PLANT PHYTATES AND OXALATES AND THEIR EFFECTS ON NUTRIENT UTILIZATION BY GOATS

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ABSTRACT

The leaves of 37 browse species usually fed to ruminants in Nigeria were analysed for their contents of phytic acid, phytin - P and oxalic acid. The study indicated average phytic acid contents ranging from 65.05 to 350.64 mg/g-1 in the trees, shrubs, herbs and grass leaves. The phytin-P and oxalate respectively ranged from 18.32 - 100 mg g⁻¹ and 0.10 - 3.5 mg 100 mg⁻¹. The herbs leaves had the highest concentration of phytate while shrubs had the highest oxalate content. The *in vivo* trial with dwarf goats showed that, when maintained on browse and cassava peels, goats consumed 3.37 ± 0.30 to 24.00 ± 1.06 mg d⁻¹ Wkg^{-0.734} of phytic acid and 0.06 ± 0.02 to 0.51 ± 0.02 g d⁻¹ W kg^{-0.734} of oxalic acid. The CP, Ca and P intakes and excretion were also monitored. These two toxicants were correlated with protein; DM intake, DM digestibility and body weight changes. Browse phytates and oxalates did not quite impair the performance of ruminant animals significantly. Following digestion, nutrients sent into the soil include Ca, P, N, C, Zn etc.

Keywords: Phytate, Oxalate, Browse anti-nutrients, Goats

INTRODUCTION

Ruminant animals depend mostly on green forage for their production as green leaves tend to be available especially during the rainy season in the tropical areas of Sub-Saharan Africa. The role of the green feed in filling their bulk and supplying nutrients to ruminants has been extensively researched into (Le Houerou, 1980; Onwuka *et al*, 1989. From a biological perspective, food serves primarily as a source of nutrients, but only a portion of the chemicals present in foods fulfil nutrients roles. Most foods contain toxic chemicals although the concentrations of these chemicals

are often too low to present any actual hazard (Taylor, 1982). These toxicants include phytin, oxalates, nitrates, saponins, cyanogens, etc. Most of the P in a wide variety of feedstuffs of plants origin is organically bound in the form of phytic acid, i.e the mixed Ca and Mg salts (Maga, 1982; Tillman and Brethour, 1958). In plants, phytic acid may be used to store P (Hall and Hodges, 1966) or energy (Biswas and Biswas, 1965).

Phytic acid chelates several minerals especially Ca, Mg, Fe, Zn and Mo and thereby reduces their bioavailability in the intestinal tract (Obeleas, 1975; Taylor, 1982; Wise, 1983). Although P in this form can still be utilized by ruminants, to an extent, the availability of Phytin-P to ruminants ranging from 33 - 90% (McDonald *et al*, 1988). Oxalate, a dibasic acid, is widespread in plants and is composed of Ca, N and Mg salts. Vegetables high in oxalates have unavailable Ca. This has implications in bone formation, mucous membrane of the stomach and intestine of animals (Oke, 1996). Calcium oxalate is available to ruminants, the rumen being the main site of degradation. Talapatra *et al* (1948) concluded earlier that oxalate was broken down to form CO₃⁻ and HCO₃⁻ with the resulting severe alkaldosis and fall in calcium balance. Since animals obtain their nutrients from plants, so much undigested nutrients are excreted in the faeces and urine, for eventual use by the plants for their metabolic activities.

This study was therefore carried out with a view to ascertaining the existing levels of phytates and oxalates and their associated minerals in browse plants consumed by small ruminants in Nigeria. The levels of these toxicants and their effects on performance of goats were also monitored. So also were the amounts voided when the plants leaves were fed.

MATERIALS AND METHODS

Collection and processing of the Plant Leaves:

Leaves of 37 browse plants (Table 1) were collected from the humid and sub-humid tropical parts of Nigeria. They were oven-dried at 50 - 60°C for 3 days and thereafter, ground through a 2mm sieve before analysing. For the feeding trials, leaves of *Manihot* sp., (MAL) *Spondias mombin* (SPL) and *Gliricidia* sp. (GLL) were used with *Manihot* sp. peels (MAP). These were sun-dried on a flat concrete floor for 3 days and fed, without grinding, to West African dwarf (WAD) goats.

Chemical Analyses

Phytin in the samples was estimated as phytic acid and phytin-P using the methods of Young and Greaves (1940) and Beutler *et al* (1980). Oxalic acid was estimated using the precipitation method of AOAC (1980). N was determined with the method of AOAC (1980). P was assayed by the Vanado-molybdate method while Ca was determined with the atomic absorption spectrophotometer using an SP 191 Pye Unicam spectrophotometer as indicated in AOAC (1980) method.

Management of the Animals

Twenty four healthy 1 to 1½-year old WAD goats (*Fouta djallon*) were arranged in a randomized block design and separated into 5 groups, each with 4 goats (2 bucks and 2 does). Fifteen trials were carried out with each trial lasting 3 weeks i.e. 2 weeks of preliminary feeding and the last week for collection of faeces and urine when housed in metabolism crates modified by Onwuka and Akinsoyinu (1989). All the goat had access to mineralized salt lick and daily fresh clean water supply. They were routinely dewormed. Leaves of the browse species specified above were fed at 0, 25, 50, 75 and 100% levels with graded levels of cassava peels, (MAP) as supplement. The goats were randomly allotted to diets and were allowed 800g browse, fed twice daily at 08.00 hrs and 16.00 hrs. Refusals were collected and weighed daily to assess feed intake.

RESULTS

The phytate, phytin-P and oxalate contents of the analysed browse trees leaves ranged from 82.03 - 292.91 mg g⁻¹; 23.15 - 88.04 mg100g⁻¹ and 0.33-2.06 mg100mg⁻¹ respectively (Table 1). The corresponding range of values for phosphorus was 0.03 - 0.47%. Some trees in the Mimosaceae family had the highest levels of phytin and Phytin-P. Phosphorus bound with phytin averaged 28%. Crude Protein levels in the leaves were reasonably high (7.50 to 26.80% while Ca, P and Zn were quite high in *Gliricidia* sp. and *Spondias* sp. leaves. Of the herbs leaves analysed (Table 2), Cassava (*Manihot* sp.) leaves had outstandingly high phytin contents on the average. Overall range was 99 - 355 mg g⁻¹ and the Phytin bound Phosphorus was also 27%. The oxalate values which ranged from 0.20 - 0.70 mg 100g⁻¹ were lower than those recorded for trees and shrubs leaves. Oxalate levels as high as 16% had previously been reported in leaves (Oke,1969). Zinc levels obtained were moderate and the Ca/P ratios exceeded 2 (two) in most cases. The toxicants and nutrients levels (Table 3) obtained in the shrubs show that the Phytin, Phytin-P and Oxalates levels were least in comparison with those of herbs, grasses and trees. Ca/P ratios were higher than 2.0 while moderate levels of crude protein and Zn were recorded.

Regression analyses show that no significant relationships were established between Phytin, Oxalate and P, Zn, Ca and CP, although low inverse correlation coefficients existed between the toxicants and calcium/phosphorus. Table 4 shows the intake and utilization of nutrients by goats fed *Manihot*, *Gliricidia* and *Spondias* leaves respectively. The goats apparently relished the cassava leaves more than the other species. The Dry Matter was digested to reasonable extents and was best when 50% of the leaves were fed. Only about 30% of the Oxalate consumed was voided in the faeces and urine. Phytate intake was highest in the cassava eaves trials. Phytate and Oxalate intakes did not affect Faecal N output, and DM digestibility coefficients (Table 5).

PHYTATES AND OXALATES UTILIZATION BY GOATS

TABLE 1: CONCENTRATIONS OF PHYTIN, OXALATE AND MINERALS IN SOME NIGERIAN TREES LEAVES

Browse Species	Phytin	Phytin-P (mg/100g)	Oxalate Protein (mg/100g)	Crude (C.P.%)	P (%)	Zn (ppm)	Ca (%)
Ascia baterii	86.77	24.38	1.02	9.38	0.17	85	0.24
Albizia adianthifolia	207.92	58.33	0.66	23.30	0.07	-	0.13
Albizia sp.	102.92	29.17	0.59	24.21	0.27	66	0.23
Baphia nitida	248.38	69.95	2.06	26.80	0.15	-	0.15
Cassia siamea	190.41	51.57	0.58	14.12	0.08	45	1.20
Cerba pentandra	160.61	45.28	1.29	17.70	0.12	40	0.18
Cryosophyllum albidum	167.39	47.11	1.07	14.80	0.06	-	0.46
Dialium guineensis	195.51	55.19	0.53	12.76	0.12	87	0.66
Elaeis	149.84	45.29	0.89	13.80	0.08	-	0.25
Gliricidia sepium	125.82	37.82	0.54	20.69	0.30	21	0.95
Musanga cecropiodes	108.62	33.02	0.54	20.69	0.30	21	0.95
Naudea diderichii	82.03	23.15	0.33	15.24	0.08	63	0.10
Parinari kerstingii	135.37	38.11	1.18	17.91	0.11	65	0.30
Samanea saman	118.52	33.02	0.54	7.50	0.47	107	0.14
Spondias mombin	227.08	68.43	0.71	17.84	0.27	88	0.29
Terminalia catapa	159.28	44.91	0.67	12.71	0.03	65	0.27
Mean $\pm$ S.E	162.32 $\pm$ 14.2	746.43 $\pm$ 4.23	0.88 $\pm$ 0.11	15.87 $\pm$ 1.40	0.162 $\pm$ 0.27	46.00 $\pm$ 862	0.45 $\pm$ 0.10

TABLE 2: PHYTATE, OXALATE AND MINERALS IN LEAVES OF SOME HERBS AND GRASS SPECIES

Browse species	Phytin (mg/g)	Oxalate-P (mg/100g)	Oxalate (%)	Crude Protein	P (%)	Zn (ppm)	Ca (%)
Aframomum mmelegueta	147.30	41.48	0.15	14.30	0.06	-	0.09
Costus afer	354.62	100.00	0.60	18.70	0.15	-	0.19
Manihot esculenta (30211)	274.29	74.29	0.58	28.04	0.22	43	0.04
Manihot esculenta (40764)	233.13	65.46	0.58	20.42	0.17	76	0.79
Manihot esculenta (60506)	145.46	44.04	0.61	24.97	0.23	68	0.22
Manihot esculenta	183.27	51.43	0.36	2.35	0.06	34	0.20
Maratocloa leucantha	350.64	98.72	0.20	9.99	0.08	-	0.32
Musa cultivar (AB)	99.47	28.02	0.75	16.91	0.10	39	0.71
Palisota hirsuta	236.15	66.31	0.38	19.66	0.20	-	0.30
Bambusa vulgaris	232.19 $\pm$ 24.97	65.37 $\pm$ 6.91	0.49 $\pm$ 0.06	18.60 $\pm$ 2.28	0.15 $\pm$ 0.02	79.09 $\pm$ 7.88	0.40 $\pm$ 0.09
Mean $\pm$ S.E							

TABLE 3: THE LEVELS OF PHYTIN, OXALATE AND FEW MINERALS IN SOME SHRUBS FOUND IN NIGERIA

Browse species	Phytin (mg/g)	Phytin - P (mg/100g)	Oxalate Mg/100g	Crude Protein (%)	P (%)	Zn (ppm)	Ca (%)
<i>Alchornea cordifolia</i>	145.51	41.08	2.51	20.57	0.12	50	0.24
<i>Alchornea</i> sp	211.89	59.68	0.53	13.85	0.08	39	0.30
<i>Bridelia ferruginea</i>	141.23	39.80	2.73	15.57	0.12	0	0.31
<i>Cnetis ferruginea</i>	293.62	82.77	3.59	19.37	0.08	-	0.62
<i>Codiaeum variegatum</i>	121.63	34.23	0.86	12.95	0.11	46	0.71
<i>Cola milenii</i>	94.49	26.60	0.10	20.98	0.28	92	0.81
<i>Combretum paniculatum</i>	140.30	39.37	1.07	30.91	0.14	-	0.20
<i>Corpolobia lutea</i>	116.57	32.72	1.114	4.70	0.08	85	0.21
<i>Microdesmis puberula</i>	65.05	18.32	0.41	23.42	0.08	-	0.557
Mean $\pm$ S.E.	147.81 $\pm$ 22.62	41.62 $\pm$ 6.38	1.44 $\pm$ 0.40	18.08 $\pm$ 2.47	0.12 $\pm$ 0.02	39.11 $\pm$ 11.58	0.44 $\pm$ 0.08

TABLE 4 NUTRIENT INTAKE AND UTILIZATION BY WAD GOATS FED BROWSE PYHTATE AND OXALATE

Characteristics	Browse leaves Types	DIETS				
		100% MAP (control)	25% Br + 75%MAP	50% Br + 50%MAP	75% Br + 25% MAP	100% Br
DM Intake (g d^{-1} 734)	MAL SPL GLL	42.20a + 5.60 42.20A + 5.60 42.20ac + 5.60	84.31b $\pm$ 3.74 59.72bcd $\pm$ 6.21 64.28b $\pm$ 4.12	75.44b $\pm$ 5.44 63.63cd $\pm$ 6.97 35.08a $\pm$ 5.68	82.19b $\pm$ 6.36 69.86d $\pm$ 5.71 31.72a $\pm$ 10.23	85.35b $\pm$ 3.78 22.34e $\pm$ 5.01 24.08a $\pm$ 7.61
App. Dry matter digestibility (%)	MAL SPL GLL	57.60ab 3.57 57.60a $\pm$ 3.57 57.60bc $\pm$ 3.57	64.88a $\pm$ 1.56 44.12b $\pm$ 4.80 67.07ab $\pm$ 2.25	62.91a $\pm$ 4.28 51.22ab $\pm$ 1.90 69.54a $\pm$ 2.31	62.09a $\pm$ 1.67 51.22ab $\pm$ 3.90 48.58cd $\pm$ 7.36	50.36b $\pm$ 3.92 14.35c $\pm$ 6.39 43.01d $\pm$ 2.47
Phytin Intake ($\text{mg d}^{-1}\text{W}_{\text{kg}}^{-0.734}$)	MAL SPL	3.37 $\pm$ 0.30 3.37 $\pm$ 0.30	12.75 $\pm$ 0.58 7.19 $\pm$ 0.46	16.72 $\pm$ 1.54 9.38 $\pm$ 1.34	21.56 $\pm$ 1.66 11.60 $\pm$ 2.20	24.03 $\pm$ 1.06 5.09 $\pm$ 1.14
Oxalate Intake ($\text{g d}^{-1}\text{W}_{\text{kg}} 0.734$)	MAL SPL GLL	0.06 $\pm$ 0.02 0.06 $\pm$ 0.02 0.06 $\pm$ 0.02	0.24 $\pm$ 0.02 0.16 $\pm$ 0.01 0.15 $\pm$ 0.02	0.34 $\pm$ 0.03 0.24 $\pm$ 0.04 0.09 $\pm$ 0.04	0.45 $\pm$ 0.04 0.39 $\pm$ 0.01 0.13 $\pm$ 0.05	0.51 $\pm$ 0.02 0.15 $\pm$ 0.03 0.13 $\pm$ 0.04
Fecal N (g kg^{-1} DM	MAL SPL GLL	10.66 $\pm$ 0.65 10.66 $\pm$ 0.65 10.66 $\pm$ 0.65	10.05 $\pm$ 1.23 13.74 $\pm$ 1.52 10.03 $\pm$ 0.28	12.82 $\pm$ 1.54 13.11 $\pm$ 1.14 7.68 $\pm$ 0.68	11.23 $\pm$ 1.76 14.62 $\pm$ 1.28 11.10 $\pm$ 1.12	14.63 $\pm$ 2.05 27.02 $\pm$ 2.34 14.09 $\pm$ 0.70
Urinary N. ($\text{g d}^{-1}\text{W}_{\text{kg}} 0.734$	MAL SPL GLL	0.02a $\pm$ 0.02 0.02a $\pm$ 0.02 0.02 $\pm$ 0.02	0.11ab $\pm$ 0.02 0.07ab $\pm$ 0.01 0.13ab $\pm$ 0.06	0.19bd $\pm$ 0.07 0.04ab $\pm$ 0.01 0.05ab $\pm$ 0.01	0.34c $\pm$ 0.07 0.08ab $\pm$ 0.03 0.11ab $\pm$ 0.05	0.31cd $\pm$ 0.03 0.104b $\pm$ 0.04 0.173b $\pm$ 0.07
Fecal Oxalate (mg d^{-1})	MAL SPL GLL	3.52 $\pm$ 0.19 3.52 $\pm$ 0.19 3.52 $\pm$ 0.19	14.40 $\pm$ 1.21 6.54 $\pm$ 0.98 5.04 $\pm$ 1.14	16.22 $\pm$ 0.00 11.46 $\pm$ 0.82 3.60 $\pm$ 1.31	21.71 $\pm$ 1.25 13.68 $\pm$ 0.96 4.07 $\pm$ 0.55	21.60 $\pm$ 1.65 6.08 $\pm$ 1.00 2.97 $\pm$ 1.11
Urinary oxalate (mg d^{-1})	MAL SPL GLL	0.55 $\pm$ 0.06 0.55 $\pm$ 0.06 0.55 $\pm$ 0.06	1.34 $\pm$ 0.08 0.63 $\pm$ 0.04 0.82 $\pm$ 0.07	1.38 $\pm$ 0.15 1.10 $\pm$ 0.11 0.42 $\pm$ 0.04	1.52 $\pm$ 0.14 1.30 $\pm$ 0.10 0.36 $\pm$ 0.02	1.79 $\pm$ 0.16 0.48 $\pm$ 0.03 0.28 $\pm$ 0.01
Ca Intake (g d^{-1})	SPL SPL GLL	0.88 $\pm$ 0.03 0.88 $\pm$ 0.03 0.88 $\pm$ 0.03	1.21 $\pm$ 0.01 1.21 $\pm$ 0.01 4.53 $\pm$ 0.04	1.45 $\pm$ 0.01 1.45 $\pm$ 0.01 2.31 $\pm$ 0.03	1.45 $\pm$ 0.01 1.39 $\pm$ 0.01 2.19 $\pm$ 0.03	1.39 $\pm$ 0.01 0.39 $\pm$ 0.01 1.59 $\pm$ 0.02

TABLE 6 INFLUENCE OF PHYTIN AND OXALATE INTAKES ON NUTRIENT INTAKE AND UTILIZATION BY DWARF GOATS FED THREE DIFFERENT BROWSE PLANTS

Y Vs. X	PREDICTION EQUATIONS	SEE	R ²	R	SIGNIFICANCE
DM Intake Vs. Phytin Intake					
MAL	$Y = 0.08X + 0.31$	0.11	0.54	0.74	xxx
SPL	$Y = 0.03X + 0.14$	0.12	0.49	0.70	xxx
GIL	$Y = 0.06X - 0.03$	0.05	0.89	0.94	xxx
Body Wt. Vs. Phytin Intake					
MAL	$Y = 1.00X - 8.38$	16.71	0.19	0.43	n.s.
SPL	$Y = 1.80X - 15.02$	11.68	0.27	0.51	x
GIL	$Y = 6.80X + 24.89$	15.89	0.39	0.62	xx
Faecal Nitrogen Vs. Phytin Intake					
MAL	$Y = 0.18X + 9.30$	3.21	0.17	0.41	n.s.
SPL	$Y = -0.18X + 17.13$	6.61	0.01	-0.104	n.s.
GIL	$Y = -0.44X - 12.41$	2.45	0.10	-0.31	n.s.
DM Dig. Coeff. Vs. Phytin Intake					
MAL	$Y = -0.28X + 63.92$	7.71	0.08	-0.28	n.s.
SPL	$Y = 0.94X + 37.68$	18.01	0.04	0.20	n.s.
GIL	$Y = 4.51X + 35.94$	17.11	0.23	0.48	x
DM Intake Vs. Oxalate Intake					
MAL	$Y = 0.65X + 0.33$	0.11	0.52	0.73	xxx
SPL	$Y = 0.78X + 0.21$	0.14	0.34	0.59	xx
GIL	$Y = 1.54X + 0.11$	0.14	0.43	0.65	xx
Body weight Changes Vs. Oxalate Intake					
MAL	$Y = 43.89X - 6.81$	16.88	0.17	0.41	n.s.
SPL	$Y = 45.82X - 10.94$	12.32	0.18	0.43	n.s.
GIL	$Y = 236.22X - 24.89$	13.39	0.61	0.78	xxx
DM Dig. Coeff. Vs. Oxalate Intake					
MAL	$Y = -13.41X + 63.84$	7.67	0.09	-0.29	n.s.
SPL	$Y = 13.07X + 42.04$	18.01	0.01	0.09	n.s.
GIL	$Y = 28.77X + 53.92$	8.47	0.021	0.15	n.s.

$x =$ $P < 0.05$ MAL = Manihot Sp. leaves
 $xx =$ $P < 0.01$ SPL = Spondias mombin leaves
 $xxx =$ $P < 0.001$ GIL = Citricida sp. leaves
 N.S. = not significant

DISCUSSION

The levels of Phytic acid found in the browse leaves analysed could have resulted from the use of phytic acid as P store by plants (Lola and Markakis, 1975). These levels were, however, higher than those reported for seeds by Tinay *et al* (1989) and comparable to those for leafy vegetables (Taylor, 1979). Although the phytin-P levels recorded were fairly high, ruminants are exceptional in their ability to utilize phytin-P and inorganic-P with the aid of phytase produced by the rumen micro-organisms (Talapatra *et al* 1948). The Oxalate concentrations also fall within the range cited by Oke (1969). With the high Ca/P ratios, the toxicity effect of these toxicants will be minimal. Evidence exist to buttress the ability of ruminants to cope with phytin and oxalate in feed (Talapatra, *et al*, 1948) and this was also confirmed in this study.

Oxalates deplete the Ca reserve but these browse species were found to contain reasonable Ca, Mg and Zn levels (Le Houerou, 1980; Akinsoyinu and Onwuka, 1988). Calcium and carbon are also released from the hydrolysis of Ca oxalate some of which will be either absorbed or excreted by the goat.

With Ca absorption rate by ruminants put at 31% (Randy *et al*, 1984; Haenlein, 1987) and P at 4% absorption (Adeloye and Akinsoyinu, 1985) quite an amount of the Ca and P intakes will be lost via faeces and urine to the soil. Such voided minerals/nutrients are thereby recycled for further use to support plants which are ploughed back in the soil, when so much N is returned to the soil. This reduces the use of inorganic N fertilizer and lends weight to the use of organic manure in farming.

This study revealed a low inverse relationship between phytin intake and DM digestibility coefficient and faecal Nitrogen. The effect on body weight may be ascribed to the associative effect of other toxicants like Saponins, tannin, etc. in the leaves (Onwuka, 1992).

This study has established the presence of phytin and oxalate in browse plants. However,

feeding trials did not show any very significant effect of these toxicants on the utilization of other nutrients by goats. Minerals such as Ca, P, Zn, N, C, etc. are excreted in the course of normal metabolism of browse by livestock and these also assist, when recycled, in replenishing soil nutrient reserves for plant use, etc.

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