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Evaluation of Macro and Micro Mineral Concentrations of Browse Forages in Relationto Ruminants Requirement: a Case Study of Gwoza, Borno State, Nigeria

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Abstract
Information is lacking on mineral nutritive potential of native pastures in pastoral rangelands in the tropics including Nigeria. An experiment, using wet nitric acid (HNO_3) digestion in a micro wave digester followed by an induced coupled plasma spectroscopy (ICPS), was carried out to quantify levels of macro and micro minerals of *in situ* conserved herbage forages of Gwoza local Government area of Borno State, Nigeria. The browse forages had variable levels of Ca, P, Mg, Na and K (ranges of 5.10-19.30, 110.70-665.80, 1.80-10.40, 0.50-1.30 and 11.50-120.00 g kg^{-1} of dry matter (DM), respectively, and were higher than the minimum recommended levels in the diets of ruminants. Content of micro minerals varied among the browse forages. The forages had higher levels of Fe (1.618-10.96 mg kg^{-1} DM) moderate contents of Zn (1.064-5.725 mg g^{-1} DM) compared to recommended dietary requirements of ruminants. The feeds had lower levels of Mn (0.234-0.887 mg g^{-1} DM), and lower levels of Co (0.004-0.011 mg kg^{-1} DM). The browse feeds had moderate levels of Se (0.085-0.168 mg g^{-1} DM). The levels of Ni ranges between 0.006-0.085 mg g^{-1} DM**)** considerably in excess of requirements. In order to optimise livestock productivity in ruminants fed on the deferred forages, specially during dry seasons, there is a need to supplement with micro mineral sources.
Keywords: Browse, Fodder, herbage, minerals, natural pasture, Tanzania

1. Introduction

Ruminant production during dry seasons in the tropics including semi-arid areas of central, north-eastern and north-western Nigeria is limited by low productivity of rangeland forages, which often contain too low crude protein (CP) to meet the minimum requirement for optimal rumen microbial activity (Annison and Bryden 1998). Feed resources of minerals include; range or pasture plants, harvested forages, concentrates and mineral supplements (McDowell and Arthington, 2005). Forage and mineral intake in feed stuff by grazing ruminant depends on the level of mineral consumption. Khan *et al*. (2005) reported that the levels of minerals in plants is a function of interaction between several factors which include soil type, plant species, stage of maturity, dry matter yield, grazing management and climate. Therefore there is the need to provide information on the availability and concentration of mineral in forages in the study area considering the level of livestock production in the study area.

Knowledge on mineral composition of browse forages would form base-line data on mineral status of available feed resources for enhanced nutrition of grazing ruminants in semi-arid areas of north-eastern Nigeria. Content of minerals of indigenous browse fodder species such as *Acacia, Ficus* and *ziziphus* sp. that grow naturally in the semi arid areas has been established (Njidda, 2011). A study was therefore conducted to assess the mineral nutritive potential of selected browse forages of Gwoza local Government of Borno state, north-eastern Nigeria.

2. Materials and methods

2.1 Description of site and the samples

All forages were harvested from Gwoza local government area of Borno State. The area is located at Longitude 11.05^0 North and Latitude 30.05^0 East and at an elevation of about 364m above sea level in the North Eastern part of Nigeria. The ambient temperature ranges between 30^0C and 42^0C being the hottest period (March to June) while it is cold between November and February with temperatures ranging between 19 - 25^0C (Alaku and Moruppa, 1988).

Thirty seven browse forages commonly found in the Semi-arid and derived Savannah zones were used in this experiment. The samples were sundried and milled and sub samples taken for analysis. The species included the following: *Acacia sieberiana, Anageisus celecarpus, Batryospermum paradoxum, Cassia sieberiana, Celtis integuifolis, Diospyrus mispliformis, Khaya senegalensis, Leptadenia lancifolia, Poupartia sirrea* and *Vitex cuneata* The browse forages were harvested from at least 10 trees per species selected at random in four locations within the study area at the end of rainy season.

2.2 Sample Preparation

About 500g of the harvested and pooled weekly samples from each plant was oven dried at 105^0C for 24hours, cooled and weighed. The weight difference between the initial weights and dried weights was taken as the moisture content of the leaves offered and then converted to percentage. Percent dry matter content was then obtained as the difference between 100 and percent moisture content (AOAC, 2002). The dried weekly samples were then bulked according to plant species and each shared into two portions. One portion was milled to pass through 1mm screen sieve, labelled and stored in sealed polythene bags for degradability and *in vitro* studies. The other portion was milled to pass through 1mm screen sieve, labelled and as well stored for proximate compositon and anti-nutritional factor determinations.

2.3 Analysis of minerals

Mineral contents of *in situ* herbage forages were determined by wet ashing using a microwave oven as described by Mullis *et al*., (2003). Forage samples (0.5 g) were weighed into Teflon-lined digestion vessels to which 5 ml of HNO_3 was added, and were allowed to digest for 25 min in a CEM MDS-2000 Microwave digester (Model No. 9240020, CEM Corporation, Mathews NC., USA). The microwave oven was set at four times and pressure phases of 40 PSI for 5 min (step 1); 80 PSI for 5 min (step 2); 120 PSI for 5 min (step 3) and 160 PSI for 10 min (step 4). After cooling, the samples were filtered through an ash-free filter paper, and diluted in ion exchanged distilled water to a final volume of 50 ml. Mineral contents were detected by Induced Coupled Plasma Spectroscopy (ICPS) (SPS 7700 Plasma Spectrometer, SII, Seiko Instruments Inc., Japan) fitted with an automatic sampler (400 Auto Sampler, SII, Seiko Instruments Inc., Japan). The samples were analyzed for macro minerals: calcium (Ca), phosphorus (P), magnesium (Mg), and sulphur (S); and micro minerals: iron (Fe), zinc (Zn), manganese (Mn), molybdenum (Mo), and cobalt (Co) and copper (Cu).

2.4 Statistical analysis

Data on content of minerals were subjected to the General Linear Model (GLM) procedure of SAS Statistical package (SAS/Statview 1999) based on the following statistical model:

$Y_i = \mu + R_i + e_{i,}$

where

Y_i is the response of a factor under investigation (mineral composition),

μ is the general mean peculiar to each observation,

R_i is the i^{th} effect on the observed parameter due to grazing land, and

e_i is the random error term.

3. Results

3.1 Content of macro minerals

Content of macro minerals of grazing land forages is shown in Table 1. The Ca levels vary significantly ($P<0.05$) ranging from 5.10 to 19.30 g kg^{-1} DM. The content of P ranged from 110.70 to 665.80 g kg^{-1} DM. There were differences ($P<0.05$) in the content of P among the browse forages except for forages. The mg content range from 1.80 in *Vitex cuneata* to 10.40 g kg^{-1} DM in *Celtis integuifolis* while the Na concentrations were generally low and ranged from 0.50 to 1.30 g kg^{-1} DM. The K concentrations had the least in *Khaya senegalensis* (11.50) and *Poupartia sirrea* had the highest values for K (120.00 g kg^{-1} DM)

3.2 Content of micro minerals

Contents of micro minerals of selected browse forages are indicated in Table 2. There was significant difference ($P>0.05$) in the content of Fe among the browse forages (Table 2). Zinc content ranged from 1.064 to 5.725 mg g^{-1} DM. Content of Co, Se and Ni showed no significant differences ($P>0.05$) among browse forages which Mn had it highest value of 0.887 in *Cassia sieberiana* and lowest 0.234 mg g^{-1} DM in *Poupartia sirrea*

4. Discussion

4.1 Macro minerals

The studied browse forages had higher levels of Ca than the lower range of Ca (3.3-4.7 g kg^{-1} DM) of most tropical grasses (Minson 1990). Variations in the levels of Ca between findings in the current work with values reported in the literature could be partly explained by botanical species composition, stage of growth and season, and variations in soil characteristics due to location of the different grazing lands. Higher contents of macro minerals, for example Ca, could probably be explained by proportion of forb species. Browse forages that were used in this study were harvested to include a mixture of grasses and forbs species that simulates the diet consumed by grazing ruminants. It could be assumed that forbs contain more minerals than would be in grass species or their mixture. Forbs also retain most of their leafy portions even during dry seasons, which are richer in minerals, including Ca (Minson 1990) than stem fractions (Underwood and Suttle 1999). High levels of Ca of these conserved forages would meet the theoretical Ca requirements of 4.0 g kg^{-1} DM diet needed for all forms of production in ruminants (ARC 1980). These forages had higher levels of Ca than dietary requirement of growing cattle (1.2-4.4 g Ca kg^{-1} DM), lactating dairy cows (1.6-4.2 g Ca kg^{-1} DM), growing lambs (0.9-5.3 g Ca kg^{-1} DM) and lactating ewes (1.2-3.7 g Ca kg^{-1} DM). However, efficiency of Ca utilisation from these forages, and therefore its bioavailability in ruminants, would depend on presence of adequate level of P, active form of vitamin D, and calcitonin and parathyroid hormone (PTH). Calcitonin and PTH mobilise conversion of vitamin D to its active form. The browse forages in the current study had higher levels of P than the mean level of 2.9 g P kg^{-1} DM of most tropical grasses (Minson 1990). Higher levels of P assayed in the current work were comparable to higher levels of P (1.6 g kg DM^{-1}) as reported by Njidda (2011). Variations in the content of P observed in the current study with those reported in the literature could be partly explained by both species' and intra-species' variations. Variable contents of P could be due to differences between varieties and cultivars in the factors that control accumulation of P in forages. The differences could be also due to variability in the available soil P and soil pH, forages' growth stage and proportions of leaf and stem fractions harvested for mineral analyses, and sampling season (Minson 1990). Contents of minerals in forages including P decrease with plant maturity (McDowell 1996). The browse forages had lower levels of Mg than most tropical grasses (3.6 vs. 2.8 g kg^{-1} DM) (Minson 1990). However, differences in the content of Mg in this study with those in the literature could be partly explained by differences between forage species, level of Mg in the soil, influences of locality and climate, growth stage, proportion of leaf and stem fractions collected for mineral analysis, and season when herbage sampling was done. The browse forages had slightly higher levels of Mg than the recommended requirement of 2 g kg^{-1} DM in the diet of cattle (ARC 1980). These forages would therefore meet the theoretical requirement of Mg for beef cattle (0.2-1.2 g kg^{-1} DM), (NRC 1996) and for lactating cows (1.2-2.1 g kg^{-1} DM), NRC (2001). These forages had also higher levels of Mg than the recommended requirements for growing lambs (0.8-1.5 g kg^{-1} DM) and lactating ewes (0.9-1.8 g Mg kg^{-1} DM), (INRA 1989), and goats (Meschy 2000). K in present investigation the level of K in all the forages was over 8 g/kg recommended for grazing animals (Underwood, 1981). However, it has been suggested that ruminants with high producing, may require K level above 10 g/kg, under stress particularly heat stress (McDowell, 1985; Khan *et al.,* 2005). Similar K concentrations were also reported by Prabowo *et al.,* (1990) in Indonesia, Ogebe *et al*., (1995) in Nigeria, and Tiffany *et al.,* (2001) in North Florida.

High contents of Fe of the browse forages were comparable to high levels of Fe of most forages (100-700 mg kg^{-1} DM) reported by McDowell (1992). Variations in the contents of Fe among grazing land forages (Table 2) could be partly explained by forage species' differences and the influence of grazing lands on the level of Fe in the soil. All the browse forages had higher levels of Fe than the critical content of Fe in animal tissues (30-50 mg kg^{-1} DM). Differences in the contents of Fe between the forages and literature values could be partly explained by variations in the content of Fe in the soil, and climatic conditions between localities. Forage Fe content is a function of forage species, soil Fe content, nature and type of soil on which forages are grown (McDowell 1992). These feeds had higher levels of Fe than the normal requirements of 30-60 mg Fe kg^{-1} DM of ruminants (McDowell, 1992). However, Fe bioavailability in ruminants would depend on feed mixture fed together and form of Fe in these feeds. The browse forages had slightly lower levels of Zn than mean content of 36 mg kg^{-1} DM of most tropical grasses (Minson 1990). The Zn content in these deferred forages could be sufficient for recommended requirement for sheep (24-51 mg Zn kg^{-1} DM). However, efficiency of Zn utilization of these forages would depend on zinc bioavailability, and its interaction with other mineral elements. Cobalt is essential in carbohydrate metabolism. Cobalt is a constituent of vitamin B_{12}, the anti-pernicious anaemia factor, and is also a constituent of enzymes in the Krebs or tricarboxylic acid (TCA) cycle. Content of Co observed in this study was comparable to that in most tropical grasses (<0.01 to 1.26 mg kg^{-1} DM) reported by Minson (1990). The deferred feeds in traditional fodder banks had higher levels of Co than the dietary recommended levels for cattle (0.06-0.07 mg kg^{-1} DM), (ARC 1980), sheep and goats (0.11 mg kg^{-1} DM) (ARC 1980; INRA 1989; Meschy 2000). The browse forages generally had lower levels of Mn than mean content of 86 mg kg^{-1} DM of tropical forages (Minson 1990). Differences in the content of Mn among the grazing lands' forages could be partly explained by the herbage species, level of available Mn in the soil, soil pH, and influence of soil pH on Mn uptake by forages. The grazing land forages had higher levels of Mn than the recommended level of 20 mg Mn kg^{-1} DM diet (ARC 1980), and had even higher levels of Mn than tabulated requirements of 40 mg Mn kg^{-1} DM of NRC (2001) of ruminants. The result of selenium in the studied browes ranged from 0.012 to 0.410 mg/g DM. Reproductive problems, retained placenta, white muscle disease and an inadequate immune system (leading to mastitis and metritis) may result when selenium is deficient in livestock rations. Selenium levels of 100 to over 9000 mg/Kg can be found in selenium accumulator plants (Johnson and Larson 1999). Consumption of these plants leads to rapid death. Chronic toxicity can occur at 5 mg/kg (Brooks, 1998). The result of nickel concentration ranged from 0.006 to 0.042 mg g^{-1} DM with a low overall mean of 0.025 mg g^{-1} for the browses. Nickel concentration ranged widely from 0.08 to 0.35 mg/kg DM with a low overall mean of 0.18 mg kg^{-1} DM. The concentration is not influence by dietary nickel intake in animals. The values recorded for Ni were above toxic levels suggested for typical plants (Tokalioglu and Kartal, 2005).

5. Conclusions

Browse forages harvested from selected had almost similar levels of macro and micro minerals with few exceptions that showed high variation. Productivity of grazing ruminants in these semi-arid areas could be improved through supplementation with micro mineral sources.

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Table 1. Family and local names of study browse plants

Browse Forages	Family name	Local names
Acacia sieberiana	Leguminoceae	Farar kaya
Anageisus celecarpus	Combretaceae	Marke
Batryospermum paradoxum	Sapotaceae	Kadanya
Cassia sieberiana	Leguminacceae (mimosae)	Maura
Celtis integuifolis	Ulmaceae	Nguzaw
Diospyrus mispliformis	Ebenaceae	Kanya or Barum
Khaya senegalensis	Meliaceae	Madachi
Leptadenia lancifolia	Aslepidaceae	Yadiya
Poupartia sirrea	Anacardiaceae	Maliya-liya
Vitex cuneata	Verbanaceae	Ngalimi

Table 2. Macro minerals concerntration of semi-arid browses of Nigeria(g kg^{-1} DM)

Browse Forages	Ca	P	Mg	Na	K
Acacia sieberiana	5.10^{e}	665.80^{a}	4.30^{c}	0.80^{e}	19.00^{d}
Anageisus celecarpus	10.80^{c}	203.70^{f}	5.30^{b}	0.50^{g}	14.80^{ef}
Batryospermum paradoxum	12.00^{b}	110.70^{h}	3.10^{f}	1.10^{c}	30.00^{b}
Cassia sieberiana	8.10^{d}	353.70^{b}	4.30^{c}	1.30^{a}	20.80^{d}
Celtis integuifolis	19.30^{a}	112.80^{h}	10.40^{a}	0.80^{e}	25.00^{c}
Diospyrus mispliformis	8.10^{d}	210.30^{e}	3.70^{e}	0.80^{e}	14.80^{f}
Khaya senegalensis	7.80^{d}	265.70^{c}	2.50^{g}	1.10^{c}	11.50^{g}
Leptadenia lancifolia	10.60^{c}	305.20^{b}	4.00^{d}	0.60^{f}	16.80^{e}
Poupartia sirrea	10.10^{c}	256.70^{d}	5.60^{b}	1.20^{b}	120.00^{a}
Vitex cuneata	12.10^{b}	165.20^{g}	1.80^{h}	0.90^{d}	15.00^{e}
MEANS	**10.4**	**264.98**	**4.5**	**0.83**	**28.77**
SEM	**1.33**	**2.76**	**0.09**	**0.04**	**1.54**

a,b,c,d=mean values along the same column with different superscripts are significantly different ($P<0.05$); Ca=Calcium; P=Phosphorus; Mg=Magnesium; Na=Sodium; K=Potassium;SEM= Standard error of means.

Table 3. Trace minerals concentration of semi-arid browses of Nigeria (mg g^{-1} DM)

Browse Forages	Fe	Zn	Co	Mn	Se	Ni
Acacia sieberiana	3.925^{c}	2.639^{c}	0.007	0.603^{b}	0.134	0.026
Anageisus celecarpus	4.702^{b}	1.664^{h}	0.004	0.319^{g}	0.085	0.011
Batryospermum paradoxum	1.982^{e}	1.632^{h}	0.006	0.388^{e}	0.168	0.006
Cassia sieberiana	10.96^{a}	4.135^{b}	0.011	0.887^{a}	0.106	0.020
Celtis integuifolis	3.126^{c}	2.500^{d}	0.006	0.457^{d}	0.130	0.027
Diospyrus mispliformis	2.738^{cd}	2.350^{e}	0.006	0.383^{e}	0.158	0.022
Khaya senegalensis	2.973^{c}	5.725^{a}	0.005	0.512^{c}	0.157	0.009
Leptadenia lancifolia	3.897^{c}	1.813^{g}	0.005	0.342^{f}	0.109	0.021
Poupartia sirrea	1.618^{e}	1.064^{i}	0.007	0.234	0.149	0.085
Vitex cuneata	3.715^{c}	2.042^{f}	0.005	0.502^{c}	0.133	0.006
MEANS	**3.9636**	**2.5564**	**0.0062**	**0.4946**	**0.1487**	**0.0233**
SEM	**0.97**	**0.21**	**0.000^{gNS}**	**0.08**	**0.09**	**0.009**

a,b,c,d=mean values along the same column with different superscripts are significantly different ($P<0.05$); Fe=Iron; Zn=Zinc; Co=Cobalt; Mn=Manganese; Se=Selinium; Ni=Nickel; SEM=Standrd error of means