ± 6·21	$63{\cdot}63^{cd}$ ± 6·97	$69{\cdot}86^{d}$ ± 5·71	$22{\cdot}34^{e}$ ± 5·01
	GLL	$42{\cdot}20^{ac}$ ± $5{\cdot}60^{a}$	$64{\cdot}28^{b}$ ± 4·12	$35{\cdot}08^{a}$ ± 5·68	$31{\cdot}72^{a}$ ± 10·23	$24{\cdot}08^{a}$ ± 7·61
Body weight changes (kg day^{-1})	MAL	$-0{\cdot}13^{a}$ ± 0·06	$0{\cdot}10^{b}$ ± 0·02	$0{\cdot}14^{b}$ ± 0·02	$0{\cdot}17^{b}$ ± 0·05	$-0{\cdot}03^{a}$ ± 0·03
	SPL	$-0{\cdot}13^{a}$ ± 0·06	$0{\cdot}04^{bc}$ ± 0·04	$0{\cdot}06^{b}$ ± 0·02	$0{\cdot}03^{bc}$ ± 0·03	$-0{\cdot}06^{ac}$ ± 0·02
	GLL	−0·13 ± 0·06	0·07 ± 0·02	0·01 ± 0·03	0·06 ± 0·08	0·02 ± 0·12
Urinary nitrogen (g day^{-1} $W_{kg}^{0.734}$)	MAL	$0{\cdot}02^{a}$ ± 0·02	$0{\cdot}11^{ab}$ ± 0·02	$0{\cdot}19^{bd}$ ± 0·07	$0{\cdot}34^{c}$ ± 0·07	$0{\cdot}31^{cd}$ ± 0·02
	SPL	$0{\cdot}02^{a}$ ± 0·02	$0{\cdot}07^{ab}$ ± 0·01	$0{\cdot}04^{ab}$ ± 0·01	$0{\cdot}08^{ab}$ ± 0·03	$0{\cdot}10^{b}$ ± 0·04
	GLL	$0{\cdot}02^{a}$ ± 0·02	$0{\cdot}13^{ab}$ ± 0·06	$0{\cdot}05^{ab}$ ± 0·01	$0{\cdot}11^{ab}$ ± 0·05	$0{\cdot}17^{b}$ ± 0·07
N digestibility coefficient	MAL	$-12{\cdot}06^{b}$ ± 6·78	$52{\cdot}77^{a}$ ± 2·55	$63{\cdot}22^{a}$ ± 3·55	$63{\cdot}38^{a}$ ± 3·12	$64{\cdot}02^{a}$ ± 5·02
	SPL	$-12{\cdot}06^{c}$ ± 6·78	$2{\cdot}75^{bc}$ ± 9·41	$23{\cdot}63^{ab}$ ± 4·08	$37{\cdot}34^{a}$ ± 5·47	$-0{\cdot}02^{c}$ ± 8·67
	GLL	$-12{\cdot}06^{b}$ ± 6·78	$32{\cdot}63^{a}$ ± 8·07	$57{\cdot}18^{a}$ ± 3·77	$54{\cdot}03^{a}$ ± 0·96	$57{\cdot}72^{a}$ ± 1·85
N-bal (g day^{-1} $W_{kg}^{0.734}$)	MAL	$-0{\cdot}07^{a}$ ± 0·03	$0{\cdot}81^{b}$ ± 0·03	$1{\cdot}40^{cd}$ ± 0·15	$1{\cdot}77^{de}$ ± 0·14	$2{\cdot}11^{e}$ ± 0·18
	SPL	$-0{\cdot}07^{ad}$ ± 0·03	$-0{\cdot}05^{ad}$ ± 0·09	$0{\cdot}20^{b}$ ± 0·02	$0{\cdot}53^{c}$ ± 0·09	$-0{\cdot}12^{d}$ ± 0·09
	GLL	$-0{\cdot}07^{a}$ ± 0·03	$0{\cdot}23^{ab}$ ± 0·14	$0{\cdot}31^{b}$ ± 0·03	$0{\cdot}39^{b}$ ± 0·21	$0{\cdot}29^{ab}$ ± 0·08
Digestibile energy intake (kcal day^{-1} $W_{kg}^{0.734}$)	MAL	$55{\cdot}3^{a}$ ± 4·56	$192{\cdot}6^{b}$ ± 7·11	$196{\cdot}2^{b}$ ± 12·46	$230{\cdot}9^{b}$ ± 15·62	$42{\cdot}5^{ac}$ ± 26·38
	SPL	$55{\cdot}3^{a}$ ± 4·56	$118{\cdot}7^{bcd}$ ± 27·1	$112{\cdot}2^{cd}$ ± 10·50	$143{\cdot}3^{d}$ ± 12·3	$12{\cdot}7^{a}$ ± 4·7
	GLL	$55{\cdot}3^{ac}$ ± 4·56	$165{\cdot}8^{b}$ ± 12·75	$103{\cdot}7^{a}$ ± 15·70	$81{\cdot}2^{ac}$ ± 33·88	$42{\cdot}9^{c}$ ± 18·03

[a,b,c,d,e]: Means in the same row with variable superscripts are significantly different ($p < 0{\cdot}05$).
Br, browse leaves, i.e. MAL, *Manihot sp.*; SPL, *Spondias sp.*; GLL, *Gliricidia sp.*; MAP, *Manihot sp.* peels.

Table 6. Mean intake of hydrocyanic acid and feed by West African dwarf goats fed browse leaves supplemented with *Manihot sp.* peels

Parameters	Browse type	Diets				
		Control 100% MAP	25% BR ± 75% MAP	50% BR ± 50% MAP	75% BR ± 25% MAP	100% BR
		Mean ± SD				
HCN intake (mg day⁻¹ $W_{kg}^{0.734}$)	MAL	4.93^a ± 0.65	9.10^b ± 0.64	6.69^{cd} ± 0.46	6.60^d ± 0.52	6.52^{de} ± 0.29
	SPL	4.93^{ab} ± 0.65	5.86^a ± 0.84	5.36^{ab} ± 0.45	4.03^b ± 0.23	0.94^c ± 0.21
	GLL	4.93^a ± 0.65	6.30^a ± 0.35	3.31^b ± 0.95	2.06^{bc} ± 0.60	1.04^{cd} ± 0.32
HCN intake (mg 100 g⁻¹ body weight)	MAL	245^a ± 29.21	452^b ± 42.46	320^a ± 19.3	318^a ± 28.2	325^a ± 16.54
	SPL	245^a ± 29.21	289^a ± 38.14	257^a ± 25.8	201^a ± 11.2	50^b ± 10.85
	GLL	245^a ± 29.21	305^a ± 15.69	164^{bc} ± 23.4	99^d ± 26.5	51^d ± 13.93

[a,b,c,d,e]: Means in the same row with variable superscripts are significantly different ($p < 0.05$).
BR, browse leaves, i.e. MAL, *Manihot sp.*; SPL, *Spondias sp.*; GLL, *Gliricidia sp.*; MAP, *Manihot sp.* peels.

Table 7. Relation between various aspects of performance (Y) and HCN intake (mg day⁻¹ $W_{kg}^{0.734}$) (X) by West African dwarf goats fed browse with *Manihot sp.* peels in differing proportions

Variables	Browse type fed	Prediction equation	Standard error of estimate (SEE)	Coefficient of determination (R^2)	Level of signifiance of R
Dry matter intake (kg day⁻¹)	*Manihot sp.*	$Y = 0.06X + 0.14$	0.12	0.40	***
	Spondias sp.	$Y = 0.07X + 0.09$	0.10	0.64	***
	Gliricidia sp.	$Y = 0.06X + 0.08$	0.09	0.70	***
Body weight changes (g day⁻¹ $W_{kg}^{0.734}$)	*Manihot sp.*	$Y = 4.23X - 21.47$	17.07	0.15	n.s.
	Spondias sp.	$Y = 1.88X - 9.74$	13.04	0.08	n.s.
	Gliricidia sp.	$Y = 0.40X + 0.29$	20.26	0.002	n.s.
Urinary nitrogen (g day⁻¹ $W_{kg}^{0.734}$)	*Manihot sp.*	$Y = 0.004X - 0.17$	0.15	0.002	n.s.
	Spondias sp.	$Y = -0.01X - 0.09$	0.05	0.09	n.s.
	Gliricidia sp.	$Y = -0.004X - 0.11$	0.11	0.01	n.s.
N-digestibility coefficient	*Manihot sp.*	$Y = 8.85X - 13.59$	28.35	0.22	*
	Spondias sp.	$Y = 0.64X + 7.62$	22.77	0.004	n.s.
	Gliricidia sp.	$Y = -6.81X + 61.94$	26.10	0.25	*
Digestible energy intake (kcal day⁻¹ $W_{kg}^{0.734}$)	*Manihot sp.*	$Y = 25.28X - 27.57$	75.92	0.24	*
	Spondias sp.	$Y = 18.79X - 9.08$	40.90	0.48	***
	Gliricidia sp.	$Y = 18.37X + 24.95$	41.56	0.49	***

n.s., $p > 0.05$. *, $p < 0.05$. **, $p < 0.01$. ***, $p < 0.001$.

plants in this family (Ariyo, O. J., pers. comm.). Dried leaves of *Manihot sp.* are suitable for animal feeding since neither mortality nor ill-health was observed in the animals used in this study. The improved dry matter intake observed in this study can be explained by the preference of goats for leaves combined with peels/pulp. Improved weight gains observed when the leaves were supplemented with peels also suggest that leaves or peels should not be fed solely to ruminants but in combination with one another. Where leaves or peels are fed as sole diets, the negative effects of hydrocyanic acid on livestock would be more evident as seen in 100% browse and 100% *Manihot sp.* peels treatments. This effect is more pronounced on the body weight changes, nitrogen digestibility coefficient and nitrogen balance. For the *Manihot sp.* trials, a 75:25 combination of leaves to peels appears appropriate since the highest positive weight change was recorded in this treatment combination. The proximate composition table indicates that the three browse species fed to the goats are isoenergetic. The gross energy values of the other analysed samples are also high (Onwuka *et al.*, 1989). However, the available energy has a greater impact on the utilization of the species (Onwuka & Akinsoyinu, 1989). The low N content of the *Manihot sp.* peels may also explain its poor utilization by goats when compared to the best utilized diet in the study (*Manihot sp.* leaves) which also has the highest N content. Although the GLL trial ranks next to the MAL using the performance of the goats, its leaves possess a smell which puts animals off and which may also have been responsible for the relatively lower feed intake.

CONCLUSION

This study has identified some browse plants fed to goats. Their leaves contain varying levels of hydrocyanic acid. Browse hydrocyanic acid influences weight gain, nitrogen digestibility and nitrogen balance of goats. In feeding browse to goats, the leaves could be dried or wilted to reduce the cyanide levels. Supplementation with an available energy source is also recommended to improve the utilization of the browse leaves.

ACKNOWLEDGEMENTS

The interest and contributions of Professor A. U. Mba (late), Dr A. O. Akinsoyinu and Professor O. O. Tewe of the Nutritional Biochemistry Department of the University of Ibadan, Nigeria are sincerely appreciated.

REFERENCES

Adegbola, A. A. & Asaolu, A. (1986). Preparation of cassava peels for use in small ruminant production in Western Nigeria. In *Towards Optimum Feeding of Agricultural By-products to Livestock in Africa*, ed. T. R. Preston & M. Y. Nuwanyakpa. ILCA, Ethiopia, pp. 109–15.

AOAC (1980). Association of Official Agricultural Chemists, *Official Methods of Analysis*, 13th edn. Washington, DC.

Brewbaker, J. L. (1989). Nitrogen fixing trees for fodder and browse in Africa. In *Alley Farming in the Humid and Sub-humid Tropics*, ed. B. T. Kang & L. Reynolds. IDRC-271e, Canada, pp. 55–70.

Charavanapavan, C. (1944). Studies in manioca and lima beans with special reference to their utilization as harmless food. *Trop. Agric.*, **100**, 164–8.

Devendra, C. (1977). Cassava as a feed source for ruminants. In *Cassava as Animal Feed*, ed. B. Nestel & M. Graham. IDRC-095e, Guelph, pp. 107–27.

Hill, D. C. (1973). Chronic cyanide toxicity in domestic animals. In *Chronic Cyanide Toxicity, Proc. Interdisciplinary workshop, London.* IDRC-010e, pp. 105–11.

Le Houérou, H. N. (ed.) (1980). Chemical composition and nutritive value of browse in Tropical West Africa. In *Browse in Africa.* ILCA, Addis Ababa, pp. 261–89.

Obioha, F. C. (1972). Utilization of cassava as human food —A review of literature and research recommendations. AID contract No. CSD/2497. IDRC, Canada.

Onwuka, C. F. I. (1983). Nutrition evaluation of some Nigerian browse plants in the humid tropics. PhD thesis, University of Ibadan, Nigeria, 266 pp.

Onwuka, C. F. I. & Akinsoyinu, A. O. (1989). Protein and energy requirements for maintenance and gain by West African dwarf goats fed cassava leaves (*Manihot utilissima*) with peels as supplement. *Small Rumin. Res.*, **2**, 291–8.

Onwuka, C. F. I., Akinsoyinu, A. O. & Tewe, O. O. (1989). Feed value of some Nigerian browse plants—chemical composition and in vitro digestibility of leaves. *East Afr. Agric. For. J.*, **54**(3).

Onwuka, C. F. I., Akinsoyinu, A. O. & Tewe, O. O. (1991). Role of sulphur in cyanide detoxification by ruminants. *Small Rumin. Res.* (in press).

Oyenuga, V. A. (1978). *Nigeria's Foods and Feeding Stuffs*, 3rd edn. Ibadan University Press, 99 pp.

Reynolds, L. & Adeoye, S. A. (1989). Planted leguminous browse and livestock production. In *Alley Farming in the Humid and Subhumid Tropics*, ed. B. T. Kang & L. Reynolds. IDRC-271e, Canada, pp. 44–54.

Skerman, P. J. (1977). *Tropical Forage Legumes.* FAO Rome, Italy. Plant Production and Protection, serial 2, 609 pp.

Steel, R. G. D. & Torrie, J. H. (1980). *Principles and Procedures of Statistics—A Biometrical Approach.* McGraw-Hill, Singapore.

Tewe, O. O. (1975). Implications of cyanogenic glucoside of cassava in the growth and reproductive performance of rats and pigs. PhD thesis, University of Ibadan, Nigeria, 517 pp.