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Evaluation of dual purpose cowpea varieties for dry season feeding of ruminant animals

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IN MEMORY OF MY LATE FATHER

Summary/Zusammenfassung

Summary

Evaluation of dual purpose cowpea varieties for dry season feeding of ruminant animals

Cowpea is of major importance to the livelihoods of millions of people in the tropics. Resource-poor small-holder farmers derive food, animal feed, cash and manure from the crop. Dual purpose cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through biological fixation. Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs.

Dual purpose cowpea can sufficiently satisfy the tripartite need of providing (i) food for the farmer (ii) fodder for livestock especially during the critical period of the year (dry season) and (iii) fertility replenishment for the soil (through nitrogen fixation) which will ensure sustainable use of the farmer's limited land (for a longer period without much depletion of its nutrients).

A field experiment was conducted between 2007 and 2008 to determine the agronomic performance and nutritive quality of some varieties of dual purpose cowpea (*Vigna unguiculata* L. Walp) grown in marginal land without fertilization. The experiment was arranged in a 2 x 2 factorial design with 2 seasons (wet and dry) and 2 groups (commercial and improved) of cowpea haulm varieties. Three improved (ITA2, ITA6 and ITA8) and three commercial (Oloyin, Peu and Sokoto) cowpea varieties were used for the study. The cowpea varieties were evaluated for biomass and grain yields, green leaf retention, chemical composition, secondary metabolites, in vitro and in sacco degradation. Biomass harvested during the wet season was used in a feeding study involving thirty West African dwarf sheep. The haulms were fed as supplements to a basal diet of *Pennisetum purpureum*. Sheep fed commercial cowpea haulms had better feed conversion ratio than those fed improved haulms but all the sheep were in positive nitrogen balance. Results from the feeding study showed that inclusion of cowpea haulms in the diet of sheep had no deleterious effects while improving the haematological and serum biochemical variables.

Both biomass and grain yields were higher in the improved varieties harvested in the wet season. Improved varieties were able to retain more leaves into the dry season than their commercial counterparts. Secondary metabolites in the haulms were considerably low and of no nutritional significance. The inability to detect condensed and precipitable tannins showed that the secondary metabolites will not have any negative effect on digestion. From the in

vitro studies carried out, commercial cowpea haulms had greater microbial mass, partitioning factor and produced less methane than the improved cowpea haulms. On the other hand, crude protein content of improved cowpea haulms were less degraded in the rumen and as a result ensured greater amount of utilizable crude protein at the duodenum. The above trend was also observed in the in sacco study. The fibrous components of the haulms had a depressing effect on organic matter degradation while the crude protein and non-fibre carbohydrates resulted in higher organic matter degradation. Effective degradability of the cowpea haulms was predicted from the chemical constituents in both seasons.

Results from these studies showed that dual purpose cowpea varieties can easily be grown by resource-poor small-holder farmers in Sub-Saharan African countries as it requires little or no input and will provide sufficient biomass that will be used as supplement during the extended dry season while providing extra food for the households.

Zusammenfassung

Bewertung von unterschiedlichen Zweinutzungssortentypen der Kuhbohne (*Vigna unguiculata*) für die Ernährung von Wiederkäuern in der Trockenzeit

Die Kuhbohne (*Vigna unguiculata* L. Walp) stellt eine Lebensgrundlage für viele Menschen in den tropischen Regionen dieser Erde dar. Ressourcenarme Kleinbauern erwirtschaften durch den Anbau von Kulturpflanzen Lebensmittel, Tierfutter, Kapital und Dünger. Die Zweinutzungs-Kuhbohne kann als Proteinlieferant für Menschen und Tiere genutzt werden und darüber hinaus durch biologische Stickstoff-(N)-Fixierung als Stickstofflieferant im Ackerbau dienen. Neben ihrer Bedeutung in der Futter- und Lebensmittelerzeugung kann die Kuhbohne deshalb als wichtiger Faktor für eine nachhaltige Landbewirtschaftung angesehen werden und dies vor allem in Regionen, in denen nur in sehr geringem Maße dem System von außen Ressourcen zugeführt werden

In einer Feldstudie auf marginalen Flächen ohne Düngung wurden in den Jahren 2007/ 2008 die agronomische Leistungsfähigkeit und der Futterwert einiger Sorten der Zweinutzungs-Kuhbohne ermittelt. Das Experiment wurde in einer 2 x 2 faktoriellen Versuchsanordnung mit 2 Jahreszeiten (Regen- und Trockenzeit) und 2 Sortentypen (je drei kommerzielle und verbesserte Sorten) der Kuhbohne durchgeführt. Für alle sechs Sorten wurden der Biomasse- und Bohnenertrag ermittelt sowie die photosynthetisch aktive Blattmasse geschätzt. Weiterhin wurde die chemische Zusammensetzung einschließlich sekundärer Pflanzeninhaltsstoffe analysiert und es wurden *in vitro*- und *in sacco*-Studien zum ruminalen Nährstoffabbau durchgeführt. Das Kraut (oberirdische Biomasse ohne Bohnen) von in der Regenzeit geernteten Pflanzen wurde in einem Fütterungsversuch an 30 Westafrikanischen Zwergschafen genutzt. Es wurde als Ergänzung zu einer Basaldiät aus Napiergras (*Pennisetum purpureum*) verfüttert. Der Futteraufwand pro Einheit Körpermassezunahme war bei den Schafen geringer, welche das Kraut der kommerziellen Sorten erhielten. Alle Schafe wiesen eine positive N-Bilanz auf. Die Ergänzung der Basalration mit Kuhbohnenkraut hatte keine nachteiligen Auswirkungen, die hämatologischen und biochemischen Kenngrößen im Blutserum der Tiere wurden sogar leicht verbessert.

Sowohl Biomasse- als auch Bohnenertrag waren bei den verbesserten Sorten höher, wenn sie in der Regenzeit geerntet wurden. Zudem waren diese Sorten in der Lage, einen höheren Anteil an grünen (photosynthetisch aktiven) Blättern in der Trockenzeit zu halten, als dies den kommerziellen Sorten möglich war. Die Konzentrationen an sekundären Pflanzeninhaltsstoffen in den Halmen waren niedrig und ohne ernährungsphysiologische Relevanz. Es

konnten weder kondensierte noch präzipitierbare Tannine nachgewiesen werden, so dass kein Einfluss dieser Stoffgruppen auf die Verdaulichkeit des Futters vorgelegen haben kann. Die *in vitro*-Studien ergaben, dass das Kraut kommerziellen Kuhbohnensorten im Pansen eine größere mikrobielle Biomassebilduung bei gleichzeitig geringerer Methanbildung aufwies als das Kraut der verbesserten Sorten. Andererseits wurde das Rohprotein im Kraut der verbesserten Sorten *in vitro* weniger stark im Pansen abgebaut und führte deshalb zu einem größeren geschätzten Fluss an Rohprotein in das Duodenum. Dieser Trend wurde mit der *in sacco*-Methode bestätigt. Der Fasergehalt im Kraut aller Sorten hatte einen negativen Effekt auf den ruminalen Abbau der organischen Masse, wobei der Rohproteingehalt und die Nicht-Faserkohlenhydrate den ruminalen Abbau der organischen Masse positiv beeinflussten. Der effektive ruminale Abbau des Kuhnbohnenkrauts konnte aus der chemischen Zusammensetzung des Krauts aus beiden Jahreszeiten geschätzt werden.

Die Ergebnisse dieser Studie zeigen, dass Kleinbauern die Zweinutzungs-Kuhbohne mit geringem Ressourcenaufwand im subsaharischen Afrika anbauen können. Dies ist möglich, da – falls überhaupt erforderlich – nur in sehr geringem Maße externer Input benötigt wird, um Biomasse für eine Mehrzwecknutzung zu produzieren. Das Kraut der Kuhbohne kann bei längerer Trockenzeit als Ergänzungsfutter eingesetzt werden und die Bohne selbst dient als Lebensmittel für den Bauern.

CONTENTS

CHAPTER 1

General introduction

General introduction

Feed constraint is the most important impediment to improved livestock production in the Sub-Saharan African (SSA) countries (Agyemang, 2002), as a result of seasonal shortages in the quantity and quality of forage from natural pastures that supply most of the feed for animals due to prolonged annual dry season. The role of livestock in providing protein which is essential in human nutrition because of its biological significance is increasingly being recognized. The low level of productivity in the livestock industry is due to a combination of underfeeding, diseases and poor husbandry. Of immediate concern therefore in any development program for improvement of livestock productivity, is the need for improved management, especially nutrition.

Fodder, the major input in livestock rearing, is cultivated on an estimated four percent of the total cultivable land in Nigeria and this figure has remained more or less static for the last three or more decades (Delgado *et al*., 1999). The ever increasing human population in SSA countries has pushed demands for food grains and other cash crops up considerably leading to large hectarages being planted to such crops. This has resulted in smaller areas left for fodder or forage production (Delgado *et al.,* 1999). The denuded grasslands, forest openings and the forests are major sources of herbage for livestock feeding (Sumberg, 2002).

As much of the arable land in SSA countries are already under cultivation, increased livestock productivity will have to come from improving the productivity per unit area or expansion of marginal lands that have traditionally supplied grazing resource to livestock (Delgado *et al.*, 1999). The expanding crop production activities and reduction in fallow periods in most of the SSA countries are already leading to competition between crop and livestock production. Land fallowing, a traditional agricultural system that helps to restore land fertility, is likely to disappear in the next 50 years (Thornton *et al.,* 2002). As indicated by the FAO (1997) report, large increases in animal production can be achieved by alterations to the feed base. According to the report, animal production could be increased about five times above the present level, by providing the nutrients that are deficient in their diets and by balancing the available nutrients closer to requirements.

Appropriate technologies to improve the performance of the local animal breeds and feed resources under the traditional system are generally lacking. Animal productivity could be increased by the introduction of low cost technologies that would improve the current systems of management. Acceptable and successful feeding systems are described as those that are simple, practical, consistently reproducible and within the limits of the farmer's resources (Douthwaite, 2002). This underscores the importance of dual purpose crops that provide food (grain) and feed (residues) in meeting household needs under the current and foreseeable future scenarios.

Justification

Cowpea is of major importance to the livelihoods of millions of people in the tropics. Peasant or subsistence farmers derive food, animal feed, and cash, together with spillover benefits to their farmlands resulting from *in situ* decay of root, leaf and stem materials and effect of ground cover from the crop (FAO, 2000). In fresh form, the young leaves, immature pods, and peas are used as vegetables, while several snacks and main meal dishes are prepared from the mature grain. The above ground parts of cowpea plant except the pods are harvested for fodder. Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in both the tropical and sub-tropical regions of Africa characterized by systems for farming that make limited use of purchased inputs because of its importance in providing food, feed for animals, improved land use and adapted to low pH and infertile soils. In these production systems, the spreading indeterminate or semi-determinate bushy growth of cowpea provides ground cover, thus suppressing weeds and providing some protection against soil erosion. In addition, some cowpea varieties cause suicidal germination of the seeds of *Striga hermonthica*, a parasitic plant of cereal crops that often have devastating effects on food crop production (Berner et al., 1996). Another important characteristic of cowpea is that it fixes atmospheric nitrogen through symbiosis with nodule bacteria, *Bradyrhizobium* spp; thus increasing the soil nitrogen levels.

Cowpeas are grown extensively in 16 African countries, with the continent producing two-thirds of the world total. Two countries – Nigeria and Niger – produce 850,000 and 271,000 metric tonnes annually or 49.3 percent of the world crop (Winrock, 1992). Cowpea in Africa is cultivated under diverse soil and climatic conditions and is traditionally intercropped with cereals. The bulk production comes from smallholder farmers in semiarid zones of the region (Winrock, 1992).

Cowpea can sufficiently satisfy the tripartite need of providing (i) food for the farmer (ii) fodder for livestock especially during the critical period of the year (dry season) and (iii) fertility replenishment for the soil (through nitrogen fixation) which will ensure sustainable use of the farmer’s limited land (for a longer period without much depletion of its nutrients).

Objectives

The general objective of the study was to evaluate dual purpose cowpea varieties for dry season feeding of ruminant animals. Specific objectives were:

1 To evaluate the green leaf retention ability, biomass and grain yields of the cowpea varieties (Chapter 2).

2 To investigate the cowpea varieties' forage with respect to their seasonal proximate composition, fibre content, minerals and anti-nutritional factors (Chapter 2).

3 To evaluate the contribution of the cowpea to soil improvement (for crop – livestock farming systems) (Chapter 2).

4 To assess the performance (average daily weight gain, etc) of west African dwarf sheep fed the cowpea forage (Chapter 3).

5 To determine their nutritive value using the *in vitro* gas production method (Chapter 4).

6 To determine the ruminal degradation kinetics of major nutrients of the forage (Chapter 5).

7 To make recommendations based on the findings of the study.

References

Agyemang, K. 2002. Dairy development in West Africa 1978-1998: Market Orientated Smallholder Dairy. Working Document No. 8. ILRI, Ibadan, Nigeria.

Berner, D.K., Carsky, R.J., Dashiell, K.E., Kling, J., Manyong, V.M., 1996. A land management based approach to integrated *Striga hermonthica* control in sub – Saharan Africa. Outlook Agric. 25, 157-164.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Curbois, C. 1999. Livestock to 2020: The Next Food Revolution. IFPRI 2020 Vision Food, Agriculture and Environment Discussion Paper 28, IFPRI, Washington DC, USA.

Douthwaite, B., 2002. Enabling innovation: a practical guide to understanding and fostering technology change. ZED Books, London & New York.

FAO, 1997. Tree Foliage in Animal Nutrition. Animal Health and Production Paper No. 139. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2000. FAOSTAT Database. http://apps.fao.org. Food and Agriculture Organization of the United Nations, Rome, Italy.

Sumberg, J. 2002. The logic of fodder legumes in Africa. Food Policy. 27, 285-300.

Thornton, P.K., Krushka, R.L., Henninger, N., Kristjanson, P., Reid, R.S., Atieno, A.N., Ndegwa, T., 2002. Mapping Poverty and Livestock in the Developing World. ILRI, Nairobi, Kenya.

Winrock, 1992. Assessment of Animal Agriculture. Winrock International, Morrilton, USA.

CHAPTER 2

Agronomic performance and nutritive quality of some commercial and improved dual purpose cowpea (*Vigna unguiculata* L. Walp) varieties on marginal land in southwest Nigeria

[1]U.Y. Anele, K.-H. Südekum, O.M. Arigbede, G. Welp, A.O. Oni, J.A. Olanite, V.O. Ojo and A.O. Jolaosho. 2010. Agronomic performance and nutritive quality of some commercial and improved dual purpose cowpea (*Vigna unguiculata* L. Walp) varieties on marginal land in southwest Nigeria. **Under review**

Introduction

Nutrition is perhaps the most important consideration in livestock management. Inability to supply feed in adequate quantity and quality is responsible for the low livestock productivity in the Sub-Saharan African (SSA) countries (Agyemang, 2002). This situation is exacerbated by the seasonal shortages in the supply of forage from natural pastures that supply most of the feed for animals due to prolonged annual dry season.

The expanding crop production activities and reduction in fallow periods in most of the SSA countries are already leading to competition between crop and livestock production. Land fallowing, a traditional agricultural system that helps to restore land fertility, is likely to disappear in the next 50 years (Thornton *et al.,* 2002). As much of the arable land in these countries are already under cultivation, increased livestock productivity will have to come from improving the productivity per unit area or expansion of marginal lands that have traditionally supplied grazing resource to livestock (Delgado *et al.*, 1999).

The resource-poor small-holder farmers produce considerable proportions of the milk and meat requirements under this poor feed situation (Agyemang, 2002). Animal productivity could be increased by the introduction of low cost technologies that would improve the current systems of management. Acceptable and successful feeding systems are described as those that are simple, practical, consistently reproducible and within the limits of the farmer's resources (Douthwaite, 2002). This underscores the importance of dual purpose crops that provide food (grain) and feed (residues) in meeting household needs under the current and foreseeable future scenarios (Delgado *et al.*, 1999).

Dual purpose cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through biological fixation (FAO, 2000; Giller, 2001). Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs.

Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total. Two countries – Nigeria and Niger – produce 850,000 and 271,000 tonnes annually or, together, 49% of the world crop (FAO, 2000). The bulk of this production comes from smallholder farmers in semiarid zones of the region.

This study investigated the agronomic performance, green leaf retention and nutritive quality of some varieties of dual purpose cowpea grown in marginal land not been utilized by crop farmers.

Materials and methods

Experimental site

The field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria and laboratory analyses were carried out at the (Institute of Animal Science and Institute of Crop Science and Resource Conservation) University of Bonn, Germany. The experimental site lies within the savanna agro-ecological zone of southwest Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Temperatures are fairly uniform with daytime values of 28 to 30^{o}C during the rainy season and 30 to 34°C during the dry season with the lowest night temperature of around 24°C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to dry season values of 55 to 84%. The temperature of the soil ranges from 24.5 to 31.0°C (Source: Agrometeorology Department, UNAAB).

Forage establishment and management

The experimental area, measuring 2600 m^2, was ploughed twice and harrowed. The area was divided into eight blocks and each block was sub-divided into 10 plots each measuring 5 x 4 m^2. Three improved (*i.e*., IITA 97k-1069-6, IITA 98k-311-8-2, IITA 98k-476-8; hereafter designated ITA-6, ITA-2 and ITA-8) and three commercial (*i.e*., “Oloyin”, “Peu”, “Sokoto”) dual-purpose cowpea varieties constituted the treatments. The dual-purpose cowpea varieties were semi-erect type and had days to pod maturity of 70 – 86 days. The improved varieties were bred for greater agronomical yield. Treatments were randomly allocated to plots within a block. The cowpea was planted in rows 0. 4 m wide with 0.3 m plant spacing in May, 2007. The experimental area was maintained weed-free throughout the first month to reduce competition. The cowpea formed a tight canopy within a short period after planting which smothered weeds. There was no fertilizer application.

Biomass and grain yields

Biomass and grain yields were determined using a 1 m x 1 m quadrat. They were harvested approximately three months after planting to represent wet season. Plants within the quadrat were uprooted, weighed, sun-dried and then threshed (to gather the grains). The second planting was carried out in September, 2007 and harvested in January, 2008 to represent dry season. The cowpea haulms, comprising the vine, leaves and roots were manually rolled and chopped into particles of 2 to 4 cm lengths for a feeding trial (Anele et al., 2010). Subsamples of the haulms were milled with a hammer mill (Model DFZH-Bühler, Uzwil, Switzerland) using a 3 mm sieve for chemical analyses.

Green leaf retention

The number of leaves on selected cowpea plants (using 1 m x 1 m quadrat) was counted during the vegetative (30-40 days) stage. The leaves were later counted during the dough stage (prior to harvest) to determine the green leaf retention of the different cowpea varieties in both seasons. In counting these leaves, attention was paid to plants whose leaves changed colour and were dry (senescent). The number of green leaves retained by each variety were ranked on a scale of 1 – 3 (where 1 = 0 leaf retained; 2 = >0≤ 50% of leaves retained; 3 = ≥ 50% of leaves retained).

Soil collection and analyses

Soil samples were randomly collected from the site before establishing the plots in January 2007, and at the end of the experiment in May 2008 at the depth of 0-15 cm. Soil samples were taken with the aid of a stainless steel auger (75 mm in diameter). The samples were thoroughly mixed and sub samples taken for analyses to determine the pre- and post-planting nutrient status of the soils. Soil pH was measured in 0.01 M $CaCl_2$ with glass electrode, particle size analyses was analyzed according to Köhn (ISO 11277, 2002) by wet sieving and sedimentation. Total carbon (ISO 19694, 1995) and nitrogen (ISO 13878, 1998) were analyzed after dry combustion with Fisons NA 2000 elemental analyser. Soil organic carbon was determined as total carbon minus inorganic carbon (Scheibler method).

Exchangeable cations were extracted with 1 M NH_4Cl according to Trüby and Aldinger (1989). Plant available macronutrients were extracted with CH_3COONH_4 at pH 7 according to van Reeuwijk (2002). Plant available phosphate was extracted with a mixture of 0.03 M CH_3COOH + 0.05 M calcium acetate + calcium lactate (CAL method, Schüller, 1969) while plant available micronutrients were extracted with 0.1 M HCl according to Viets and Lindsay (1974).

Chemical analyses

The cowpea haulms were milled through a 1 mm sieve in a hammer mill. Prior to milling, samples were oven-dried at 60°C for 96 h while dry matter (DM) was determined by oven-drying at 100°C for 24 h. Samples were mixed separately and subsampled for analyses.

The samples were later analyzed for crude protein (CP), ether extract (EE), ash, neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin. Crude protein (ID 984.13), ash (ID 942.05) and EE (ID 963.15) were analysed according to standard methods of AOAC (1990). Mineral composition of the haulms was determined according to VDLUFA (2007). Lignin was determined by solubilisation of cellulose with sulphuric acid in the ADF residue (Van Soest et al., 1991). The NDF and ADF were determined according to Van Soest et al. (1991), with NDF determined without use of α-amylase or sodium sulphite. Both NDF and ADF were expressed without residual ash. Non-fibre carbohydrates (NFC) were calculated as: NFC = 1000 - CP - ash - EE - NDF, with all variables expressed as g kg^{-1} DM.

In vitro organic matter digestibility was determined according to Blümmel and Lebzien (2001). Incubated residues were refluxed with neutral detergent solution (prepared without sodium sulphite) for 1 h with subsequent recovery of the truly undegraded substrate in Dacron fibre bags (4 x 12 cm, 40 µm pore size: Ankom, Macedon, NY, USA). Total phenolics were estimated with the Folin-Ciocalteau reagent according to Makkar (2003) and expressed as tannic acid equivalents. Total tannins were determined as the difference in total phenolics after treatment with insoluble polyvinyl polypyrrolidone (Makkar, 2003) and condensed tannins were determined by butanol-HCl method Makkar (2003). Protein precipitable tannins were determined with bovine serum albumin according to Hagerman and Butler (1978).

Statistical analysis

Data were subjected to analysis of variance using the general linear method (GLM) procedure of SAS (2002) in a 2 x 2 factorial arrangement. The model used was:

$$Y_{ijkl} = \mu + G_i + H_j(Gi) + S_k + (GS)_{ik} + \varepsilon_{ijkl}$$

Where: Y_{ijk} = observation, μ = population mean, G_i = group effect (i = 1 to 2), Hj(Gi) = haulm within group effect, H_j = haulm effect (j = 1 to 6), S_k = season effect (k = 1 to 2), $(GS)_{ij}$ = interaction between group and season, and ε_{ijk} = residual error.

Means were then compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Differences among means with $P<0.05$ were accepted as representing statistically significant differences. Probability values less than 0.001 are expressed as '$P<0.001$' rather than the actual value.

Correlation analysis was used to establish relationships between IVOMD and some chemical constituents. Prediction equations of IVOMD values of the cowpea haulms were developed by stepwise regression analysis, using the PROC REG of SAS (2002). The stepwise procedure only introduced variables in the model when they contributed to a significant improvement in the estimation of the dependent variable.

Results

Physicochemical properties of the soil

The physicochemical characteristics of the composite soil samples taken from 0-15 cm depth of the experimental site in 2007 and 2008 are shown in Table 1. Typically with tropical soils, the soil was low in organic C (4.1 and 2.5 g kg^{-1}), total N (0.25 and 0.27 g kg^{-1}) and in available macro and micronutrients (e.g. P: 5.91 and 5.33 mg kg^{-1}). The soil was slightly acidic with pH ranging between 5.40 and 5.45. Soil texture was characterized by a high proportion of sand (86%) and small proportions of silt (10%) and clay (4%). According to the FAO/WRB system, this grain size distribution is classified as loamy sand.

Biomass

A group (improved *versus* commercial) x season interaction was observed for the biomass yield of the cowpea with improved cowpea varieties harvested during the wet season having the greatest ($P=0.003$) DM yield of 8755 kg ha^{-1}. The biomass yield of the improved cowpea varieties was consistently superior ($P<0.05$) to the commercial cowpea. Higher ($P<0.001$) biomass yield were observed in cowpea harvested in the wet season.

Grain yield

Grain yield of the cowpea followed a similar trend observed in the biomass yield with values ranging between 390 and 475 kg ha^{-1} (Table 2). There was no interaction between group and season. The grain yields of the improved cowpea varieties were superior ($P<0.001$) to that of the commercial cowpea. Season did not affect grain yield of the cowpea varieties.

Table 1: Pre- and post-physicochemical characteristics of the composite soil samples taken from the experimental site at 0-15 cm in 2007 and 2008.

Soil properties	2007	2008
pH ($CaCl_2$)	5.40	5.45
Total N (g kg^{-1})	0.25	0.27
Organic carbon (g kg^{-1})	4.06	4.49
Exchangeable cations (cmol kg^{-1})	21.3	21.6
Plant available macro nutrients (mg kg^{-1})		
Calcium	211	225
Phosphorus	5.91	5.33
Sodium (Na)	0.91	1.06
Potassium (K)	57.7	65.3
Magnesium (Mg)	42.7	41.0
Plant available micro nutrients (mg kg^{-1})		
Copper	0.35	0.39
Iron	3.82	4.06
Manganese	47.5	40.1
Zinc	0.59	1.51
Particle size distribution (%)		
Coarse sand (2 – 0.63 mm)	28.6	
Middle sand (0.63 – 0.2 mm)	40.3	
Fine sand (0.2 – 0.063 mm)	17.5	
Coarse silt (0.063 – 0.02 mm)	6.17	
Middle silt (0.02 – 0.0063 mm)	2.53	
Fine silt (0.0063 – 0.002 mm)	1.07	
Clay (< 0.002)	3.54	

n = 6

Green leaf retention

There was no interaction between group and season for the green leaf retention of the cowpea varieties. Improved cowpea varieties harvested during the wet season were able to retain more than 50% of their leaves into the dry season. On average, they were able to retain between 25 and 50% of their leaves. The improved varieties retained more (P<0.001) leaves than the commercial cowpea.

Chemical composition

The DM contents of the haulms ranged from 940 to 951 g kg^{-1} (Table 3). Group x season interactions were observed for CP, lignin and hemicellulose contents of the cowpea haulms.

Table 2: Seasonal biomass dry matter (DM) and grain yields (kg ha^{-1}) and green leaf retention of the cowpea varieties.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Biomass	6461^{b}	8755^{a}	3711^{c}	3194^{c}	466.5	*	ns	***	**
Grain	403	475	390	460	11.0	***	ns	ns	ns
Green leaf retention[2]	2	3	2	2	0.3	***	***	ns	ns

Means with different letters within rows differ (P<0.05).
[1]H(Group), haulms within group.
[2]Values based on a scale of 1 – 3, where 1 = 0 – 25% leaves retained; 2 = 25 – 50% leaves retained; 3 = > 50% leaves retained.
ns, non-significant; *, P < 0·05; **, P < 0·01; ***, P < 0·001.

Table 3: Chemical composition (g kg^{-1} dry matter (DM) unless stated) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
DM(g kg^{-1})	948	942	933	931	2.3	ns	ns	***	ns
CP[2]	181^{b}	147^{c}	217^{a}	212^{a}	4.0	***	ns	***	**
EE[3]	18.9	16.3	42.2	28.6	3.34	*	ns	***	ns
Ash	94.3	30.5	71.4	30.5	10.35	***	ns	ns	ns
NDF[4]	569	612	379	403	14.9	*	ns	***	ns
ADF[5]	399	419	208	233	15.1	ns	ns	***	ns
Lignin	206^{a}	162^{b}	107^{c}	113^{c}	8.1	*	*	***	**
Hemicellulose	169^{b}	193^{a}	171^{b}	170^{b}	5.4	*	ns	*	*
Cellulose	194	257	101	120	11.9	**	ns	***	ns
NFC[6]	136	193	289	325	12.7	***	ns	***	ns

Means with different letters within rows differ (P<0.05).
[1]H(Group), haulms within group.
[2]CP, crude protein.
[3]EE, ether extract.
[4]NDF, neutral detergent fibre expressed exclusive residual ash.
[5]ADF, acid detergent fibre expressed exclusive residual ash.
[6]NFC, non-fibre cabohydrates.
ns, non-significant; *, P < 0·05; **, P < 0·01; ***, P < 0·001.

Crude protein content of the cowpea haulms was higher ($P<0.001$) in the commercial cowpea haulms during the dry season. The NDF content though not significant (group x season) was greater ($P<0.05$) in the improved than commercial haulms with values of 612 vs 569 and 403 vs 379 g kg^{-1} DM during the wet and dry seasons, respectively. Despite their high fibre contents, haulms from both cowpea varieties contained significant amounts of NFC, which were higher ($P<0.05$) in improved varieties.

Group x season interactions were observed for all the macro elements with the exception of sodium (Table 4). No interaction was observed for the trace elements.

In vitro organic matter degradability and secondary metabolites

No interaction was observed for IVOMD and secondary metabolites of the cowpea haulms (Table 5). Condensed and protein precipitable tannins were not detected. Greater ($P<0.001$) IVOMD and total phenol were observed in the dry season while tannins values were greater ($P<0.001$) in the wet season.

Relationships and prediction of IVOMD from chemical composition

Positive relationship existed between CP and IVOMD in both seasons (Table 6). These variables (CP and IVOMD) were negatively correlated with the secondary metabolites. The NDF was positively correlated with the commercial haulms in both seasons but negatively correlated with the improved haulms. Total phenol and tannins were positively ($P<0.001$) correlated in both varieties and seasons

A stepwise regression analysis was used to establish regression models for predicting IVOMD. The results showed that IVOMD of the cowpea haulms could be predicted from the chemical composition via regression models:

Commercial haulms (wet season): $Y_{IVOMD} = -3703 + 19.95_{CP} + 92.31_{Total\ phenol}$, $r^2 = 0.66$

Commercial haulms (dry season): $Y_{IVOMD} = 586 – 2.01_{NDF} + 3.71_{ADF} + 0.69_{NFC}$, $r^2 = 0.74$

Improved haulms (wet season): $Y_{IVOMD} = -1563 + 4.64_{NDF} + 2.86_{ADF} + 2.59_{NFC}$, $r^2 = 0.93$

Improved haulms (dry season): $Y_{IVOMD} = -113 + 5.65_{CP} - 1.21_{ADF}$, $r^2 = 0.86$

Discussion

Physicochemical properties of the soil

Nitrogen, phosphorus and potassium are the major determinants of soil fertility, forage yield and quality. Low levels of these elements in most tropical soils have been the major cause of low dry matter yields of tropical forages and have prompted attention to inorganic fertilizer usage in Nigeria. Particle size distribution was only reported for 2007 because this is

Table 4: Mineral composition (g kg^{-1} DM) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Calcium	13.34	9.03	23.15	25.09	0.982	ns	***	***	**
Phosphorus	2.79	1.83	2.05	1.98	0.097	***	***	**	***
Magnesium	3.47	2.76	5.56	6.01	0.276	ns	ns	***	*
Sodium	0.37	0.44	0.23	0.24	0.027	ns	ns	***	ns
Potassium	11.26	14.79	15.45	16.11	0.521	***	***	***	**
Zinc	0.76	0.65	0.62	0.67	0.059	ns	ns	ns	ns
Iron	1.01	0.44	0.67	0.57	0.126	*	**	ns	ns
Manganese	6.63	6.85	7.65	7.16	0.266	ns	***	*	ns

Means with different letters within rows differ (P<0.05).

[1]H(Group), haulms within group.

ns, non-significant; *, $P < 0{\cdot}05$; **, $P < 0{\cdot}01$; ***, $P < 0{\cdot}001$.

Table 5: In vitro organic matter degradability and secondary metabolites (g kg^{-1} DM unless stated) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
IVOMD (g kg^{-1} OM)	635	585	665	802	24	ns	**	***	ns
Total phenol	7.96	7.45	9.51	9.31	0.25	ns	ns	***	ns
Tannins	3.83	3.31	2.11	1.86	0.22	ns	ns	***	ns
Condensed tannins	Nd[2]	nd	nd	nd	-	-	-	-	-
PPT[3]	Nd	nd	nd	nd	-	-	-	-	-

[1]H(Group), haulms within group.

[2]nd, not detected.

[3]PPT, protein precipitable tannins.

ns, non-significant; **, $P < 0{\cdot}01$; ***, $P < 0{\cdot}001$.

a stable soil parameter. Not much inference was drawn from the soil data because of the length of the study but it showed that cowpea can do well in most of the marginal lands that are not being utilized and will help to restore such lands over time through fixation of nitrogen (Giller, 2001). The main reason why no fertilizer was used was to reduce the cost of production as much as possible and the perceived reluctance on the part of the resource-poor small-holder farmers to spend money on inorganic fertilizer. This can easily be addressed by the use of dung from the animals.

Biomass yield

Biomass yield of the cowpea varied between the two varieties and in both seasons. Improved varieties had greater herbage yields in both seasons. Similar results on greater yield of improved cowpea varieties over local varieties had been reported by Singh *et al.* (2003). Seasonal differences in the biomass yield of the cowpea might be linked to seasonal variation in the amount and distribution of rainfall which played a significant role with greater yields recorded during the wet season compared to lower yields during the dry season. Wet season biomass yield was about three-fold greater than dry season yield in improved cowpea and approximately 42% greater in commercial cowpea.

Grain yield

As observed in the biomass yield, grain yield of the cowpea varied between the two groups but the magnitude of the variation was less than that observed in the biomass yield. Differences in the seasonal grain yield of the cowpea were not significant which showed that some climatic factors like sun radiation or day-length, may have influenced grain yield more than rainfall. Singh et al. (2003) reported 70% higher grain yield in improved cowpea over local varieties.

Green leaf retention

The range of values for green leaf retention of the cowpea varieties showed that the improved varieties were more efficient in retaining their leaves. The annual long dry season between November and March is the most critical or stressful period for ruminant animals under the tropical condition as most grasses are dried and are generally low in nutritive quality (Nuru, 1988). So any feed resource that could retain its leaves during the dry season will be invaluable in addressing the seasonal shortages in forage production. The cowpea varieties did not only retain significant leaves, the quality of the haulms was also high.

Chemical composition

Although the commercial cowpea haulms had greater CP content than the improved haulms, the range of 147 to 217 g CP kg^{-1} DM for the cowpea haulms is above the range of 110 – 130 g CP kg^{-1} DM which is adequate for maintenance and growth of beef cattle (NRC, 1996).

The cowpea haulms used in this study had higher CP content than those used by Savadogo et al. (2000a, 2000b). Such variation in quality of crop residues may be due to factors such as genetic characteristics (Singh and Schiere, 1995), environment (soil characteristics, rainfall) and crop management (level of fertilisation, plant density, stage of maturity at harvest, methods of harvesting, and storage) (Walli et al., 1994). Kaasschieter et al. (1998) reported CP values for cowpea ranging from 78 to 217 g kg^{-1} DM. FAO (1981) reported 37 ± 4.3, 144, and 99 g CP kg^{-1} DM for sorghum stover, cowpea and groundnut haulms, respectively.

Fibre concentrations were greater in improved *versus* commercial cowpea haulms. Despite the greater fibre concentration in improved haulms, significant proportion was in form of NFC and cellulose which are easily degraded unlike the commercial haulms which had greater lignin concentration.

Higher NFC contents of improved cowpea haulms indicate that they should stimulate ammonia-N utilization in the rumen better than the commercial (Tylutki et al., 2008). As N utilization by rumen microorganisms is related to the amount of available fermentable energy, the NFC in the cowpea haulms could improve the efficiency of microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Ørskov and Grubb, 1978).

Calcium and phosphorus make up to 70% of the total mineral elements in the body and have vital functions in almost all tissues in the body and must be available to livestock in proper quantities and ratio. They play special roles in the proper functioning of the rumen microorganisms especially those which digest plant cellulose, utilization of energy from feeds, protein metabolism amongst other functions (McDowell *et al.,* 1993). The range of values recorded for Ca (9.03 – 25.09 g kg^{-1} DM) in the present study is above the critical level of 3 g kg^{-1} DM recommended for ruminant needs in the warm wet climates (McDowell *et al.*, 1993). Only the P level of commercial cowpea haulms (during the wet season) was above the critical level of 2.5 g kg^{-1} DM for ruminant animals.

Table 6: Relationships between the chemical compositions of the cowpea haulms.

Season	Variety		CP	NDF	IVOMD	TP	Tannins
Wet	Commercial						
		CP	1	-0.20^{ns}	0.61*	-0.31^{ns}	-0.65*
		NDF		1	0.09ns	0.53^{ns}	0.63*
		IVOMD			1	-0.32^{ns}	-0.23^{ns}
		TP				1	0.80***
		Tannins					1
	Improved						
		CP	1	-0.69*	0.06^{ns}	-0.52^{ns}	-0-35^{ns}
		NDF		1	-0.32^{ns}	0.58*	0.47^{ns}
		IVOMD			1	-0.75**	-0.79**
		TP				1	0.97***
		Tannins					1
Dry	Commercial						
		CP	1	-0.26^{ns}	0.36^{ns}	-0.09^{ns}	-0.03^{ns}
		NDF		1	0.17^{ns}	0.47^{ns}	0.50^{ns}
		IVOMD			1	-0.02^{ns}	-0.24^{ns}
		TP				1	0.93***
		Tannins					1
	Improved						
		CP	1	-0.29^{ns}	0.83***	-0.67**	-0.42^{ns}
		NDF		1	-0.08^{ns}	0.07^{ns}	0.23^{ns}
		IVOMD			1	-0.63*	-0.60*
		TP				1	0.86***
		Tannins					1

ns, non-significant; *, $P < 0{\cdot}05$; **, $P < 0{\cdot}01$; ***, $P < 0{\cdot}001$.

In vitro organic matter degradability and secondary metabolites

The observed differences in the IVOMD of the cowpea haulms may be due to differences in their content of potentially digestible materials. Less fibre content (especially lignin) of the cowpea haulms during the dry season may have contributed to higher IVOMD values observed in the dry season. Lignin is known to interfere with digestibility by limiting the surface area for microbial attachment.

The values of total phenol and tannins reported for the cowpea haulms in this study is considered low and of no nutritional significance (Mueller-Harvey, 2006). The inability to detect condensed and protein precipitable tannins showed that the secondary metabolites will not have any negative effect on digestion.

Relationships and prediction of IVOMD from chemical composition

The IVOMD could be predicted from the chemical composition of the haulms in both seasons. The stepwise regression equation obtained for improved haulms in the dry season had a high coefficient of determination (R^2 = 0.93). The prediction of IVOMD of the haulms was improved when any of the fibre fractions was included in the model (0.93, 0.86 and 0.74, compared to 0.66 when no fibre fraction was included with root mean square of 21.3, 26.4, 25.7 and 105, respectively).

Conclusion

Results from this study and an earlier paper (Anele et al., 2010) showed that these dual purpose cowpea varieties can easily be grown on marginal land as it requires little or no input and will ensure sufficient biomass as supplement during the dry season while providing extra food (grains) for human consumption. The sustainability of this cropping is not yet clear. While nitrogen input can be assured by biological fixation, the long-term support of plants with further macro- and micronutrients will have to be investigated. A recycling of nutrients in terms of fertilization with dung or manure is highly recommended in order to avoid a decline in soil fertility.

References

Agyemang, K., 2002. Dairy development in West Africa 1978-1998: Market Orientated Smallholder Dairy. Working Document No. 8. ILRI, Ibadan, Nigeria.

Anele, U.Y., Arigbede, O.M., Südekum, K.-H., Ike, K.A., Oni, A.O., Olanite, J.A., Amole, G.A., Dele, P.A., Jolaosho, A.O., 2010. Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of West African dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season. Anim. Feed Sci. Technol. 159, 10-17.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Blümmel, M., Lebzien, P., 2001. Predicting ruminal microbial efficiencies of dairy ration by in vitro techniques. Livest. Prod. Sci. 68, 107-117.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Curbois, C., 1999. Livestock to 2020: The Next Food Revolution. IFPRI 2020 Vision Food, Agriculture and Environment Discussion Paper 28, IFPRI, Washington, DC, USA.

Douthwaite, B., 2002. Enabling Innovation: A Practical Guide to Understanding and Fostering Technology Change. ZED Books, London & New York. pp. 266.

FAO, 1981. Tropical Feeds: Feed information summaries and nutritive values. FAO Animal Production and Health Series No. 12. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO, 2000. FAOSTAT Database. http://apps.fao.org. Food and Agriculture Organization of the United Nations, Rome, Italy.

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. 2nd edition. CAB International, Wallingford, UK.

Hagerman, A.E., Butler, L.G., 1978. Protein precipitation method for the quantitative determination of tannins. J. Agric. Food Chem. 26, 809-812.

ISO 19694, 1995. Soil Quality – determination of organic and total carbon after dry combustion (elemental analysis). Beuth-Verlag, Berlin.

ISO 13878, 1998. Soil Quality – determination of total nitrogen content by dry combustion (elemental analysis). Beuth-Verlag, Berlin.

ISO 11277, 2002. Soil Quality – determination of particle size distribution in mineral soil material – method by sieving and sedimentation. Beuth-Verlag, Berlin.

Kaasschieter, G.A., Coulibaly, Y., Heitkonig, I.M.A., Ketelaars, J.J.M.H., 1998. Supplementation of Cattle: a necessity. [La supplementation du bétail: une nécéssité!] In: Breman, H., Sissoko, K. (Eds.), L'intensification Agricole au Sahel. Karthala, Paris, France. pp. 79-105.

Makkar, H.P.S., 2003. Quantification of Tannins in Tree and Shrub Foliage. A Laboratory Manual. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Mcdowell, L.R., Conrad, J.H., Humbry, F.G., 1993. Minerals for Grazing Ruminants in Tropical Regions. Bulletin, The US Agency for Literature Development and Caribbean Basin Advisary Group (CBAG) USA.

Mueller-Harvey, I., 2006. Unravelling the conundrum of tannins in animal nutrition and health. J. Sci. Food Agric. 86, 2010-2037.

NRC (National Research Council), 1996. Nutrient Requirements of Beef Cattle. 7th edition, National Academy of Science, Washington, DC, USA.

Nuru, S., 1988. Research and development in pastoral production system in Nigeria: Past, present and future. An invited paper presented at the National Conference on Pastoralism in Nigeria held from 26 – 29th June, 1988. NAPRI, A. B. U., Zaria, Nigeria.

Ørskov, E.R., Grubb, D.A., 1978. The minimal nitrogen metabolism of lambs. Proc. Nutr. Soc. 38, 24A.

Savadogo, M., Zemmelink, G., Nianogo, A.J., 2000a. Effect of selective consumption on voluntary intake and digestibility of sorghum (*Sorghum bicolor* L. Moench) stover, cowpea (*Vigna unguiculata* L. Walp.) and groundnut (*Arachis hypogaea* L.) haulms by sheep. Anim. Feed Sci. Technol. 84, 265-277.

Savadogo, M., Zemmelink, G., Nianogo, A.J., Van Keulen, H., 2002b. Cowpea (*Vigna unguiculata* L. Walp) and groundnut (*Arachys hypogea* L.) haulms as supplements to sorghum (*Sorghum bicolor* L. Moench) stover: intake, digestibility and optimum feeding levels. Anim. Feed Sci. Technol. 87, 57-69.

SAS®, 2002. User's guide: Statistics, Version 9.1. SAS Institute, Inc. Cary, NC, USA.

Schüller, H., 1969. Die CAL-Methode, eine neue Methode zur Bestimmung des pflanzenverfügbaren Phosphors in Böden.Z. Pflanzenernähr. *Bodenkunde*, 123, 48-63.

Singh, B.B., Ajeigbe, H.A., Tarawali, S.A., Fernandez-Rivera, S., Abubakar, M., 2003. Improving the production and utilization of cowpea as food and fodder. Field Crops Res. 84, 169-177.

Singh, K., Schiere, J.B., 1995. Principles and Applications with Emphasis on Indian Livestock Production. Handbook for Straw Feeding Systems. ICAR/WAU, New Delhi, India.

Thornton, P.K., Krushka, R.L., Henninger, N., Kristjanson, P., Reid, R.S., Atieno, A.N., Ndegwa, T., 2002. Mapping Poverty and Livestock in the Developing World. ILRI, Nairobi, Kenya.

Trüby, P., Aldinger, E., 1989. Eine Methode zur Bestimmung austauschbarer Kationen in Waldböden. - Z. Pflanzenernähr. Bodenkunde, 152, 301-306.

Tylutki, T.P., Fox, D.G., Durbal, V.M., Tedeschi, L.O., Russell, J.B., Van Amburgh, M.E., Overton, T.R., Chase, L.E., Pell, A.N., 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174-202.

van Reeuwijk, L.P., 2002. Editor. Procedures for Soil Analysis. 6th edition. Technical Paper/International Soil Reference and Information Centre, Wageningen, The Netherlands.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

VDLUFA, 2007. Verband Deutscher Landwirtschaftlicher Unterschungs- und Forschungsanatalten. Handbuch der Landwirtschaftlichen Versuchs- und Untersuchungsmethodik (VDLUFA-Methodenbuch), Bd. III. Die Chemische Untersuchung von Futtermitteln. VDLUFA-Verlag. Darmstadt, Germany.

Viets, F.G. Jr., Lindsay, W.L., 1974. Testing soils for zinc, copper, manganese and iron. In: Soil testing and plant analysis. Eds. L. M. Walsh and J. D. Beaton. Soil Sci. Soc. Am. Inc. Madison, Wisc. USA.

Walli, T.K., Harika, A.S., Sharma, D.D., 1994. Influence of crop management practices and post-harvest techniques on quantity and quality of straws. In: Joshi, A.L., Doyle, P.T., Oosting, S.J. (Eds.), Variation in the Quantity and Quality of Fibrous Crop Residues. Proceedings of the National Seminar. Baif Development Research Foundation, Pune, India, pp. 53-66.

CHAPTER 3

Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of West African dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season

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Introduction

It has been well documented that tropical livestock production is faced with non-availability of year-round feed resources due to prolonged annual dry seasons arising from fluctuations in environmental factors, which directly and indirectly limit the quantity of herbage available to animals from natural grazing and/or crop residues. During the dry season, ruminants often depend on low quality crop residues as the major feed source, often resulting in sub-maintenance feeding and weight losses (Tarawali et al., 1999). A strategy to increase animal productivity in countries with scarce feed resources is to identify agro-based by-products that are adequate in nutrients, particularly crude protein (CP) and energy, and that can be used as basal diets with little or no supplementation (Okike et al. 2001). There is an urgent need for more agro-based feedstuffs for the livestock industry, especially in developing countries, as a result of the increase in the cost of conventional feedstuffs such as maize grain, soybean meal and oil seed cakes, as well as increasing livestock populations. Estimates have shown that ignoring crop residues as a feed resource will result in serious feed shortages. In these scenarios, crop farmers may own their own livestock for ready access to manure, while simultaneously selling some marginal land to livestock keepers who settle and begin crop farming using the manure from their animals (and possibly traction) as an input (Okike et al. 2001).

Agriculture in Sub-Saharan African countries is intensifying in response to increasing populations of humans and livestock. As a result, increased productivity demands are placed on integrated crop-livestock systems with more emphasis on legumes such as cowpea (*Vigna unguiculata* L. Walp). Cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through fixation (FAO, 2000). Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs.

Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total. Two countries – Nigeria and Niger – produce 850,000 and 271,000 tonnes annually or, together, 49% of the world crop (FAO, 2000). The bulk of this production comes from smallholder farmers in semiarid zones of the region.

This study investigated effects of feeding milled cowpea haulms on voluntary intake, digestibility, performance and haematological variables of West African dwarf (WAD) sheep.

Materials and methods

Experimental site

The field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. The site lies within the savanna agro-ecological zone of south-western Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Temperatures are fairly uniform with daytime values of 28 to 30°C during the rainy season and 30 to 34°C during the dry season with the lowest night temperature of around 24°C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to dry season values of 55 to 84%. The temperature of the soil ranges from 24.5 to 31.0°C (Source: Agrometeorology Department, UNAAB).

Forage establishment and management

The experimental area, measuring 2600 m^2, was ploughed twice and harrowed. The area was divided into eight blocks and each block was sub-divided into 10 plots each measuring 5 x 4 m^2. Three improved (*i.e.*, IITA 97k-1069-6, IITA 98k-311-8-2, IITA 98k-476-8; hereafter designated ITA-6, ITA-2 and ITA-8) and three commercial (*i.e.*, “Oloyin”, “Peu”, “Sokoto”) dual-purpose cowpea varieties constituted the treatments. Treatments were randomly allocated to plots within block. The cowpea was planted in rows 0.4 m wide with a 0.3 m plant spacing in May of 2007. The experimental area was maintained weed-free throughout the first month to reduce competition. The cowpea formed a tight canopy within a short period after planting which smothered weed growth. Grains were harvested approximately three months after planting by picking the pods. The haulms, comprised of the vine, leaves and roots were later uprooted, manually rolled and milled with a hammer mill (Model DFZH-Bühler AG, Uzwil, Switzerland) using a 3 mm sieve. Milled haulms were fed to the animals as a forage supplement to a basal diet of *Pennisetum purpureum*, which was harvested from the paddock at the Teaching and Research Farm of the UNAAB. It was cut back about 4 weeks before the commencement of the study and was manually chopped into particles of 2 to 4 cm lengths.

Experimental animals, feed and management

Thirty WAD sheep aged 10 ± 1.3 months with body weights (BW) of 8.9 ± 0.12 kg, raised under semi-intensive conditions, were used in a completely randomized experiment.

They were housed individually in wooden pens with slatted floors which were disinfected two weeks prior to the experiment. Sheep were quarantined for 3 weeks and, during this period, they were de-wormed and sprayed against internal and external parasites with 1 ml/10 kg BW of albendazole and 0.5 ml/10 kg BW of ivermectin, respectively.

The 30 sheep were balanced as closely as possible for BW and randomly allotted to one of six dietary treatments. These dietary treatments, which were all fed a basal diet of *P. purpureum*, consisted of milled cowpea haulms from the six varieties (fed as forage supplements) and designated as ITA2, ITA6, ITA8, Oloyin, Peu and Sokoto haulm diets. The sheep were adapted to the experimental diets and pen environment for 14 days and actual data collection was 106 days. The sheep were fed about 450 g/day (dry matter (DM) basis) of the supplements, based on 50 g/(kg BW x day) with concurrent adjustment as the experiment progressed based on their BW. The forage supplement was fed in the morning at 07:00 h and orts removed the following morning before offering fresh feed. Throughout the experiment, sheep had free access to water. Daily feed offered and orts were recorded and BW was measured weekly in the morning before feeding. Approximately 1 kg of fresh *P. purpureum* was fed to each sheep daily. The basal forage was fed 3 h after feeding the supplements in order to ensure maximum supplement consumption. The feeding experiment was conducted in the dry season (*i.e.*, December 2007 to April 2008). Feed conversion ratio (FCR) was calculated as the ratio (kg/kg) of average daily DM intake to average daily BW gain.

Blood sampling

Blood samples (approximately 10 ml) were collected from each sheep via jugular vein puncture using hypodermic syringes before feeding. Blood collection was at the start and end of the experiment. Blood, 5 ml, was drawn into a heparinized tube to prevent coagulation while the remaining 5 ml was left in the syringe to coagulate. Blood samples were then analysed for packed cell volume (PCV), haemoglobin (Hb) concentration, red blood cells (RBC) and white blood cells (WBC) from the heparinized blood while serum metabolites such as glucose, urea, globulin, albumin, creatinine, glutamate pyruvate transaminase (GPT) and glutamate oxalate transaminase (GOT) were estimated from the supernatant of the coagulated blood.

Balance study

After the end of the feeding experiment, the sheep were subjected to an N balance study, in which each was kept individually in a metabolic cage having provision for quantitative collection of faeces and urine. The initial 7 days were for adaptation of the sheep and the latter 7 days for collection of samples. Daily feed intake was measured during the whole collection period. Orts, faeces and urine were collected every morning. Nitrogen loss from urine by volatilization was prevented by adding 200 ml of (100 ml/l) sulphuric acid solution into the urine collection containers. These were stored in a freezer at -5°C until analysis. Efficiency of N utilization was calculated as: N balance/N intake.

Chemical analyses

Feed samples, orts and faeces were milled through a 1 mm sieve in a hammer mill. Prior to milling, samples were oven-dried at 60^{o}C for 96 h while DM was determined by oven-drying at 100^{o}C for 24 h. Samples were mixed separately and subsampled for analyses. The samples were later analyzed for CP, ether extract (EE), ash, neutral detergent fibre (NDFom), acid detergent fibre (ADFom) and lignin(sa). Fresh samples were used for faecal N determination. Crude protein (ID 984.13), ash (ID 942.05) and EE (ID 963.15) were analysed according to standard methods of AOAC (1990). Both NDFom and ADFom were expressed without residual ash. Lignin(sa) was determined by solubilisation of cellulose with sulphuric acid in the ADF residue (Van Soest et al., 1991). The NDFom and ADFom were determined according to Van Soest et al. (1991), with NDFom determined without use of α-amylase or sodium sulphite. Non-fibre carbohydrates (NFC) were calculated as:

NFC = 1000 - CP - ash - EE – NDFom, with all variables expressed as g/kg DM.

Statistical analysis

Data were subjected to analysis of variance using the GLM procedure of SAS (2002) in a completely randomized design with five replicates. Data for performance characteristics and haematological variables were analyzed differently with initial BW used as a covariate in analyzing performance characteristics whereas pre-experimental haematological values were used as covariates in analyzing post-experimental haematological values. The model was:

$$Y_{ijk} = \mu + G_i + H_j(G_i) + \varepsilon_{ijk}$$

where: Y_{ijk} = observation, μ = population mean, G_i = group (*i.e.*, commercial, improved) effect (I = 1 to 2), Hj(Gi) = haulm diets within group effect, H_j = haulm diets effect (J = 1 to 6) and εijk = residual error.

Means were then compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Differences among means with

P<0.05 were accepted as representing statistically significant differences. Probability values less than 0.001 are expressed as '*P*<0.001' rather than the actual value.

Results

Chemical composition

The DM contents of the supplements ranged from 940 to 951 g/kg (Table 1). The supplements had relatively high CP concentrations (131 to 188 g/kg DM). The NDFom and

Table 1: Chemical composition (g/kg DM unless stated) of the varieties of cowpea haulms.

	Improved			Commercial				*P*		Grass[1]
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto	SEM	Group (G)	H(G)[8]	
DM[2] (g/kg)	946	940	940	948	951	946	3.2	0.045	0.503	933
CP[3]	152[ab]	131[b]	161[a]	171	180	188	5.3	<0.001	0.009	55
EE[4]	17	21	14	18	26	19	2.2	0.159	0.296	25
Ash	115	81	107	141	233	183	18.1	<0.001	0.293	111
NDFom[5]	622	653	562	581	553	574	31.8	0.126	0.374	718
ADFom[6]	441	466	349	398	393	408	32.0	0.483	0.181	424
Lignin(sa)	194[a]	165[ab]	126[b]	176	220	221	13.6	0.002	0.014	75
Cellulose	247	301	223	222	173	187	21.6	0.013	0.254	349
NFC[7]	94	115	156	89	8	36	3.2	0.007	0.224	51

Means with different letters within group differ (*P*<0.05).
[1]n = 8
[2]DM, dry matter.
[3]CP, crude protein.
[4]EE, ether extract.
[5]NDFom, neutral detergent fibre expressed exclusive residual ash.
[6]ADFom, acid detergent fibre expressed exclusive residual ash.
[7]NFC, non-fibre carbohydrates.
[8]H(G), haulms within group

ADFom contents were not higher in improved *versus* commercial haulms. Despite their high fibre contents, haulms from both cowpea varieties contained substantial amounts of NFC, which were higher (*P*<0.01) in improved varieties. Commercial haulms had higher CP and ash contents which resulted in lower NFC content.

As expected, the chemical composition of the experimental diets fed to the sheep (Table 2) was consistent with the chemical composition of the ingredients

Intake and digestibility

Sheep fed improved cowpea haulm diets had higher (*P*<0.01) intake of DM, NDFom and ADFom *versus* those fed the commercial haulm diets and, within improved varieties (Table 3), intake of ITA8 was lowest (P<0.05). Intake of CP was not affected by the haulm

Table 2: Ingredient and chemical composition (g/kg DM unless stated) of haulm diets offered to the sheep.

	Improved			Commercial		
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto
Ingredient composition						
Cowpea haulms	450	450	450	450	450	450
Grass	550	550	550	550	550	550
Chemical composition of diets[1]						
Dry matter (g/kg)	939	936	936	940	941	939
Crude protein	93	84	96	101	105	108
Ether extract	20	22	19	21	24	21
Ash	106	91	102	117	157	135
Neutral detergent fibre(om)	633	645	606	616	605	613
Acid detergent fibre(om)	405	415	365	387	386	391
Lignin(sa)	121	108	92	114	133	133
Cellulose	284	306	273	274	253	259
Non-fibre carbohydrates	148	159	177	145	109	123

[1]Calculated from analyses of diet ingredients.

Table 3: Voluntary intake (g/day unless stated) and digestibility of WAD sheep fed cowpea haulm diets.

	Improved			Commercial				*P*	
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto	SEM	Group (G)	H(G)[6]
Intake									
Grass:suppl[1]	39:61	49:51	46:54	42:58	50:50	42:58	-	-	-
DM[2]	506[a]	489[a]	408[b]	409	443	438	14.8	0.005	<0.001
CP[3]	65.4[a]	55.1[b]	53.6[b]	56.5	59.4	64.1	1.77	0.186	<0.001
NDFom[4]	334[a]	336[a]	258[b]	262	283	280	10.2	<0.001	<0.001
ADFom[5]	219[a]	218[a]	156[b]	167	182	182	6.2	<0.001	<0.001
Digestibility									
DM[2]	0.60	0.54	0.59	0.46[b]	0.69[a]	0.53[ab]	0.036	0.573	0.002
CP[3]	0.55[a]	0.39[b]	0.59[a]	0.42[b]	0.69[a]	0.56[ab]	0.038	0.136	<0.001
NDFom[4]	0.67	0.61	0.65	0.53[b]	0.73[a]	0.61[ab]	0.031	0.394	0.002
ADFom[5]	0.75	0.72	0.73	0.63[b]	0.79[a]	0.70[ab]	0.023	0.159	0.002

Means with different letters within group differ ($P<0.05$).
[1]Voluntary intake proportion of grass and supplemental haulms
[2]DM, dry matter.
[3]CP, crude protein.
[4]NDFom, neutral detergent fibre expressed exclusive residual ash.
[5]ADFom, acid detergent fibre expressed exclusive residual ash.
[6]H(G), haulms within group

source, but within the improved varieties, sheep fed ITA2 had higher (P<0.05) intake than those fed ITA6 and ITA8 haulm diets.

There was no group (*i.e.*, improved *versus* commercial) effect in the apparent digestibility coefficients for all nutrients determined. However, Peu always had higher (*P*<0.05) digestion than Oloyin, with Sokoto intermediate, within commercial varieties. Only CP digestion was affected within improved varieties, with ITA6 being less (*P*<0.05) than ITA2 and ITA8.

Performance

There was a group effect for all performance characteristics (Table 4), with sheep fed commercial haulm diets gaining more BW than those on improved haulm diets (*P*=0.007). These sheep also had a lower FCR *versus* sheep fed improved haulm diets. Differences in FCR between haulms occurred with sheep fed improved haulm diets.

Table 4: Performance characteristics of WAD sheep fed cowpea haulm diets.

Variables	Improved			Commercial				*P*	
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto	SEM	Group (G)	H(G)[3]
Final BW[1] (kg)	12.1	11.9	12.3	12.3	12.6	12.7	0.18	0.007	0.451
Growth rate (g/d)	30.0	28.7	31.9	32.5	34.5	35.9	1.70	0.007	0.450
FCR[2]	10.9[a]	9.0[ab]	7.6[b]	7.6	6.3	7.1	0.50	<0.001	<0.001

Means with different letters within group differ (*P*<0.05).
[1]BW, body weight.
[2]FCR, feed conversion ratio (kg dry matter intake/kg BW gain).
[3]H(G), haulms within group

Nitrogen balance

All sheep were in positive N balance (Table 5), and there were no group effects in any variable determined. There were differences (*P*<0.001) between haulms within group. For the improved haulm diets, N balance was higher in sheep fed ITA2 and ITA8 while sheep fed Peu haulm diet had higher N balance than those fed Oloyin. Efficiency of N utilization, expressed as coefficient of N retained, followed similar trend as the N balance, being higher in sheep fed Peu for the commercial haulm diets, while sheep fed ITA8 haulm diet had higher efficiency than those fed ITA6.

Haematological variables

During the experiment, all blood values were within the normal reference range for sheep of similar breed and age group (Table 6). Group differences were observed in PCV,

Table 5: Nitrogen utilization (g/day) in WAD sheep fed cowpea haulm diets.

	Improved			Commercial				*P*	
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto	SEM	Group	H(G)[3]
N Intake	10.4[a]	8.8[b]	8.5[b]	9.0	9.5	10.2	0.28	0.197	<0.001
Faecal N[1]	4.6[ab]	5.3[a]	3.4[b]	5.2[a]	2.9[b]	4.4[ab]	0.34	0.304	<0.001
Urinary N	2.1	1.2	1.3	1.1	2.6	1.9	0.23	0.102	<0.001
N output	6.8[a]	6.6[a]	4.8[b]	6.4	5.5	6.4	0.24	0.867	<0.001
N Balance	3.6[a]	2.2[b]	3.7[a]	2.6[b]	3.9[a]	3.7[ab]	0.26	0.224	<0.001
ENU[2]	0.34[ab]	0.25[b]	0.43[a]	0.29[b]	0.41[a]	0.37[ab]	0.013	0.419	<0.001

Means with different letters within group differ ($P<0.05$).
[1]N, nitrogen.
[2]ENU, efficiency of N utilization (N balance/N intake).
[3]H(G), haulms within group

Table 6: Haematological variables of West African Dwarf sheep fed cowpea haulm diets.

	Improved			Commercial				*P*	
	ITA2	ITA6	ITA8	Oloyin	Peu	Sokoto	SEM	Group (G)	H(G)[8]
PCV[1](%)	27.8	28.1	26.7	25.5	24.9	26.6	1.11	0.042	0.763
Hb [2](g/l)	9.2	8.9	8.6	9.1	7.3	8.8	0.46	0.205	0.100
WBC[3] (10^9/l)	9.1	9.1	9.2	9.1	9.0	9.0	0.04	0.006	0.081
RBC[4] (10^{12}/l)	10.0	10.1	8.8	9.4	9.0	10.4	0.40	0.904	0.065
Glucose (mg/l)	70.3	71.2	71.1	74.5	75.4	70.3	2.35	0.249	0.589
STP[5] (g/l)	64.9	67.8	66.5	69.5	66.5	67.9	2.68	0.520	0.941
Albumin (g/l)	36.0	35.9	39.0	34.7	37.2	35.4	1.31	0.249	0.384
Globulin (g/l)	31.3	34.4	37.7	32.3	26.7	30.0	1.94	0.031	0.284
SGOT[6] (IU/l)	99.4	102.5	104.3	105.9	105.0	105.3	1.76	0.051	0.396
SGPT[7] (IU/l)	42.4	41.9	42.1	44.5	42.7	44.9	3.51	0.528	0.993
Urea (mg/l)	33.4	37.9	30.2	33.0	34.1	29.3	3.27	0.489	0.659
Creatinine (mg/l)	1.02	1.01	1.03	0.90	0.88	0.96	0.041	0.009	0.689

[1]PCV, packed cell volume.
[2]Hb, haemoglobin.
[3]WBC, white blood cell.
[4]RBC, red blood cell.
[5]STP, serum total protein
[6]SGOT, serum glutamate oxalate transaminase.
[7]SGPT, serum glutamate pyruvate transaminase.
[8]H(G), haulms within group.

WBC, Globulin and creatinine contents of the sheep with higher values for sheep fed improved cowpea haulm diets.

Discussion

Chemical composition

Under practical farming conditions, the nutritive value of haulms is often low because cowpea is grown primarily for grain. Thus, in practice, residues often have a lower proportion of leaves, and a lower CP content, than those from research sites. The cowpea haulms used in this study had higher CP content than those used by Savadogo et al. (2000a, 2000b). Such variation in quality of crop residues may be due to factors such as genetic characteristics (Singh and Schiere, 1995), environment (soil characteristics, rainfall) and crop management (level of fertilisation, plant density, stage of maturity at harvest, methods of harvesting, and storage) (Walli et al., 1994). Kaasschieter et al. (1998) reported CP values ranging from 78 to 217 g/kg DM for cowpea. FAO (1981) reported 37 ± 4.3, 144, and 99 g CP/kg DM for sorghum stover, cowpea and groundnut haulms, respectively. Although our commercial cowpea haulms had higher CP content than the improved haulms, the range of 131 to 188 g CP/kg DM for the cowpea haulms fed to the sheep was comparable to the requirements of small ruminants for about 50 g daily BW gain (Paul et al., 2003).

Higher NFC contents of improved cowpea haulms indicate that they should stimulate ammonia-N utilization in the rumen better than the commercial (Tylutki et al., 2008). As N utilization by rumen microorganisms is related to the amount of available fermentable energy, the NFC in the cowpea haulms could improve the efficiency of microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Ørskov and Grubb, 1978).

Nutrient intake and digestibility

Only the CP intake of ITA2 and Sokoto haulm diets were in the range of CP (60 to 90 g/day) required for sheep in the tropics (Paul et al., 2003). For the improved cowpea haulms, higher voluntary intake of haulms *versus* grass (which had less CP than the haulms) was responsible for the higher CP intake for sheep fed ITA2. The same trend was observed in sheep fed Sokoto cowpea haulms, within the commercial varieties. It has been shown that CP intake is a major determinant of ruminant performance due to increased availability of fermentable CP and other nutrients required by rumen bacteria, as well as a greater opportunity for dietary protein to escape rumen fermentation.

The relatively high digestibility values reported for DM, NDFom and ADFom demonstrate the ability of WAD sheep to utilize these cowpea haulms. The digestibility values for CP, below 0.50, for sheep fed ITA6 (improved) and Oloyin (commercial) haulm diets, suggest elevated levels of lignified N.

Performance

Sheep fed commercial cowpea haulms gained more weight than those fed improved haulms despite higher DM intake of the latter. This showed that they were able to utilize commercial cowpea haulms better than the improved. This observation was supported by lower FCR for sheep fed commercial haulm diets. The positive BW gain in all the sheep indicated that all cowpea haulms more than met their maintenance energy requirements. This was expected, since the apparent digestibilities of the haulms were relatively high. Conrad and Hibbs (1968) reported that rumen function is impaired, and feed intake and animal performance markedly reduced, when CP content of diet is less than 75 g/kg DM. However, as these diets all exceeded 80 g/kg DM, a CP limitation, impairing haulm digestion, was unlikely.

Nitrogen balance

Higher N balance of sheep fed ITA2 and ITA8 *versus* ITA6 can be attributed to lower digestibility of CP in the latter (0.39). The same trend was observed in sheep fed commercial haulm diets as those fed Oloyin retained less N. The N intakes of sheep in this study were lower than the value of 14.0 to 17.4 g/d in sheep fed cowpea grain (Singh et al., 2006), but comparable with sheep supplemented with *Morinda lucida,* although those sheep retained less N (Osakwe and Drochner, 2006). Our N balance values, which were all positive, show the potential of cowpea haulms to facilitate N utilization. .

Haematological variables

According to Karesh and Cook (1995), examining blood for their constituents helps to monitor and evaluate incidence of disease in animals. Haematological and biochemical indices may give some insight as to their production performance potential (Orheruata and Aikhuomobhogbe, 2006). Mean PCV values obtained in this study were within the range of 18 to 38% cited by Orheruata and Aikhuomobhogbe (2006) for WAD goats. In contrast, Taiwo and Ogunsanmi (2003) reported higher values of 37 and 36% for clinically healthy WAD goats and sheep.

The Hb range in this study was lower than the average value of 114 g/l reported for Red Sokoto goats (Tambuwal et al. 2002). Values for Hb in all the diets confirm the high protein quality of the diets (Pellet and Young, 1980).

The RBC counts reported in this study were within the range of 9.2 to 13.5 x 10^{12}/l reported by Tambuwal et al. (2002), and 9.9 and 18.7 x 10^{12}/l by Taiwo and Ogunsanmi (2000). As RBC indices aid in the characterization of anaemia (Merck, 1979), the RBC counts recorded in these animals do not suggest a susceptibility to anaemia-related disease conditions. Lower values in sheep fed commercial haulm diets were not important, as all values were in the range of 7.5 to 27.9 x 10^{9}/l (Orheruata and Aikhuomobhogbe, 2006).

A correlation between serum total protein and performance variables in livestock has been reported (Coles, 1986). As the diets in this study did not significantly affect the total protein levels in the serum of the sheep, thus indicating the safety of these haulms as supplements for sheep.

Conclusion

Results indicate that use of cowpea haulms caused no health challenge. Cowpea haulms can be used to sustain animal growth during the dry season.

References

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Azab, M.E., Abdel-Maksoud, H.A., 1999. Changes in some haematological and biochemical parameters during pre-partum and post-partum periods in female Baladi goats. Small Rumin. Res. 34, 77-85.

Coles, E. H., 1986. Veterinary Clinical Pathology, 4th ed. W. B. Saunders Co., Philadelphia, PA, USA, pp. 486.

Conrad, H.R., Hibbs, J.W., 1968. Nitrogen utilization by the ruminant: application of its nutritive value. J. Dairy Sci. 51, 276-284.

Ekpenyong, T.E., Biobaku, W.O., 1986. Growth response of rabbits fed activated sewage and dried poultry waste. J. Appl. Rabbit Res. 1, 14-16.

FAO, 1981. Tropical Feeds: Feed information summaries and nutritive values. FAO Animal Production and Health Series No. 12. Food and Agriculture Organization of the United Nations, Rome, Italy, pp. 529.

FAO, 2000. FAOSTAT Database. http://apps.fao.org. Food and Agriculture Organization of the United Nations, Rome, Italy.

Kaasschieter, G.A., Coulibaly, Y., Heitkonig, I.M.A., Ketelaars, J.J.M.H., 1998. Supplementation of cattle: a necessity. [La supplementation du bétail: une nécéssité!] In: Breman, H., Sissoko, K. (Eds.), L'intensification Agricole au Sahel. Karthala, Paris, France. pp. 79-105.

Karesh, W.B., Cook, R.A., 1995. Application of veterinary medicine to *in situ* conservation. Oryx 29, 244-252.

Keele, C.A., Neil, E., 1971. Samson Wrights Applied Physiology. 12th Edition, ELBS and OUB, London, UK.

Merck, 1979. The Merck Veterinary Manual. 5th edition, Siegmund, O. H. (ed), Merck, Rahway, NJ, USA.

Okike, I., Jabbar, M.A., Manyong, V.M., Smith, J.W., Akinwunmi, J.A., Ehui, S.K., 2001. Agricultural intensification and efficiency in the West African savannas: Evidence from northern Nigeria. Socioeconomics and Policy Research Working Paper 33. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Orheruata, A.M., Akhuomobhogbe, P.U., 2006. Haematological and blood biochemical indices in West African dwarf goats vaccinated against *Pestes des petit ruminants* (PPR). Afr. J. Biotechnol. 5, 743-748.

Ørskov, E.R., Grubb, D.A., 1978. The minimal nitrogen metabolism of lambs. Proc. Nutr. Soc. 38, 24A.

Osakwe, I.I., Drochner, W., 2006. Nutritive value of *Morinda lucida* and its fermentation parameters in West African dwarf (WAD) sheep when fed as supplement to grass hay. Small Rumin. Res. 64, 107-115.

Paul, S.S., Mandal, A.B., Mandal, G.P., Kannan, A., Pathak, N.N., 2003. Deriving nutrient requirements of growing Indian sheep under tropical conditions using performance and intake data emanated from feeding trials conducted in different research institutes. Small Rumin. Res. 50, 97-107.

Pellet, P.Z., Young, N.P., 1980. Nutritional Evaluation of Protein Feeds. United Nation Universal World Hunger Programme. Food and Nutrition Bulletin (Suppl. 4). United Nations University, Tokyo, Japan.

Savadogo, M., Zemmelink, G., Nianogo, A.J., 2000a. Effect of selective consumption on voluntary intake and digestibility of sorghum (*Sorghum bicolor* L. Moench) stover, cowpea

(*Vigna unguiculata* L. Walp.) and groundnut (*Arachis hypogaea* L.) haulms by sheep. Anim. Feed Sci. Technol. 84, 265-277.

Savadogo, M., Zemmelink, G., Nianogo, A.J., Van Keulen, H., 2002b. Cowpea (*Vigna unguiculata* L. Walp) and groundnut (*Arachys hypogea* L.) haulms as supplements to sorghum (*Sorghum bicolor* L. Moench) stover: intake, digestibility and optimum feeding levels. Anim. Feed Sci. Technol. 87, 57-69.

SAS®, 2002. User's guide: Statistics, Version 9.1. SAS Institute, Inc. Cary, NC, USA.

Singh, S., Kundu, S.S., Negi, A.S., Singh, P.N., 2006. Cowpea (*Vigna unguiculata*) legume grains as protein source in the ration of growing sheep. Small Rumin. Res. 63, 247-254.

Singh, K., Schiere, J.B., 1995. Principles and Applications with Emphasis on Indian Livestock Production. Handbook for Straw Feeding Systems. ICAR/WAU, New Delhi, India.

Taiwo, V.O., Ogunsanmi, A.O., 2003. Haematology, plasma, whole blood and erythrocyte biochemical values of clinically healthy captive-rared grey duiker (*Sylvicarpa grimmia*) and West African dwarf sheep and goats in Ibadan, Nigeria. Israel J. Vet. Med. 58, 57-61.

Tambuwal, F.M., Agale, B.M., Bangana, A., 2002. Haematological and biochemical values of apparently healthy Red Sokoto goats. In: Proceedings of the 27th Annual Conference of the Nigerian Society for Animal Production (NSAP), 17-21 March 2002, Federal University of Technology, Akure, Nigeria, pp. 50-53.

Tarawali, S.A., Peters, M., Schultz-Kraft, R., 1999. Forage Legumes for Sustainable Agriculture and Livestock Production in Sub-humid West Africa. ILRI, Nairobi, Kenya.

Tylutki, T.P., Fox, D.G., Durbal, V.M., Tedeschi, L.O., Russell, J.B., Van Amburgh, M.E., Overton, T.R., Chase, L.E., Pell, A.N., 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174-202.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

Walli, T.K., Harika, A.S., Sharma, D.D., 1994. Influence of crop management practices and post-harvest techniques on quantity and quality of straws. In: Joshi, A.L., Doyle, P.T., Oosting, S.J. (Eds.), Variation in the Quantity and Quality of Fibrous Crop Residues. Proceedings of the National Seminar. Baif Development Research Foundation, Pune, India, pp. 53-66.

CHAPTER 4

Chemical characterization, in vitro dry matter and ruminal crude protein degradability and microbial protein synthesis of some cowpea (*Vigna unguiculata* L. Walp) haulm varieties

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Introduction

Insufficient quantity and quality of traditional forage resources in many tropical regions, particularly those with acidic, low-fertility soils and prolonged annual dry season arising from fluctuations in environmental factors (which directly and indirectly limit the quantity of herbage available to animals either from natural grazing and/or crop residues) are major constraints for farmers to improve livestock productivity.

Agriculture in the Sub-Saharan African countries is intensifying in response to increasing populations of humans and livestock. Estimates have shown that ignoring crop residues as a feed resource will result in serious feed shortages. In these scenarios, crop farmers may own their own livestock for ready access to manure, while simultaneously selling some marginal land to livestock keepers who settle and begin crop farming using the manure from their animals (and possibly traction) as an input (Delgado, 1999). As a result, increased productivity demands are placed on integrated crop-livestock systems with more emphasis on legumes such as cowpea (*Vigna unguiculata* L. Walp). Cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through fixation (FAO, 2000). Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs (Anele et al., 2010).

Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total. Two countries – Nigeria and Niger – produce 850,000 and 271,000 tonnes annually or, together, 49% of the world crop (FAO, 2000). The bulk of this production comes from smallholder farmers in semiarid zones of the region.

The use of an in vitro gas technique in evaluating feedstuffs (through the measurement of variables like methane, microbial mass and short chain fatty acids (SCFA)) is a very effective and robust way of estimating energy loss from diets, microbial and feed nitrogen supply to ruminants.

The objective of this study was to estimate intervarietal differences of the nutritive value of some cowpea haulms. This was achieved by determination of in vitro apparent and true degraded dry matter (DM), utilizable crude protein at the duodenum (uCP; total CP at the duodenum minus endogenous CP), methane production, protozoa population, microbial mass and efficiency of three improved and three commercial varieties of cowpea haulms.

Materials and methods

Experimental site

The field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. The site lies within the savanna agro-ecological zone of south-western Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Temperatures are fairly uniform with daytime values of 28 to 30^{o}C during the rainy season and 30 to 34°C during the dry season with the lowest night temperature of around 24°C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to dry season values of 55 to 84%. The temperature of the soil ranges from 24.5 to 31.0°C (Source: Agrometeorology Department, UNAAB).

Forage establishment and management

The experimental area, measuring 2600 m^2, was ploughed twice and harrowed. The area was divided into eight blocks and each block was sub-divided into 10 plots each measuring 5 x 4 m^2. Three improved (*i.e*., IITA 97k-1069-6, IITA 98k-311-8-2, IITA 98k-476-8; hereafter designated ITA-6, ITA-2 and ITA-8) and three commercial (*i.e*., “Oloyin”, “Peu”, “Sokoto”) dual-purpose cowpea varieties constituted the treatments. The dual-purpose cowpea varieties were semi-erect types and had 70 to 86 days to pod maturity. The improved varieties were modified for greater biomass and grain yields. Treatments were randomly allocated to plots within block. The inner six blocks (36 plots) were selected for sampling to avoid border effects. Samples collected from two blocks were bulked together to constitute one field replicate. As a result, three field replicates were obtained from the 6 blocks. The cowpea was planted in rows 0.4 m wide with a 0.3 m plant spacing in May, 2007. The experimental area was maintained weed-free throughout the first month to reduce competition. The cowpea formed a tight canopy within a short period after planting which smothered weeds. Grains were harvested approximately three months after planting to represent wet season. The second planting was carried out in August and harvested in November, 2007 to represent dry season. The haulms, comprising of the vine, leaves and roots were later uprooted, manually rolled and chopped into particles of 2 to 4 cm lengths and milled with a hammer mill (Model DFZH-Bühler AG, Uzwil, Switzerland) using a 3 mm sieve.

Chemical analyses

Feed samples were successively ground in mills with 3 and 1 mm sieves. Prior to milling, samples were oven-dried at 60^{o}C for 96 h while DM was determined by oven-drying at 100^{o}C for 24 h. Total nitrogen (N) was estimated by combustion assay (LECO Instrumente, Mönchengladbach, Germany), CP was expressed as N x 6.25, ash (ID 942.05) and ether extract (EE) (ID 963.15) were analysed according to the standard methods of AOAC (1990). Neutral detergent fibre (NDFom) was determined according to Van Soest et al. (1991) without use of α-amylase or sodium sulphite and expressed without residual ash. Acid detergent fibre (ADF) was analyzed according to AOAC (1997; method 973.18) and expressed exclusive residual ash. Lignin(sa) was determined by solubilisation of cellulose with sulphuric acid in the ADF residue (Van Soest et al., 1991). Non-fibre carbohydrates (NFC) were calculated as:

NFC = 1000 - CP - ash - EE – NDFom, with all variables expressed as g/kg DM. Short chain fatty acids concentrations were determined using a splitless injector Perkin-Elmer auto system gas chromatograph (Perkin-Elmer, Inc., Shelton, CN, USA).

In vitro gas production measurement

In vitro gas production was determined according to Menke and Steingass (1988). Rumen fluids were collected prior to feeding from three fistulated Merino sheep (≈ 70 kg body weight) fed a standard diet (600 g grass hay/600 g pelleted concentrate). Feeds were offered in two equal meals at 07:00 and 19:00 h. Rumen fluid was strained through two layers of cheesecloth into a prewarmed, insulated flask. All laboratory handling of rumen fluid was carried out under a continuous flow of CO_2. Samples (200±2 mg) with and without PEG (200±2 mg) of the air-dry haulms were accurately weighed into 100 ml glass syringes, the syringe pistons were lubricated with vaseline and inserted into the syringes. The inclusion of PEG was necessary because we had no data on the content of tannins especially the improved varieties. In vitro incubation of the samples was conducted in triplicate. Syringes were filled with 30 ml of medium consisting of 10 ml of rumen fluid and 20 ml of buffer solution as described by Menke and Steingass (1988) except that the concentration of $NaHCO_3$ was reduced to 33 g/l and that of $(NH_4)HCO_3$ increased to 6 g/l. Three blanks containing 30 ml of medium only were included. The syringes were placed in a rotor inside the incubator (39°C) with about one rotation per min.

Cumulative gas volume measurements of samples were read manually from the three replicates each at 0, 4, 8, 12, 18, 24, 32, 48, 56, 72, 80 and 96 h of incubation. After subtraction of gas production from blank syringes, data were fitted to exponential model (Ørskov and McDonald, 1979) as:

$$y = B(1 - \exp^{-c\times[t-\text{lag}]}),$$

where 'y' is the cumulative volume of gas produced at time 't' (h), 'B' the asymptotic gas volume, 'c' the rate constant and 'lag' is the time (h) between inoculation and commencement of gas production.

Halftime of gas production ($t^1/_2$) [*i.e.*, the time (h) when half of the asymptotic gas volume (B; ml) was produced] was calculated as:

$t^1/_2$ =(ln 2/c)+lag.

In vitro apparently (ivADDM) and truly (ivTDDM) degraded dry matter

After the initial 96 h gas run, substrate specific $t^1/_2$ was calculated and a second incubation with the samples as substrates were conducted to obtain degradability measures at substrate-specific $t^1/_2$ and 24 h for each substrate. Collection and handling of ruminal fluid was the same as that described for the 96 h incubations. Eight syringes were prepared for each substrate, providing four syringes for apparent and four for true degradability measurements (with and without PEG) in each incubation run. The incubations were terminated at $t^1/_2$ and 24 h, and the volume of gas was recorded. The whole process was repeated to have four analytical replicates. True substrate degradability of diets (Van Soest et al., 1991) at $t^1/_2$ and 24 h was measured by refluxing the incubation residue with ND solution (prepared without sodium sulphite) for 1 h with subsequent recovery of the truly undegraded substrate in Dacron fibre bags (4 x 12 cm, 40 µm pore size: Ankom, Macedon, NY, USA).

The ivTDDM coefficient was calculated as:

Feed (DM) incubated-residue (DM) recovered in the crucibles/Feed (DM) incubated

In vitro apparent degraded DM was determined at $t^1/_2$ and 24 h by high-speed centrifugation (20,000 x *g*) of incubation residues at 20°C for 30 minutes (Blümmel and Lebzien, 2001) following placement in iced cubes (about -4°C) to stop fermentation. Blanks were also centrifuged and residues weighed and used to correct for residues from the ruminal inoculum.

In vitro apparent degraded DM coefficient was calculated as:

Feed (DM) incubated-[pellet (DM)-blank pellet (DM)]/Feed (DM) incubated

Partitioning factor (PF) was calculated as the ratio of mg of ivTDDM to ml of gas thereby produced.

In vitro microbial N analysis

Undegradable dietary N (UDN) in vitro was quantified by N determination in the truly undegraded $t^1/_2$ and 24 h dry residues recovered in the fibre bags after ND solution treatment. In other words UDN was estimated as fibre bound N (NDFN) after incubation. Rumen degradable N (RDN) was calculated as: RDN = feed N - NDFN ($t^1/_2$ or 24 h). In vitro microbial N production (MN) was estimated directly by using the N content of the apparently degraded substrate after centrifugation (pellet N) and NDFN in diets at $t^1/_2$ and 24 h, using the equation:

Microbial N production at $t^1/_2$ (24 h) = pellet N at $t^1/_2$ (24 h) - blank pellet N at 0 h incubation - NDFN at $t^1/_2$ (24 h).

Estimation of the contents of utilizable crude protein at the duodenum (uCP)

For uCP determination (Lebzien and Voigt, 1999), a method was used which combined the Hohenheim feed test with the measurement of ammonia in the incubated fluid (Steingass et al., 2001). Samples were incubated in two runs at $t^1/_2$ and 24 h. The gas production was recorded after $t^1/_2$ and 24 h. Ammonia N was determined using steam distillation (Vapodest 50s Carousel; Gerhardt, Königswinter, Germany). To alkalize the incubated fluid prior to distillation, 5 ml of 1 M sodium hydroxide solution was added. For estimating the uCP after $t^1/_2$ and 24 h of incubation, the following formula was used:

uCP (g/kg DM) = [(NB + NF – NI) * 6.25] / (IW * DM)

where NB (mmol/ml) = average ammonia N content of the blanks, NF (mg) = N content of the forage sample, NI (mmol/ml) = ammonia N content of the incubated fluid after $t^1/_2$ or 24 h, IW (mg) = initial weight of the incubated sample and DM (g/kg).

Protozoa count and methane estimation

For methane (CH_4) estimation, 150±2 mg (with and without PEG) of the samples were used. The rationale behind the reduced quantity of sample is to limit the volume of gas below 60 ml. After recording the final gas volume at the end of incubation ($t^1/_2$ and 24 h), the lower end of the syringe was connected to the lower end of a pipette containing 4.0 ml of NaOH (10 M). The NaOH (10 M) was then introduced from the latter into the incubated contents, thereby avoiding gas escape. Mixing of the contents with the NaOH solution allowed for the absorption of CO_2, with the gas volume remaining in the syringe considered to be CH_4 (Demeyer et al., 1988). For protozoan enumeration, 1 ml of sample was added to 9 ml of 4% formaldehyde solution. Total protozoan count was made in 30 microscopic fields at a magnification of 100x using Fuchs-Rosenthal counting chamber (depth 0.2 mm, 0.0125 µl per grid).

Statistical analysis

Data were subjected to analysis of variance using the GLM procedure of SAS (2002) in a 2 x 2 x 2 factorial arrangement with 3 field replicates. The model used was:

$$Y_{ijklm} = \mu + G_i + H_j(Gi) + S_k + P_l + (GS)_{ik} + (GP)_{il} + (SP)_{kl} + (GSP)_{ikl} + \varepsilon_{ijklm}$$

Where: Y_{ijklm} = observation, μ = population mean, G_i = group effect (improved *versus* commercial) (i = 1 to 2), $H_j(G_i)$ = haulms within group effect, S_k = season effect (k = 1 to 2), P_l = PEG effect (l = 1 to 2), $(GS)_{ik}$ = interaction between group and season, $(GP)_{il}$ = interaction between group and PEG, $(SP)_{kl}$ = interaction between season and PEG, $(GSP)_{ikl}$ = interaction between group, season and PEG; and ε_{ijklm} = residual error. After the initial analysis, PEG did not have any effect on the measured variables, so a reduced model was subsequently used for the statistical analyses.

$$Y_{ijk} = \mu + G_i + H_j(Gi) + S_k + (GS)_{ik} + \varepsilon_{ijk}$$

All variables are already explained above. Means were then compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Differences among means with $P<0.05$ were accepted as representing statistically significant differences. Probability values less than 0.001 are expressed as '$P<0.001$' rather than the actual value.

Results

Chemical composition

Group x season interactions were observed for CP, lignin(sa) and hemicellulose contents of the cowpea haulms. Crude protein content of the cowpea haulms was greater ($P<0.001$) in the commercial cowpea haulms and during the dry season (Table 1). The NDFom content though not significant (group x season) was greater (P<0.05) in the improved than commercial haulms with values of 612 vs 569 and 403 vs 379 g/kg DM during the wet and dry seasons, respectively. Despite their high fibre contents, haulms from both cowpea varieties contained significant amounts of NFC.

In vitro gas production characteristics

Gas production profiles of the cowpea haulms at wet and dry seasons are presented in Fig. 1. There were differences in the asymptotic (b) gas production of the cowpea haulms with

Table 1: Chemical composition (g/kg DM unless stated) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[7]	Season	G x S
DM[1](g/kg)	948	942	933	931	2.3	0.114	0.241	<0.001	0.409
CP[2]	181^{b}	147^{c}	217^{a}	212^{a}	4.0	<0.001	0.633	<0.001	0.002
EE[3]	18.9	16.3	42.2	28.6	3.34	0.023	0.577	<0.001	0.116
Ash	94.3	30.5	71.4	30.5	10.35	<0.001	0.233	0.281	0.279
NDFom[4]	569	612	379	403	14.9	0.033	0.244	<0.001	0.546
ADFom[5]	399	419	208	233	15.1	0.155	0.192	<0.001	0.835
Lignin(sa)	206^{a}	162^{b}	107^{c}	113^{c}	8.1	0.028	0.011	<0.001	0.003
Hemicellulose	169^{b}	193^{a}	171^{b}	170^{b}	5.4	0.041	0.604	0.045	0.030
Cellulose	194	257	101	120	11.9	0.002	0.330	<0.001	0.072
NFC[6]	136	193	289	325	12.7	<0.001	0.088	<0.001	0.405

Means with different letters within rows differ (*P*<0.05).
[1]DM, dry matter.
[2]CP, crude protein.
[3]EE, ether extract.
[4]NDFom, neutral detergent fibre expressed exclusive residual ash.
[5]ADFom, acid detergent fibre expressed exclusive residual ash.
[6]NFC, non-fibre cabohydrates.
[7]H(Group), haulms within group.

greater values recorded for the commercial cowpea haulms harvested during the dry season. Substrate specific $t^1/_2$ was on the average shorter during the dry season, being 8.19 and 8.26 h and for wet season, 10.3 and 13.3 h for commercial and improved haulms, respectively.

In vitro dry matter digestibility, partitioning factor and protozoa population

In vitro apparently degraded DM, ivTDDM, microbial mass, protozoa population, methane and partitioning factor of the haulms at substrate specific $t^1/_2$ are presented in Table 2. Interactions between group and season were observed for microbial mass, methane and PF of the

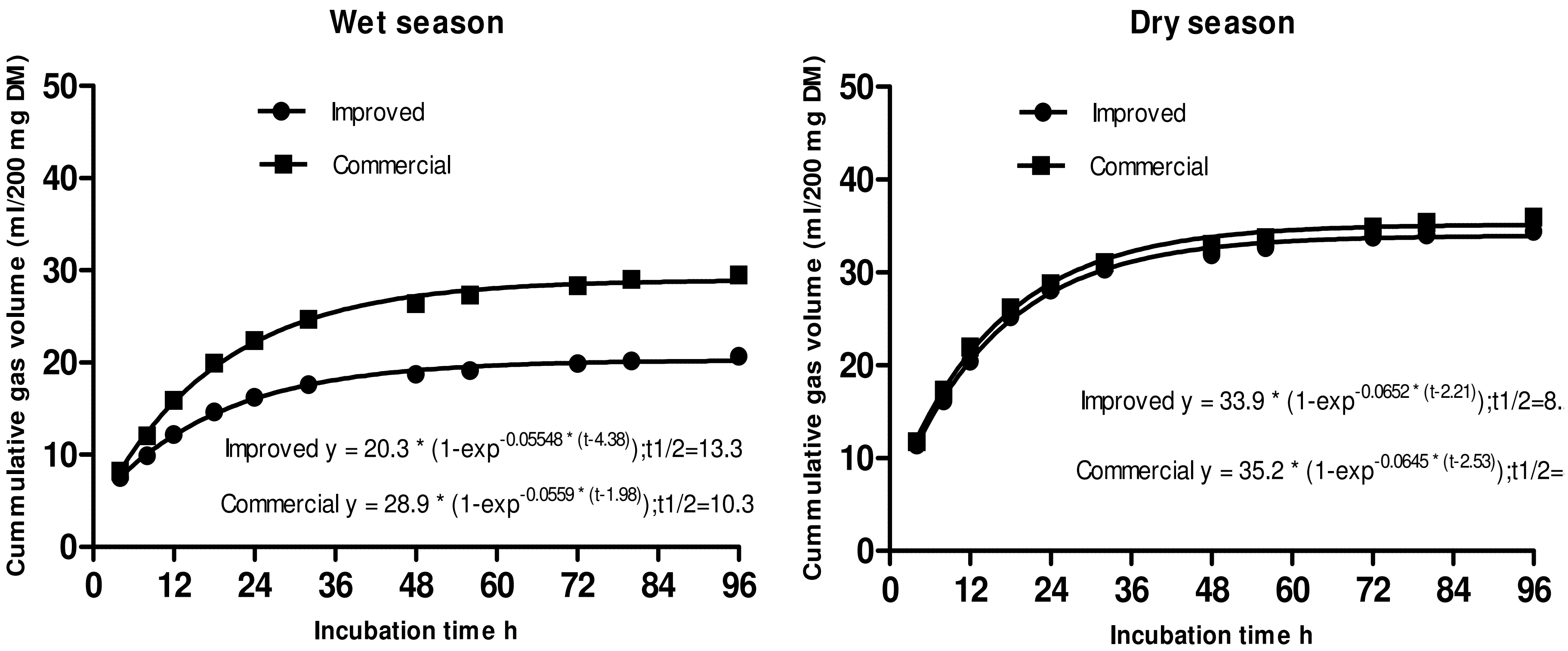

Fig. 1: In vitro gas production profiles of the cowpea haulms at wet and dry seasons. Gas production profiles have been fitted to curves using the equation ($y = B*(1\text{-}exp^{-c*[t\text{-}lag]})$) with time to half maximal gas production ($t^{1}/_{2}$) expressed in hours. Standard errors for maximal gas production and rate of gas production for wet season were 0.18, 0.0031; 0.29, 0.0032; for dry season, 0.23, 0.0029; 0.31, 0.0036 for improved and commercial haulms, respectively.

Table 2: Half time ($t^1/_2$) in vitro apparent and true dry matter degradability coefficients, microbial mass (g/kg DM), efficiency of microbial production (partition factor) (mg/ml), methane (g/kg dry matter (DM)) and protozoa population (10^6/ml) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[4]	Season	G x S
IVADDM[1]	0.177	0.254	0.323	0.359	0.0126	<0.001	0.034	<0.001	0.106
IVTDDM[2]	0.469	0.492	0.652	0.679	0.0137	0.076	0.374	<0.001	0.833
Microbial mass	316[a]	226[b]	310[a]	302[a]	13.6	<0.001	0.111	0.016	0.003
Protozoa population	1.39	1.39	1.29	1.62	0.085	0.052	0.324	0.457	0.061
Methane	12.73[b]	16.40[a]	16.13[a]	15.53[a]	0.097	0.022	<0.001	0.059	0.002
PF[3]	3.98[ab]	3.09[c]	4.36[a]	3.39[bc]	0.320	<0.001	<0.001	0.002	<0.001

Means with different letters within rows differ ($P<0.05$).
[1]IVADDM, in vitro apparently degraded dry matter.
[2]IVTDDM, in vitro truly degraded dry matter.
[3]PF, partioning factor.
[4]H(Group), haulms within group.

Table 3: Twenty-four hour (24 h) in vitro apparent and true dry matter degradability coefficients, microbial mass (g/kg DM), efficiency of microbial production (PF) (mg/ml), methane (g/kg dry matter (DM)) and protozoa population (10^6/ml) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[4]	Season	G x S
IVADDM[1]	0.209[c]	0.347[b]	0.431[a]	0.446[a]	0.0143	<0.001	<0.001	<0.001	<0.001
IVTDDM[2]	0.502	0.569	0.750	0.767	0.0167	0.013	0.062	<0.001	0.132
Microbial mass	275[a]	209[b]	300[a]	303[a]	9.7	0.002	0.006	<0.001	<0.001
Protozoa population	1.07[ab]	1.26[a]	1.13[ab]	0.95[b]	0.069	0.952	0.004	0.073	0.010
Methane	18.46[c]	27.20[b]	31.90[a]	31.80[a]	0.126	<0.001	<0.001	<0.001	<0.001
PF[3]	2.98	2.79	3.97	3.16	0.145	0.229	0.521	<0.001	0.217

Means with different letters within rows differ ($P<0.05$).
[1]IVADDM, in vitro apparently degraded dry matter.
[2]IVTDDM, in vitro truly degraded dry matter.
[3]PF, partioning factor.
[4]H(Group), haulms within group.

commercial and improved cowpea haulms. Commercial cowpea haulms had greater (P=0.003) microbial mass while the improved cowpea haulms produced more (P=0.002) methane. Both ivADDM and ivTDDM coefficients were greater (P>0.05) in the improved than commercial haulms. Greater ivADDM and ivTDDM coefficients were recorded during the dry season. The PF values of the haulms at substrate specific $t^1/_2$ ranged from 2.49 to 4.36 with greater (P<0.001) values for commercial cowpea haulms. After 24 h incubation, group x season interactions were also observed for ivADDM, microbial mass, methane and protozoa population of the haulms (Table 3). Microbial mass, methane and PF at 24 h followed similar trend observed at substrate specific $t^1/_2$. Improved cowpea haulms had greater ivADDM coefficient and protozoa population.

In vitro feed N partitioning, microbial N and utilizable CP at the duodenum

In vitro N partitioning of the cowpea haulms, microbial N and uCP at substrate specific $t^1/_2$ and 24 h are shown in Tables 4 and 5, respectively. There were strong interactions (P<0.001) between group and season for the N content, NDFN and RDN contents of the haulms at both time periods. At both substrate specific $t^1/_2$ and 24 h, the N compounds of the commercial haulms were degraded more (P<0.001) in the rumen than the improved varieties. The improved cowpea haulms supplied greater (P<0.001) uCP at both times. The amount of uCP was consistently greater during the dry season and it decreased with increasing incubation time as more time was available for CP to be degraded in ruminal fluid.

Short chain fatty acid production

Interactions between group and season were observed for the iso- and n-valerate contents of the haulms at substrate specific $t^1/_2$ (Table 6) and for acetate and total SCFA contents of the haulms at 24 h (Table 7). On the average, improved cowpea haulms had greater SCFA concentration than commercial haulms. The SCFA concentration increased with increasing incubation time with greater values at 24 h than at substrate specific $t^1/_2$. Acetate to propionate ratios ranged from 4.08 to 4.22 at substrate specific $t^1/_2$ and from 3.79 to 4.03 after 24 h of incubation. Although not significant (P>0.05), acetate to propionate ratios were numerically greater for improved cowpea haulms at both time intervals.

Table 4: Half time ($t^{1}/_{2}$) microbial nitrogen, utilizable crude protein at the duodenum (uCP), ammonia N (NH_3-N), neutral detergent fibre-bound N (NDFN) and rumen degraded N (RDN).

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Sample N (mg)	2.89^{b}	2.35^{c}	3.47^{a}	3.39^{a}	0.036	<0.001	0.101	<0.001	<0.001
Microbial N (mg)	1.88^{a}	1.21^{b}	1.79^{a}	1.76^{a}	0.130	0.007	0.337	0.076	0.015
uCP (g/kg DM)	83.51	94.61	102.18	110.16	1.202	<0.001	<0.001	<0.001	0.196
NH_3-N (mmol/ml)	0.36	0.33	0.35	0.31	0.003	<0.001	<0.001	<0.001	0.718
NDFN (mg)	0.21^{a}	0.15^{c}	0.19^{b}	0.16^{c}	0.004	<0.001	<0.001	0.135	<0.001
RDN (mg)	2.66^{b}	2.21^{c}	3.22^{a}	3.21^{a}	0.025	<0.001	0.002	<0.001	<0.001

Means with different letters within rows differ (*P*<0.05).
[1]H(Group), haulms within group.

Table 5: Twenty-four hour (24 h) microbial nitrogen, utilizable crude protein at the duodenum (uCP), ammonia N (NH_3-N), neutral detergent fibre-bound N (NDFN) and rumen degraded N (RDN).

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Sample N (mg)	2.89^{b}	2.35^{c}	3.47^{a}	3.39^{a}	0.036	<0.001	0.101	<0.001	<0.001
Microbial N (mg)	1.62	1.64	2.12	2.02	0.098	0.675	0.481	<0.001	0.529
uCP (g/kg DM)	71.81	88.33	78.03	94.02	1.628	<0.001	<0.001	<0.001	0.871
NH_3-N (mmol/ml)	0.42	0.38	0.44	0.39	0.006	<0.001	0.038	<0.001	0.393
NDFN (mg)	0.19^{a}	0.12^{b}	0.12^{b}	0.11^{b}	0.005	<0.001	0.005	<0.001	<0.001
RDN (mg)	2.69^{b}	2.25^{c}	3.29^{a}	3.26^{a}	0.03	<0.001	<0.001	<0.001	<0.001

Means with different letters within rows differ (*P*<0.05).
[1]H(Group), haulms within group.

Discussion

Chemical composition

The chemical composition of the cowpea haulms showed substantial variations across group and season. Dry matter and CP contents of the commercial cowpea haulms were greater compared to improved haulms. The CP levels in the current study are above the range of 110 - 130 g/kg DM which is adequate for maintenance and growth of small ruminants (NRC, 1985). This implied that the cowpea haulms especially the commercial haulms can be used as CP supplement to poor quality grasses during the dry season.

Fibre concentrations were greater in improved than commercial cowpea haulms. Despite the greater fibre concentration in improved haulms, significant proportion was in form of NFC and cellulose which are easily degraded unlike the commercial haulms which had greater lignin concentration. Higher NFC contents of improved cowpea haulms indicate that they should stimulate ammonia-N utilization in the rumen better than the commercial varieties (Tylutki et al., 2008). As N utilization by rumen microorganisms is related to the amount of available fermentable energy, the NFC in the cowpea haulms could improve the efficiency of microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Cabrita et al., 2006).

In vitro DM digestibility, microbial efficiency and protozoa population

The observed differences in the ivADDM and ivTDDM of the cowpea haulms may be due to the differences in their content of potentially digestible materials. On the average, DM of the improved varieties of the cowpea haulms was degraded more in vitro at both time intervals than the commercial haulms. Greater lignin(sa) concentration observed in commercial haulms may have interfered with the DM digestibility by limiting the surface area for microbial attachment. The values observed for both apparently and truly degraded DM were about 50% greater in the dry than wet season. Expectedly, more DM was degraded at 24 h than at substrate specific $t^{1}/_{2}$.

Greater DM degradability of the improved cowpea haulms did not translate to greater microbial mass as commercial cowpea haulms were able to partitioning more energy to microbial mass. This was also supported by greater PF values for commercial than improved haulms. Microbial biomass production estimated at substrate specific $t^{1}/_{2}$ was on the average greater than when estimated at 24 h.

Table 6: Half time ($t^{1}/_{2}$) concentrations of short-chain fatty acids (SCFA, mmol/l) of cowpea haulms during incubation.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Acetate	26.57	28.11	30.30	30.79	0.429	0.021	<0.001	<0.001	0.228
Propionate	6.50	6.66	7.37	7.63	0.138	0.139	<0.001	<0.001	0.722
Iso-Butyrate	0.46	0.45	0.49	0.44	0.022	0.186	0.002	0.576	0.403
n-Butyrate	5.21	5.06	3.94	3.63	0.189	0.229	<0.001	<0.001	0.671
Iso-Valerate	0.97^{a}	0.79^{b}	0.75^{bc}	0.67^{c}	0.024	<0.001	<0.001	<0.001	0.036
n-Valerate	0.48^{a}	0.39^{c}	0.44^{b}	0.43^{b}	0.011	<0.001	<0.001	0.774	<0.001
Total SCFA	40.21	41.46	43.3	43.6	0.539	0.153	0.023	<0.001	0.381
Acetate:Propionate (mol/mol)	4.12	4.22	4.13	4.08	0.050	0.606	<0.001	0.183	0.164

Means with different letters within rows differ (*P*<0.05).
[1]H(Group), haulms within group.

Table 7: Twenty-four hour (24 h) concentrations of short-chain fatty acids (SCFA, mmol/l) of cowpea haulms during incubation.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
Acetate	29.71^{c}	34.19^{b}	37.36^{a}	38.27^{a}	0.442	<0.001	<0.001	<0.001	<0.001
Propionate	7.57	8.53	9.73	10.20	0.170	<0.001	<0.001	<0.001	0.164
Iso-Butyrate	0.58	0.57	0.82	0.73	0.028	0.126	0.002	<0.001	0.149
n-Butyrate	6.18	6.45	5.11	4.85	0.268	0.989	<0.001	<0.001	0.336
Iso-Valerate	1.32	1.23	1.43	1.23	0.043	<0.001	<0.001	0.227	0.157
n-Valerate	0.61	0.59	0.75	0.70	0.019	0.103	0.045	<0.001	0.461
Total	45.99^{c}	51.57^{b}	55.19^{a}	55.99^{a}	0.618	<0.001	<0.001	<0.001	<0.001
Acetate:Propionate (mol/mol)	3.95	4.03	3.85	3.79	0.051	0.821	<0.001	<0.001	0.150

Means with different letters within rows differ (*P*<0.05).
[1]H(Group), haulms within group.

The trend observed in ivADDM and ivTDDM was also noticed in microbial biomass production as values from haulms harvested during the dry season were greater than those harvested during the wet season. The achievement of maximum ruminal feed conversion into microbial biomass is a widely accepted concept of ruminant nutrition because high microbial efficiency improves microbial protein supply to the small intestine and, proportionally, reduces fermentative gaseous carbon losses (Beever, 1993).

At both time intervals, improved cowpea haulms had greater protozoa population than commercial haulms. Expectedly, improved cowpea haulms produced more methane at both time intervals. Greater fibre content of improved cowpea haulms may have contributed to its higher methane volume. Greater methane values obtained at 24 h than at substrate specific $t^1/_2$ was expected because of the extended period of time which will increase the amount of substrate degraded. Methane production was greater during the dry season at both time intervals. Methane is an estimate of the relative energy loss during fermentation.

The main component affecting methane production is the type of carbohydrate and relative rate of fermentation. Johnson and Johnson (1995) showed that there was decreased methane production with increased energy intake, when expressed relative to gross energy. Van Soest (1994) indicated that a high grain diet and/or the little addition of soluble carbohydrate with resulting shift in the fermentation pattern in the rumen are associated with hostile environment for methanogens in which passage rates are increased, ruminal pH is lowered and certain population of protozoa, ruminal ciliates and methanogens may be eliminated or inhibited. This was not the case with the cowpea haulms especially the improved haulms which had greater fibre concentration.

The PF of the cowpea haulms (3.09 – 4.36) at substrate specific $t^1/_2$ and (2.79 – 3.97) after 24 h were within the theoretical range of 2.75 – 4.41 for feedstuffs, reflecting adenosine triphosphate (Y_{ATP}) of 10 – 32 mg, and Y_{ATP} of 32 mg is considered to be maximum microbial efficiency (Blümmel et al., 1997a). This implied that the haulms produced enough ATP for microbial growth. Greater PF values for commercial haulms were reflected in their greater microbial mass compared with improved haulms. The concept of the PF value is based on the stoichiometrical relationship between SCFA and gas volumes and on the fact that well-defined amounts of substrate in terms of carbon (C), hydrogen (H) and oxygen (O) are needed for the formation of SCFA and fermentative CO_2, CH_4 and H_2O (Blümmel et al., 1997b).

In vitro feed N partitioning, microbial N and utilizable CP in the duodenum

The N compounds of commercial cowpea haulms were more degradable in the rumen than that of the improved cowpea haulms which resulted in greater ammonia N concentrations observed in the former at both time intervals. Maximizing the utilization of rumen degraded N and its conversion into microbial protein is a key objective of protein feeding strategies. The RDN at substrate specific $t^1/_2$ and 24 h were similar. Whilst the rumen presents advantages, particularly when animals are offered low quality feeds, it can be a major cause of inefficiency of N utilization in ruminants. Determination of microbial CP degradability is thus important in formulating a sound supplementation strategy for efficient utilization of basal as well as supplementary diet components (Singh et al., 2005).

The microbial N content observed with the cowpea haulms followed the same trend observed in the ammonia N. On the average, commercial haulms had greater microbial N values than the improved varieties. Over half of the amino acids absorbed by ruminants, and often two-third to three-quarters, are derived from microbial protein (Agricultural and Food Research Council, 1992). The greater N content of commercial cowpea haulms may have contributed to greater ammonia N and microbial N concentrations for these haulms. The improved variety of the cowpea haulms had greater uCP values than their commercial counterpart. The greater uCP values for improved cowpea haulms may be due to the fact that they were less degraded in the rumen and thereby were able to deliver moderate amounts of ruminally undegraded CP to the small intestine.

Short chain fatty acids production

The amount of SCFA was about 10 units lower at substrate specific $t^1/_2$ compared with 24 h but the relative proportions of individual SCFA were similar at both time intervals. The fact that improved cowpea haulms had greater SCFA concentration than the commercial haulms confirmed previous report that microbial mass and SCFA are inversely related (Hungate, 1966). The cowpea haulms tended to produce greater proportion of acetate with the ratio of acetate to propionate ranging from 3.79 to 4.22. The acetate to propionate ratio was marginally lower in the dry season.

Conclusions

Although the cowpea haulms are fibrous materials, the results of the in vitro degradability study showed they were effectively utilized by the rumen microbes which will result in the supply of energy and amino acids to the host. On the basis of CP content, microbial mass and PF, the commercial cowpea haulms varieties performed better while on the basis of SCFA production and uCP, improved varieties of the cowpea haulms were better. In conclusion, both improved and commercial haulms can be effectively utilized as supplements to low quality forages or as a basal diet for lactating dairy cattle during the dry season.

References

Agricultural and Food Research Council, 1992. Nutritive requirements of ruminant animals: protein. Nutr. Abstr. Rev., Series B 62, 787-835.

Anele, U.Y., Arigbede, O.M., Südekum, K.-H., Ike, K.A., Oni, A.O., Olanite, J.A., Amole, G.A., Dele, P.A., Jolaosho, A.O., 2010. Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of West African dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season. Anim. Feed Sci. Technol. 159, 10-17.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

AOAC, 1997. Official Methods of Analysis, 16th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Beever, D.E., 1993. Ruminant animal production from forages: present position and future opportunities. In: Baker, M.J. (Ed.), Grasslands for Our World. SIR Publishing, Wellington, New Zealand, pp. 158-164.

Blümmel, M., Makkar, H.P.S., Becker, K., 1997a. In vitro gas production: a technique revisited. J. Anim. Physiol. Anim. Nutr. 77, 24-34.

Blümmel, M., Lebzien, P., 2001. Predicting ruminal microbial efficiencies of dairy ration by in vitro techniques. Livest. Prod. Sci. 68, 107-117.

Blümmel, M., Steingass, H., Becker, K., 1997b. The relationship between in vitro gas production, in vitro microbial biomass yield and N^{15} incorporation and its implications for the prediction of voluntary feed intake of roughages. Br. J. Nutr. 77, 911-921.

Cabrita, A.R.J., Dewhurst, R.J., Abreu, J.M.F., Fonseca, A.J.M., 2006. Evaluation of the effects of synchronising the availability of N and energy on rumen function and production responses of dairy cows – a review. Anim. Res. 55, 1-24.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Curbois, C., 1999. Livestock to 2020: The Next Food Revolution. IFPRI 2020 Vision Food, Agriculture and Environment Discussion Paper 28, IFPRI, Washington, DC, USA.

Demeyer, D., De Meulemeester, M., De Graeve, K., Gupta, B.W., 1988. Effect of fungal treatment on nutritive value of straw. Med. Fac. Landbouww. Rijksuniv. Gent 53, 1811-1819.

FAO, 2000. FAOSTAT Database. http://apps.fao.org. FAO, United Nations, Rome, Italy.

Hungate, R.E., 1966. The Rumen and its Microbes. Academic Press, NY, USA.

Johnson, K.A., Johnson, D.E., 1995. Methane emissions from cattle. J. Anim. Sci. 73, 2483-2492.

Lebzien, P., Voigt, J., 1999. Calculation of utilizable crude protein at the duodenum of cattle by two different approaches. Arch. Anim. Nutr. 52, 363-369.

Menke, K.H., Steingass, H., 1988. Estimation of the energetic feed value obtained from chemical analysis and gas production using rumen fluid. Anim. Res. Dev. 28, 7-55.

NRC (National Research Council), 1985. Nutrient Requirements of Sheep. 6th edition, National Academy of Science, Washington, DC, USA.

Ørskov, E.R., McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. (Camb.) 92, 499-503.

SAS®, 2002. User's guide: Statistics, Version 9.1. SAS Institute, Inc. Cary, NC, USA.

Singh, B., Sahoo, A., Sharma, R., Bhat, T.K., 2005. Effect of polyethylene glycol on gas production parameters and nitrogen disappearance of some tree forages. Anim. Feed Sci. Technol. 123-124, 351-364.

Steingass, H., Nibbe, D., Südekum, K.-H., Lebzien, P., Spiekers, H., 2001. Schätzung des nXP-Gehaltes mit Hilfe des modifizierten Hohenheimer Futterwerttests und dessen Anwendung zur Bewertung von Raps- und Sojaextraktionsschroten. 113. VDLUFA-Kongress Berlin, Kurzfassung der Vorträge. p. 114.

Tylutki, T.P., Fox, D.G., Durbal, V.M., Tedeschi, L.O., Russell, J.B., Van Amburgh, M.E., Overton, T.R., Chase, L.E., Pell, A.N., 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174-202.

Van Soest, P.J., 1994. Nutritional Ecology of the Ruminant (2nd. ed.). Comstock Publishing Associates/Cornell University Press, Ithaca, NY, USA.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

CHAPTER 5

Chemical composition, rumen degradability and protein fractionation of some commercial and improved cowpea (*Vigna unguiculata* L. Walp) haulm varieties

Introduction

In Nigeria, out of the total meat supply from the domestic sources, cattle accounts for 45%, sheep and goats 35% and 20% from pigs and poultry (Nuru, 1988). Ruminant animal production systems in Sub-Saharan African (SSA) countries are generally characterized by limitations posed by non-availability of year-round feed resources due to prolonged annual dry season. Delgado *et al.* (1999) estimated that the demand for meat and milk in developing and SSA countries is likely to double in the next 20 years as a result of growth in human population and incomes.

Fodder, the major input in livestock rearing, is cultivated on an estimated four percent of the total cultivable land in Nigeria and this figure has remained more or less static for the last three or more decades (Delgado *et al*., 1999). The ever increasing human population in SSA countries has pushed demands for food grains and other cash crops up considerably leading to large hectarages being planted to such crops. This has resulted in smaller areas left for fodder or forage production (Delgado *et al.,* 1999). The denuded grasslands, forest openings and the forests are major sources of herbage for livestock feeding (Sumberg, 2002).

One of the biggest challenges to researchers in the sub-Saharan African countries is the provision of adequate feed for ruminant animals, especially during the dry season, unlike in the rainy season when there are abundant forages with fairly high nutrient quality. As indicated by the FAO (1997) report, large increases in animal production can be achieved by alterations to the feed base (FAO, 1997). According to the report, animal production could be increased about five times above the present level, by providing the critical catalytic nutrients that are deficient in their diets and by balancing the available nutrients closer to requirements.

Animal productivity could be increased by the introduction of low cost technologies that would improve the current systems of management. Acceptable and successful feeding systems are described as those that are simple, practical, consistently reproducible and within the limits of the farmer's resources (Douthwaite, 2002). This underscores the importance of dual purpose crops that provide food (grain) and feed (residues) in meeting household needs under the current and foreseeable future scenarios (Delgado *et al*., 1999).

Cowpea has the potential to function as a key integrating factor in intensifying systems through supplying protein in human diets, and fodder for livestock, as well as bringing N into the farming system through fixation (FAO, 2000). Going beyond its importance for food and feed, cowpea can be regarded as a fulcrum of sustainable farming in regions characterized by systems for farming that make limited use of purchased inputs (Anele et al., 2010). Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total. Two countries – Nigeria and Niger – produce 850,000 and 271,000 tonnes annually or, together, 49% of the world crop (FAO, 2000). The bulk of this production comes from smallholder farmers in semiarid zones of the region.

This study investigated the seasonal chemical composition, in sacco degradation of major nutrients and protein fractionation of three improved and commercial varieties of cowpea haulms.

Materials and methods

Experimental site

The field experiment was conducted at the Teaching and Research Farm, University of Agriculture, Abeokuta (UNAAB), Ogun State, Nigeria. The site lies within the savanna agro-ecological zone of south-western Nigeria (latitude: 7°N, longitude 3.5°E, average annual rainfall: 1037 mm). Abeokuta has a bimodal rainfall pattern that typically peaks in July and September with a break of two to three weeks in August. Temperatures are fairly uniform with daytime values of 28 to 30^{o}C during the rainy season and 30 to 34°C during the dry season with the lowest night temperature of around 24°C during the harmattan period between December and February. Relative humidity is high during the rainy season with values between 63 and 96% as compared to dry season values of 55 to 84%. The temperature of the soil ranges from 24.5 to 31.0°C (Source: Agrometeorology Department, UNAAB).

Forage establishment and management

The experimental area, measuring 2600 m^2, was ploughed twice and harrowed. The area was divided into eight blocks and each block was sub-divided into 10 plots each measuring 5 x 4 m^2. Three improved (*i.e.*, IITA 97k-1069-6, IITA 98k-311-8-2, IITA 98k-476-8; hereafter designated ITA-6, ITA-2 and ITA-8) and three commercial (*i.e.*, “Oloyin”, “Peu”, “Sokoto”) dual-purpose cowpea varieties constituted the treatments. The dual-purpose cowpea varieties were semi-erect type and had days to pod maturity of 70 – 86 days. The improved varieties were modified for greater agronomical (biomass and grain) yield.

Treatments were randomly allocated to plots within block. The inner 6 blocks (36 plots) were selected for sampling to avoid border effect. Samples collected from 2 blocks were bulked together to constituted one field replicate. As a result, 3 field replicates were obtained from the 6 blocks. The cowpea was planted in rows 0.4 m wide with a 0.3 m plant spacing in May, 2007. The experimental area was maintained weed-free throughout the first month to reduce competition. The cowpea formed a tight canopy within a short period after planting which smothered weeds. Grains were harvested approximately three months after planting to represent wet season. The haulms, comprising of the vine, leaves and roots were later uprooted, manually rolled and chopped into particles of 2 to 4 cm lengths and milled with a hammer mill (Model DFZH-Bühler AG, Uzwil, Switzerland) using a 2.5 mm sieve. A lot of leaves were lost in the process of drying the haulms harvested during the wet season because of rainfall. The second planting was carried out in August and harvested in November, 2007 to represent dry season.

Animals and diet

Three 12-year old German Red Pied steers, with a mean live weight of 1300 kg were utilized in the experiment. Each steer was fitted with a 10 cm internal diameter ruminal cannula (Model 1C, Bar Diamond, Parma, ID, USA) and housed indoors in a stall in a temperature controlled room (18°C). The steers received a mixed diet consisting of 6 kg maize silage, 2 kg hay and 2 kg mixed concentrates. Animals were fed the diets to meet their maintenance requirement (Agricultural Research Council, 1980). The daily allotment of feed was offered in two equal meals at 07:00 and 19:00 hours. The steers had continuous access to water during the experiment. Prior to the experiment, a period of two weeks was allowed for dietary adaptation.

In situ procedure

Samples of milled haulms (about 5 g) were weighed into polyester bags (R510, Ankom Technology, Fairport, NY, US) with pore size 50±15 µm. Duplicates samples of each variety were incubated in the rumen of the three steers. The bags were tied to an 800 g cylindrical plastic weight with 20 cm cable binders. All bags were inserted into the ventral sac of the rumen at 07:00 hours, immediately before the morning feeding. Incubation periods were 6, 12, 24, 48, 72, 96 and 336 h. At the end of each incubation period, bags were removed and immersed in ice to stop further microbial activity and then washed for 30 min on a cold rinse cycle in a washing machine. Zero time disappearance values (0 h) were obtained by washing pre-soaked, unincubated bags in a similar fashion.

Water-soluble material (WS) was estimated by washing duplicate samples through a folded filter paper (No. $595^{1/2}$, Schleicher and Schuell, Dassel, Germany). All washed bags and filter paper residues were freeze-dried. Water-insoluble OM and CP escaping in small particles (SP) from the bags during washing were estimated by subtracting water-soluble OM and CP from 0-h values. The single values obtained for CP disappearances (DIi) were then corrected (C) for SP by the equation (Weisbjerg et al., 1990):

$CDI_i = DI_i - SP \times (1 - ((DI_i - (SP + WS))/(1 - (SP + WS))))$.

Degradation of OM and CP (CDEG) was calculated using the equation of McDonald (1981):

$CDEG = a + b\ (1 - e^{-c\ (t - L)})$ for $t > L$,

where CDEG = disappearance at time t corrected for SP, a = an intercept representing the proportion of OM and CP solubilized at initiation of incubation (time 0; soluble fraction), b = the fraction of OM and CP insoluble but degradable in the rumen, c = a rate constant of disappearance of fraction b, t = time of incubation, and L = lag phase. The non-linear parameters a, b, c, and L were estimated by an iterative least squares procedure (SAS, 2002). The effective degradability (ED) of OM and CP was calculated using the following equation (McDonald, 1981):

$ED = a + (bc/(c + k)) \times e^{-k\ L}$,

where k is the estimated rate of outflow from the rumen and a, b, c, and L are the same parameters as described earlier. The ED of OM and CP was estimated as ED2, ED4 and ED6 assuming rumen solid outflow rates of 2, 4, and 6% per h, which is representative for low, medium, and high passage rate for forages. The in sacco ruminally undegraded fraction was estimated by subtracting the ED from 100 (100-ED).

Correction for microbial attachment (A) (% residue N) to undegraded particles was carried out according to Krawielitzki et al. (2006) using the exponential equation:

$$A = A_{max}\ (1 - e^{-Ct}),$$

where Amax is the maximum extent of bacterial contamination at $t \approx \infty$, C is the rate of contamination (% h-1) and t denotes the incubation time (h). Amax was estimated by treating a subsample of the residue with neutral detergent solution (NDS) (t > 16 h) with the assumption that the residues only contained cell wall bound protein (NDIN) and microbial matter was ND soluble. Duplicates of 0.5 g were boiled for 1 hour in NDS, rinsed thoroughly with distilled water, reweighed and analysed for CP. The difference in CP between pre- and post NDS treated residues was taken as microbial CP. The mean from the 24, 48, 72, 96 and 336 h residues was used as the Amax parameter. The rate of microbial attachment (C) was calculated as:

$$C\ (\%\ h^{-1}) = 13.3 + 0.09\ NDF - 0.35\ CP$$ (Krawielitzki et al., 2006).

Crude protein fractionation

Crude protein fractions of samples were partitioned into five fractions according to the Cornell net carbohydrate and protein system (Sniffen et al. 1992) modified according to Licitra et al. (1996). These are fraction A, non protein nitrogen (NPN), it was calculated as the difference between total nitrogen and true CP nitrogen precipitated with sodium tungastate (0.30 M) and 0.5 M sulfuric acid; fraction B_1, buffer soluble protein, it was calculated as the difference between true CP nitrogen and insoluble CP nitrogen and was estimated with borate-phosphate buffer (pH 6.7-6.8) and freshly prepared 10 % sodium azide solution. Fraction B_2, neutral detergent soluble CP (NDSCP), was calculated as the difference between insoluble CP nitrogen and CP insoluble in neutral detergent while fraction $B_{3,}$ acid detergent soluble CP, was calculated as the difference between NDSP and acid detergent insoluble CP. Fraction C is assumed to be indigestible. All fractions, including CP, were analysed in triplicate and the N content determined by Kjeldahl procedure.

Chemical analyses

Feed samples were successively ground in mills with 3 and 1 mm sieves to determine the chemical composition. Prior to milling, samples were oven-dried at 60^{o}C for 96 h while DM was determined by oven-drying at 100^{o}C for 24 h. Total nitrogen (N) was estimated by combustion assay (LECO Instrument, Monchengladbach, Germany), CP was expressed as N x 6.25, ash (ID 942.05) and ether extract (EE) (ID 963.15) were analysed according to the standard methods of AOAC (1990). Neutral detergent fibre (NDFom) was determined according to Van Soest et al. (1991) without use of α-amylase or sodium sulphite and expressed without residual ash. Acid detergent fibre (ADF) was analyzed according to AOAC (1997; method 973.18) and expressed exclusive residual ash. Lignin(sa) was determined by solubilisation of cellulose with sulphuric acid in the ADF residue (Van Soest et al., 1991). Non-fibre carbohydrates (NFC) were calculated as:

NFC = 1000 - CP - ash - EE – NDF, with all variables expressed as g/kg DM.

Statistical analysis

Data were subjected to analysis of variance using the GLM procedure of SAS (2002) in a 2 x 2 x 2 factorial arrangement with 3 field replicates. The model used was:

$$Y_{ijklm} = \mu + G_i + H_j(Gi) + S_k + (GS)_{ik} + \varepsilon_{ijklm}$$

Where: Y_{ijklm} = observation, μ = population mean, G_i = group effect (improved *versus* commercial) (i = 1 to 2), $H_j(G_i)$ = haulms within group effect, S_k = season effect (k = 1 to 2), $(GS)_{ik}$ = interaction between group and season, and ε_{ijklm} = residual error.

Means were then compared by applying the probability of difference (PDIFF) option of the least squares means statement in the GLM procedure. Differences among means with $P<0.05$ were accepted as representing statistically significant differences. Probability values less than 0.001 are expressed as '$P<0.001$' rather than the actual value.

Results

Chemical composition

Group x season interactions were observed for CP, lignin and hemicellulose contents of the cowpea haulms. Crude protein content of the cowpea haulms was greater ($P<0.001$) in the commercial cowpea haulms and during the dry season (Table 1). The NDF content though not significant (group x season) was greater (P<0.05) in the improved than commercial haulms with values of 612 vs 569 and 403 vs 379 g/kg DM during the wet and dry seasons, respectively. Despite their high fibre contents, haulms from both cowpea varieties contained significant amounts of NFC.

Nonlinear parameter estimates and effective degradability values

Nonlinear parameters estimates and effective degradability values of OM and CP of the cowpea haulms are shown in Tables 2 and 3, respectively. Group x season interactions were observed for the insoluble but degradable fraction 'b' and effective degradation at an outflow rate of 2% for the OM. The proportion of substrate degraded in the samples harvested in wet season was generally lower (P<0.001) than those harvested in dry season. More (P<0.05) OM was degraded in improved cowpea haulms than in commercial haulms.

The effective degradability values of the OM at all three assumed passage rates were higher (P<0.001) for improved cowpea haulms. Group x season interactions were only observed for the soluble fraction 'a' for the CP of the haulms. As observed in OM degradation, higher (P<0.001) proportions were degraded in the samples harvested in the dry season but more CP was degraded in commercial than in improved haulms. No lag time was observed in the degradation of CP. The effective degradability values of the CP at all three assumed passage rates were similar for both haulm varieties.

Table 1: Chemical composition (g/kg DM unless stated) of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[7]	Season	G x S
DM[1](g/kg)	948	942	933	931	2.3	0.114	0.241	<0.001	0.409
CP[2]	181[b]	147[c]	217[a]	212[a]	4.0	<0.001	0.633	<0.001	0.002
EE[3]	18.9	16.3	42.2	28.6	3.34	0.023	0.577	<0.001	0.116
Ash	94.3	30.5	71.4	30.5	10.35	<0.001	0.233	0.281	0.279
NDFom[4]	569	612	379	403	14.9	0.033	0.244	<0.001	0.546
ADFom[5]	399	419	208	233	15.1	0.155	0.192	<0.001	0.835
Lignin(sa)	206[a]	162[b]	107[c]	113[c]	8.1	0.028	0.011	<0.001	0.003
Hemicellulose	169[b]	193[a]	171[b]	170[b]	5.4	0.041	0.604	0.045	0.030
Cellulose	194	257	101	120	11.9	0.002	0.330	<0.001	0.072
NFC[6]	136	193	289	325	12.7	<0.001	0.088	<0.001	0.405

Means with different letters within rows differ ($P<0.05$).

[1]DM, dry matter.

[2]CP, crude protein.

[3]EE, ether extract.

[4]NDFom, neutral detergent fibre expressed exclusive residual ash.

[5]ADFom, acid detergent fibre expressed exclusive residual ash.

[6]NFC, non-fibre cabohydrates.

[7]H(Group), haulms within group.

Table 2: Nonlinear estimates and effective degradability coefficients of organic matter of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
a[2]	0.02	0.04	0.13	0.17	0.007	<0.001	0.051	<0.001	0.065
b	0.30[c]	0.37[b]	0.56[a]	0.56[a]	0.018	0.046	0.628	<0.001	0.036
c	0.019	0.026	0.056	0.053	0.0029	0.607	0.367	<0.001	0.073
lag	2.25	1.78	0.01	0.62	0.536	0.896	0.183	0.003	0.321
ED (2%)[3]	0.16[c]	0.23[b]	0.54[a]	0.57[a]	0.011	<0.001	0.011	<0.001	0.037
ED (4%)	0.11	0.17	0.46	0.48	0.009	<0.001	0.003	<0.001	0.052
ED (6%)	0.08	0.13	0.40	0.43	0.008	<0.001	<0.001	<0.001	0.079
Undegraded	0.68	0.59	0.31	0.26	0.016	<0.001	0.140	<0.001	0.116

Means with different letters within rows differ (*P*<0.05).

[1]H(Group), haulms within group.

[2]a = The portion of OM solubilized at initiation of incubation; b = the fraction of OM insoluble but degradable in the rumen; c = the constant rate (percentage per hour) of disappearance of fraction b; Lag = lag phase (hours) prior to the commencement of degradation of fraction b; Undegraded = 100 – (a + b).

[3]Effective degradability at three ruminal passage rates.

The CP and NFC of the haulms were positively correlated with the degradation constants in both seasons while NDF and ADL had negative relationships with the degradation constants (Table 4). A stepwise regression analysis was used to establish regression models for

Table 3: Nonlinear estimates and effective degradability coefficients of crude protein of the cowpea haulms.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
a	0.05[c]	0.04[c]	0.15[b]	0.20[a]	0.010	0.500	0.099	<0.001	0.018
b	0.40	0.34	0.50	0.42	0.014	<0.001	0.085	<0.001	0.456
c	0.015	0.019	0.046	0.041	0.0036	0.932	0.103	<0.001	0.193
lag	0	0	0	0	0	-	-	-	-
ED (2%)[3]	0.21	0.21	0.50	0.47	0.011	0.196	0.317	<0.001	0.233
ED (4%)	0.15	0.16	0.42	0.40	0.009	0.552	0.298	<0.001	0.390
ED (6%)	0.13	0.13	0.37	0.36	0.007	0.990	0.193	<0.001	0.750
Undegraded	0.55	0.61	0.35	0.38	0.013	0.002	0.003	<0.001	0.289

Means with different letters within rows differ (*P*<0.05).

[1]H(Group), haulms within group.

[2]a = The portion of CP solubilized at initiation of incubation; b = the fraction of CP insoluble but degradable in the rumen; c = the constant rate (percentage per hour) of disappearance of fraction b; Lag = lag phase (hours) prior to the commencement of degradation of fraction b; Undegraded = 100 – (a + b).

[3]Effective degradability at three ruminal passage rates.

predicting effective degradation at an assumed outflow rate of 2% (Table 5). The results showed that effective degradation could be predicted from the chemical constituents of the haulms.

Table 4: Relationships between OM degradation characteristics and chemical constituents of the cowpea haulms.

Season	Variety		CP[1]	NDF	ADL	NFC
Wet	Commercial					
		a[2]	0.19^{ns}	-0.08^{ns}	-0.01^{ns}	0.36^{ns}
		b	0.66^{ns}	-0.33^{ns}	-029^{ns}	0.01^{ns}
		c	0.14^{ns}	-0.42^{ns}	-0.60^{ns}	0.48^{ns}
		ED[3]	069*	-0.33^{ns}	-0.51^{ns}	0.24^{ns}
	Improved					
		a	0.21^{ns}	-0.10^{ns}	-0.25^{ns}	0.16^{ns}
		b	0.33^{ns}	-0.59^{ns}	-0.63^{ns}	0.69*
		c	0.09^{ns}	0.04^{ns}	-0.67*	0.10^{ns}
		ED	0.26^{ns}	-0.43^{ns}	-0.83**	0.62^{ns}
Dry	Commercial					
		a	0.36^{ns}	-0.23^{ns}	-0.43^{ns}	0.10^{ns}
		b	0.34^{ns}	-0.38^{ns}	-0.61^{ns}	0.48^{ns}
		c	0.11^{ns}	-0.50^{ns}	-0.45^{ns}	0.52^{ns}
		ED	0.25^{ns}	-0.59^{ns}	-0.86**	0.47^{ns}
	Improved					
		a	0.73*	-0.29^{ns}	-0.46^{ns}	0.75*
		b	0.59^{ns}	-0.11^{ns}	-0.15^{ns}	0.56^{ns}
		c	0.72*	0.02^{ns}	0.31^{ns}	0.59^{ns}
		ED	0.66*	-0.01^{ns}	-0.08^{ns}	0.52^{ns}

ns, non-significant; *, $P < 0.05$; **, $P < 0.01$.

[1]CP, crude protein; NDF, neutral detergent fibre; ADL, acid detergent fibre; NFC, non-fibre carbohydrates.

[2]a = The portion of OM solubilized at initiation of incubation; b = the fraction of OM insoluble but degradable in the rumen; c = the constant rate (percentage per hour) of disappearance of fraction b; Lag = lag phase (hours) prior to the commencement of degradation of fraction b; Undegraded = 100 – (a + b).

[3]ED, effective degradability.

Protein fractionation

The contents of CP fractions of the cowpea haulms are shown in Table 2. Interactions between and season were observed for all the fractions except B_1. Greatest proportions of fractions A and B_3 were observed in improved haulm varieties during the dry and wet seasons, respectively, while the commercial haulm varieties had the greatest content of fractions B_2 and C during the wet season. The proportion of degradable CP fractions (A, B_1, B_2 and B_3) ranged from 741 to 828 g/kg CP, representing between 65-79% of total CP content of the haulms.

Discussion

Chemical composition

The chemical composition of the cowpea haulms showed substantial variations across group and season. Dry matter and CP contents of the commercial cowpea haulms were greater compared to improved haulms. The CP levels in the current study are above the range of 110 - 130 g/kg DM which is adequate for maintenance and growth of small ruminants (NRC, 1985). This implied that the cowpea haulms especially the commercial haulms can be used as CP supplement to poor quality grasses during the dry season.

Fibre concentrations were greater in improved than commercial cowpea haulms. Despite the greater fibre concentration in improved haulms, significant proportion was in form of NFC and cellulose which are easily degraded unlike the commercial haulms which had greater lignin concentration.

Higher NFC contents of improved cowpea haulms indicate that they should stimulate ammonia-N utilization in the rumen better than the commercial varieties (Tylutki et al., 2008). As N utilization by rumen microorganisms is related to the amount of available fermentable energy, the NFC in the cowpea haulms could improve the efficiency of microbial protein synthesis by promoting better utilization of rumen ammonia released from feeds with high content of rumen degradable CP (Cabrita et al., 2006).

Nonlinear parameter estimates and effective degradability values

Less than 50% of the samples were degraded in samples harvested in wet season. Lower degradation observed in the wet season samples can be trace to the proportion (> 80%) of vines in the samples. Due to rainfall, significant amount of the leaves were lost, leading to lower leaf:stem. This did not affect haulms harvested during the dry season. All the haulms recorded more than 75% OM and CP degradabilities at 48 h. The fact that the haulms CP contents were not extensively degraded ruminally is good for efficient utilization of CP.

Table 5: Linear regression analysis to predict effective degradation from chemical constituents.

Season	Variety	Model	RMS[1]	r^2	*P*
Wet					
	Commercial	$ED = 0.45253 - 0.00138_{CP} - 0.00022177_{ADL}$	0.025	0.65	0.042
	Improved	$ED = 0.39851 - 0.00098473_{ADL}$	0.103	0.70	0.005
Dry					
	Commercial	$ED = 0.77334 - 0.00215_{ADL}$	0.146	0.73	0.003
	Improved	$ED = 0.14682 + 0.00233_{CP} - 0.00057763_{ADL}$	0.012	0.64	0.004

[1]RMS, root mean square.

Extensive ruminal degradation of CP results into ammonia production above the level that can be utilized for microbial protein synthesis or reabsorbed into the rumen and converted into urea then excreted in urine. This constitutes a loss to the nitrogen economy of the animal and consequently put a limit on animal production (Cabrita et al., 2006).

The trend observed in OM and CP degradabilities was in conformity with earlier in vitro study (Anele et al., 2010) in which higher OM was degraded in the improved haulms and higher CP was degraded in the commercial haulms.

The correlation analysis showed that increment in NDF and ADL contents will result in depressing effect on OM degradation of the haulms. On the contrary, increase in CP and NFC contents will result in higher OM degradation values for the haulms varieties. Effective degradability of the cowpea haulms could be predicted from the chemical constituents in both seasons. The prediction of effective degradability of the haulms was higher when only lignin

Table 6: Protein fractions (g/kg) of the cowpea haulms varieties.

	Wet season		Dry season		SEM	*P*			
	Commercial	Improved	Commercial	Improved		Group	H(Group)[1]	Season	G x S
A[2]	100[d]	185[c]	285[b]	342[a]	9.5	<0.001	0.010	<0.001	0.159
B_1	106	140	114	109	11.3	0.223	0.688	0.309	0.912
B_2	267[a]	145[b]	182[b]	159[b]	13.6	<0.001	0.789	0.016	0.001
B_3	268[b]	310[a]	223[c]	218[c]	8.9	0.047	0.185	<0.001	0.014
C	259[a]	220[b]	196[bc]	172[c]	7.8	<0.001	0.013	<0.001	0.346

Means with different letters within rows differ ($P<0.05$).

[1]H(Group), haulms within group.

[2]A, non protein nitrogen; B_1, buffer soluble protein; B_2, neutral detergent soluble protein; B_3, acid detergent soluble protein; C, indigestible protein.

was used in the model (0.73 and 0.70, compared to 0.65 and 0.64 when CP was included with root mean square of 0.146, 0.103, 0.025 and 0.012, respectively).

Protein fractionation

There has not been any report on the protein fractions of cowpea haulms, hence no comparison with any previous finding can be made. The B fractions, which is true protein (B_1, B_2 and B_3) accounted for more than half of CP in the haulms with the exception of improved haulms during the dry season. On the average, the B fractions were more in the commercial than improved varieties. The B_3 fraction, which contains a high percentage of rumen undegradable protein with degradation rate of less than 1.5%/h (Sniffen et al., 1992), was higher in the improved haulms. Higher proportion of A fraction was also observed in the improved haulms (harvested in dry season) making them suitable for feedstuffs with rapidly degradable carbohydrate to ensure synchronous release of available nitrogen and organic matter ruminally. The importance of synchronous release of available energy and nitrogen in the rumen is currently under intensive discussion. Dewhurst et al. (2000), Givens and Rulquin (2004) and Cabrita et al., (2006) described the relationship between ruminal protein and carbohydrate availability and its impact on microbial protein synthesis in the rumen and protein supply to the small intestine. Fraction C contains proteins associated with lignin, tannin-protein complexes and Maillard products that are not degradable in the rumen and are indigestible in the intestine (Krishnamoorthy et al., 1982). Higher amount of fraction C in the wet season can be linked with the extended drying period because of rainfall.

Conclusions

Results showed that adequate attention must be placed in handling of the haulms to minimize the amount of leaves lost during the wet season. Cowpea haulms harvested in the absence of rainfall and lower humidity were of higher quality than those harvested during the wet season.

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References

Agricultural Research Council, 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agric. Bureau, Farnham Royal.

Anele, U.Y., Arigbede, O.M., Südekum, K.-H., Ike, K.A., Oni, A.O., Olanite, J.A., Amole, G.A., Dele, P.A., Jolaosho, A.O., 2010. Effects of processed cowpea (*Vigna unguiculata* L. Walp) haulms as a feed supplement on voluntary intake, utilization and blood profile of

West African dwarf sheep fed a basal diet of *Pennisetum purpureum* in the dry season. Anim. Feed Sci. Technol. 159, 10-17.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

AOAC, 1997. Official Methods of Analysis, 16th ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Cabrita, A.R.J., Dewhurst, R.J., Abreu, J.M.F., Fonseca, A.J.M., 2006. Evaluation of the effects of synchronising the availability of N and energy on rumen function and production responses of dairy cows – a review. Anim. Res. 55, 1-24.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., Curbois, C., 1999. Livestock to 2020: The next food revolution. IFPRI 2020 Vision Food, Agriculture and Environment Discussion Paper 28, IFPRI, Washington.

Dewhurst, R.J., Davies, D.R., Merry, R.J., 2000. Microbial protein supply in the rumen. Anim. Feed Sci. Technol. 85, 1-21.

Douthwaite, B., 2002. Enabling innovation: a practical guide to understanding and fostering technology change. ZED Books, London & New York.

FAO, 1997. Tree foliage in animal nutrition. FAO Animal Health and Production Paper No. 139, FAO, Rome.

FAO, 2000. FAOSTAT Database. http://apps.fao.org. FAO, United Nations, Rome, Italy.

Givens, D.I., Rulquin, H., 2004. Utilisation by ruminants of nitrogen compounds in silage-based diets. Anim. Feed Sci. Technol. 114, 1-18.

Krawielitzki, K., Schmidt, Th., Voigt, J., Kowalczyk, J., Gabel, M., 2006. Dynamics of microbial contamination of protein during ruminal in situ incubation of feedstuffs. J. Anim. Feed Sci. 15, 313-328.

Krishnamoorthy, U., Muscato, T.V., Sniffen, C.J., Van Soest, P.J., 1982. Nitrogen fractions in selected feedstuffs. J. Dairy Sci. 65, 217–225.

Licitra, G., Hernandez, T.M., Van Soest, P.J., 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Anim. Feed Sci. Technol. 57, 347-358.

McDonald, P., 1981. A revised model for the estimation of protein degradability in the rumen, J. Agric. Sci. 96, 251-252.

NRC (National Research Council), 1985. Nutrient requirements of sheep. 6th edition, National Academy of Science, Washington, DC, USA.

Nuru, S., 1988. Research and development in pastoral production system in Nigeria: Past, present and future. An invited paper presented at the National Conference on Pastoralism in Nigeria held from 26 – 29th June, 1988. NAPRI, A. B. U., Zaria, Nigeria.

SAS®, 2002. User's guide: Statistics, Version 9.1. SAS Institute, Inc. Cary, NC, USA.

Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., Fox, D.G., Russel, J.B. 1992. A net carbohydrate and protein system for evaluating cattle diets II carbohydrate and protein availability. J. Anim. Sci. 70, 3562-3577.

Sumberg, J., 2002. The logic of fodder legumes in Africa. Food Policy 27, 285-300.

Tylutki, T.P., Fox, D.G., Durbal, V.M., Tedeschi, L.O., Russell, J.B., Van Amburgh, M.E., Overton, T.R., Chase, L.E., Pell, A.N., 2008. Cornell Net Carbohydrate and Protein System: A model for precision feeding of dairy cattle. Anim. Feed Sci. Technol. 143, 174-202.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

CHAPTER 6

General conclusions

General conclusions

In conclusion, biomass yield from the cowpea varieties (especially the improved ones) is a pointer to the ability of the cowpea varieties to produce sufficient biomass to meet the shortfall in seasonal supply of forage. The cowpea varieties had high crude protein and low secondary metabolite contents which make them suitable as supplements to low quality grasses prevalent in the dry season. On average, they were able to retain between 25 and 60% of their leaves. The improved varieties retained more leaves than the commercial cowpea. These dual purpose cowpea varieties can easily be grown on marginal land as it requires little or no input and will ensure sufficient biomass as supplement during the dry season while providing extra food (grains) for human consumption. The sustainability of this cropping is not yet clear. While nitrogen input can be assured by biological fixation, the long-term support of plants with further macro- and micronutrients will have to be investigated. A recycling of nutrients in terms of fertilization with dung or manure is highly recommended in order to avoid a decline in soil fertility. Also not much inference was drawn from the soil data because of the length of the study but it indicated that cowpea can do well in most of the marginal lands (which are low in pH and fertility) that are not being utilized and will help to restore such lands over time through fixation of nitrogen (Giller, 2001).

In the animal experimentation, while dry matter intake was higher in animals fed improved cowpea haulms, digestibility was not affected. Animals fed commercial cowpea haulms had better feed conversion ratio than their counterparts on improved haulms. All animals were in positive nitrogen balance. Results showed that cowpea haulms can be utilized as a supplement for livestock production and its inclusion in the diet of sheep had no deleterious effects while improving the haematological and serum biochemical variables. All blood values were within the normal reference range for animals of similar breed and age group.

Although the cowpea haulms can easily be classified as fibrous materials, the results of the in vitro degradability study showed they were effectively utilized by the rumen microbes which will result in the supply of energy and amino acids to the host. On the basis of crude protein content (CP), microbial mass and partitioning factor, the commercial cowpea haulms varieties performed better while on the basis of short chain fatty acids production and utilizable crude protein at the duodenum, improved varieties of the cowpea haulms were better.

The trend observed in organic matter (OM) and CP degradabilities was in conformity with earlier in vitro study in which higher OM was degraded in the improved haulms and higher CP was degraded in the commercial haulms. Correlation analysis showed that increase in neutral detergent fibre and acid detergent fibre contents of the haulms will result in depressing effect on OM degradation. On the contrary, increase in CP and NFC contents will result in higher OM degradation values for the haulms varieties. Effective degradability of the cowpea haulms could be predicted from the chemical constituents in both seasons. The CP fractionation of the cowpea haulms, showed that true protein accounted for more than half of CP in the haulms with the exception of improved haulms during the dry season. The acid detergent insoluble CP fraction, which contains a high percentage of rumen undegradable protein with degradation rate of less than 1.5%/h (Sniffen et al., 1992), was higher in the improved haulms.

The above results validated that cowpea haulm is an important agro-based by-product that is adequate in protein and energy to sustain ruminant animal production in Nigeria and other Sub-Saharan African countries during the extended dry season.

References

Giller, K.E., 2001. Nitrogen Fixation in Tropical Cropping Systems. 2nd edition. CAB International, Wallingford, UK.

Sniffen, C.J., O'Connor, J.D., Van Soest, P.J., Fox, D.G., Russel, J.B., 1992. A net carbohydrate and protein system for evaluating cattle diets. II. Carbohydrate and protein availability. J. Anim. Sci. 70, 3562-3577.

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Curriculum vitae

Publications:

Journal articles

U.Y. Anele, K.-H. Südekum, J. Hummel, O.M. Arigbede, A.O. Oni, J.A. Olanite, C. Böttger, V.O. Ojo, A.O. Jolaosho. 2011. Chemical characterization, in vitro dry matter and ruminal crude protein degradability and microbial protein synthesis of some cowpea (*Vigna unguiculata* L. Walp) haulms varieties. Animal Feed Science and Technology 163, 161-169.

A.O. Oni, C.F.I. Onwuka, O.M. Arigbede, **U.Y. Anele,** O.O. Oduguwa, O.S. Onifade and Z.L. Tan. 2011. Chemical composition and nutritive value of four varieties of cassava leaves grown in South-Western Nigeria. Animal Physiology and Animal Nutrition DOI: 10.1111/j.1439-0396.2010.01086.x

U.Y. Anele, O.M. Arigbede, K.-H. Südekum, K.A. Ike, A.O. Oni, J.A. Olanite, G.A. Amole, P.A. Dele and A.O. Jolaosho. 2010. Nutrient utilization and blood profile of West African dwarf sheep on cowpea (*Vigna unguiculata* L. Walp) haulms diet. Animal Feed Science and Technology 159, 10-17.

J.A. Olanite, **U.Y. Anele,** O.M. Arigbede, A.O. Jolaosho and O.S. Onifade. 2010. Effect of plant spacing and nitrogen fertilizer levels on the growth, dry-matter yield and nutritive quality of Columbus grass (*Sorghum almum* stapf) in southwest Nigeria. Grass and Forage Science 65, 369-375.

A.O. Oni, O.M. Arigbede, O.O. Oni, C.F.I. Onwuka, **U.Y. Anele,** B.O. Oduguwa and K.O. Yusuf. 2010. Effects of feeding different levels of dried cassava leaves (*Manihot esculenta*, Crantz) based concentrates with *Panicum maximum* basal on the performance of growing West African Dwarf goats. Livestock Science 129, 24-30.

A.O. Oni, C.F.I. Onwuka, O.M. Arigbede, O.O. Oni, **U.Y. Anele,** K.O. Yusuf, B.O. Oduguwa and O.S. Onifade. 2010. Chemical composition and in sacco degradability of four varieties of cassava leaves grown in southwestern Nigeria in the rumen of sheep. Tropical Animal Health Production 42, 1385-1393.

U.Y. Anele, O.M. Arigbede, K.-H. Südekum, A.O. Oni, A.O. Jolaosho, J.A. Olanite, A.I. Adeosun, P.A. Dele, K.A. Ike and O.B. Akinola. 2009. Seasonal chemical composition, *in* *vitro* gas production and *in sacco* dry matter degradability of four indigenous multipurpose tree species in Nigeria. Animal Feed Science Technology 154, 47-57.

U.Y. Anele, O.M. Arigbede, J.A. Olanite, I.O. Adekunle*, A.O. Jolaosho, O.S. Onifade and A.O. Oni. 2008. Early growth and seasonal chemical composition of three indigenous multipurpose tree species (MPTS); *Moringa oleifera, Millettia griffoniana* and *Pterocarpus santalinoides* in Abeokuta, Nigeria. Agroforestry systems 73, 89-98.

O.M. Arigbede, **U.Y. Anele,** B.O. Oduguwa, O.A. Jolaosho, J.A. Olanite and O.S. Onifade. 2008. Replacement value of corn offal with soybean haulms meal in the diets of West African Dwarf goats. Arch. Zootec. 57 (219), 369-372.

A.O. Jolaosho, **U.Y. Anele,** O.M. Arigbede, J.A. Olanite and O.S. Onifade. 2007. Effects of growth habits of legumes on weed population in grass/legume mixed swards. Arch. Zootec. 58 (221), 133-136.

O.M. Arigbede, **U.Y. Anele,** A.O. Jolaosho, O.S. Onifade, J.A. Olanite and T.A. Wahab. 2008. Seasonal chemical composition and *In vitro* gas production of African Bread fruit (*Treculia africana*) var. Deene. Arch. Zootec. 57 (218), 113-121.

O.M. Arigbede, **U.Y. Anele,** J.A. Olanite, I.O. Adekunle, O.A. Jolaosho, and O.S. Onifade. 2006. Seasonal *in vitro* gas production parameters of three multi - purpose tree species in Abeokuta, Nigeria. Livestock Research for Rural Development. Volume 18, Article #142. Retrieved October 19, 2006, from http://www.cipav.org.co/lrrd/lrrd18/10/arig18142.htm

O. Oni, C. F. I. Onwuka, O. O. Oduguwa, O. S. Onifade, O. M. Arigbede, O. O. Oni and **U. Y. Anele**. 2006. Nutrients intake and digestibility by West African Dwarf goats fed *Enterolobium cyclocarpum* (Jacq.) Griseb. and citrus pulp – based diets. Journal of Animal and Veterinary Advances 5, 828-831.

A.H. Akinmutimi, A. Usman and **U.Y. Anele**. 2002. Acute toxicity studies of raw *Mucuna utilis* extracts using broiler chicks. J. Appl. Chem. & Agric. Res. 8, 73-76.

Conference proceedings:

U.Y. Anele, J. Hummel, O.M. Arigbede, C. Böttger and K.-H. Südekum. 2010. Chemical composition and nutritive value of some cowpea (Vigna unguiculata L. Walp) haulm varieties. Joint Annual Conference, Denver, Colorado. July 11-15, 2010. J. Anim. Sci. Vol. 88, E-Suppl. 2, W118.

Olanite, J. A., A. O. Jolaosho, O. M. Arigbede, O. S. Onifade and **U. Y. Anele** (2008). Persistence of *Chamaerista rotundifolia* (Wynn) in *Panicum maximum* (Ntchisi) under varying spacing and legume planting methods. Eds Organizing Committee of 2008 IGC/IRC Conference, China. June 29 - July 4 2008. P 729.

Jolaosho, A. O. Oduguwa, B. O. Arigbede, O. M. Olanite, J. A. Onifade, O. S. **U. Y. Anele** and Amole, G. A. (2008). Effects of ingestion by cattle on germinability of seeds of three different browse plants. Eds Organizing Committee of 2008 IGC/IRC Conference, China. June 29 - July 4 2008. P 552.

O. S. Onifade, T. A. Amole, A. O. Jolaosho, O. M. Arigbede, J. A. Olanite, **U. Y. Anele** and A. M. Oyeladun (2008). Effects of sowing methods and seeding rates on chemical composition of *Tephrosia bracteolata*. Eds Organizing Committee of 2008 IGC/IRC Conference, China. June 29 - July 4 2008. P.568.

U. Y. Anele, A. O. Jolaosho, O. S. Onifade, O. M. Arigbede and J. A. Olanite. 2007. Effects of growth habits of legumes on weed population in grass/legume mixed swards. Proceedings 32nd Annual conference of Nigerian Society of Animal Production, March 18 – 21 (2007) University of Calabar, Cross River State. pp. 252-254.

O. M. Arigbede, **U. Y. Anele,** O. A. Jolaosho, J. A. Olanite and O. S. Onifade. 2007. Seasonal chemical composition, dry matter, organic matter and crude protein of some indigenous multi – purpose tree species by West African dwarf goats. Proceedings of an International Forage Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand. pp. 344-350.

O. M. Arigbede, **U. Y. Anele,** O. A. Jolaosho, O. S. Onifade, J. A. Olanite and T. A. Wahab. 2007. Seasonal chemical composition and *in vitro* gas production of African Bread fruit

(*Treculia africana* var. Decne). Proceedings of an International Forage Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand. pp. 338-343.

A. O. Jolaosho, B. O. Oduguwa, O. M. Arigbede, **U. Y. Anele,** T. A. Amole, O. S. Onifade, J. A. Olanite and R. O. Ojo. 2007. Effects of different temperature regimes on the viability of rain tree (*Albizia* saman) seeds. Proceedings of an International Forage Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand. pp. 332-337.

U. Y. Anele, O. M. Arigbede, J. A. Olanite, I. O. Adekunle, A. O. Jolaosho and O. S. Onifade. 2006. Green leaf retention and seasonal chemical composition of three indigenous multipurpose tree species: *Moringa oleifera, Millettia griffoniana* and *Pterocarpus santalinoides* in Abeokuta, Nigeria. 8th British Grassland Research Conference, 4 – 6 September, Cirencester, UK. pp. 81-82.

O. Jolaosho, **U. Y. Anele,** O. S. Onifade, O. M. Arigbede and J. A. Olanite. 2006. Comparative study of the growth rate and smothering effect of six grasses in grass/legume mixtures. 8th British Grassland Research Conference, 4 – 6 September, Cirencester, UK. pp. 83-84.

O. Jolaosho, O. S. Onifade, M. O. Arigbede, J. A. Olanite, **U. Y. Anele** and L. Raheem. 2006. Recovery rates and germinability of seeds from *A. saman* pods fed to cattle as dry season feeds. 8th British Grassland Research Conference, 4 – 6 September, Cirencester, UK. pp. 1-2.