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Influence of age at harvest on the organic nutrients degradability of shrub and tree forage plants by West African dwarf sheep

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Abstract

The harvesting stage of forage plants has been identified as one of the major factors influencing feed intake and digestibility. However, most of the studies in the literature surrounding harvest stage effects are conceptualized for herbaceous grasses and legumes, while shrubs and tree plants like Tephrosia bracteolata and Gmelina arborea are left out, leaving out a research area that is yet to be explored. This study therefore evaluated the chemical composition and nutrient degradability (dry matter, crude protein and neutral detergent fibre) of T. bracteolata and G. arborea harvested at different ages. The chemical composition of the plants were determined at each harvest stage, following which three West African dwarf rams carrying permanent cannula were used for the degradability trials. The plants were harvested at 8, 12, 16 and 20 weeks after planting (WAP) and incubated in the rumen of fistulated rams for 48 hours, after which the dry matter, crude protein and neutral detergent fibre degradability were determined. Collected data was analysed using two way analysis of variance. Results showed that as the plant aged, the crude protein contents decreased (P<0.05) while the fibre fractions increased. The DM degradability values of 29.68 to 55.37 % were recorded for T. bracteolata with the least and highest values recorded at 20 and 8 WAP respectively. The same observation was recorded for G. arborea. Highest potential crude protein degradation (CPD) was recorded at 12 WAP for T. bracteolata (75.79 %) and G. arborea (59.68 %). The highest (P<0.05) potential neutral detergent fibre degradation was recorded at 16 WAP for T. bracteolata (76.77 %) and at 8 WAP for G. arborea (48.63 %). This study concluded that T. bracteolata should be harvested at 12 – 16 WAP as protein supplement while G. arborea plants may be supplied to ruminants as supplementary diets during dry season to augment poor quality feed available during the period.

Keywords: *Fistulation, Gmelina arborea*, nutrients degradation, *Tephrosia bracteolata,* ruminants

Influence de l'âge à la récolte sur la dégradabilité des éléments nutritifs organiques des plantes fourragères arbustives et arborées par les moutons nains d'Afrique de l'Ouest

Résumé

Le stade de récolte des plantes fourragères a été identifié comme l'un des principaux facteurs influençant la consommation alimentaire et la digestibilité. Cependant, la plupart des études *dans la littérature concernant les effets du stade de récolte sont conceptualisées pour les graminées herbacées et les légumineuses, tandis que les arbustes et les plantes arborescentes comme Tephrosia bracteolate et Gmelinaarborea ont été laissés de côté, laissant de côté un domaine de recherche qui reste à explorer. Cette étude a donc évalué la composition chimique et la dégradabilité des nutriments (matière sèche, protéines brutes et fibres détergentes neutres) de T. bracteolata et G. arborea récoltées à différents âges. Les compositions chimiques des plantes ont été déterminées à chaque étape de récolte, puis trois béliers nains d'Afrique de l'Ouest portant une canule permanente ont été utilisés pour les essais de dégradabilité. Les plantes ont été récoltées à 8, 12, 16 et 20 semaines après la plantation (SAP) et incubées dans le rumen de béliers fistulés pendant 48 heures, après quoi la dégradabilité de la matière sèche, des protéines brutes et des fibres au détergent neutre a été déterminée. Les données recueillies ont été analysées à l'aide d'une analyse de variance à deux voies. Les résultats ont montré qu'à mesure que la plante vieillissait, la teneur en protéines brutes diminuait (P<0,05) tandis que les fractions de fibres augmentaient. Les valeurs de dégradabilité de DM de 29,68 à 55,37 % ont été enregistrées pour T. bracteolata avec les valeurs les plus faibles et les plus élevées enregistrées à 20 et 8 SAP respectivement. La même observation a été enregistrée pour G. arborea. La dégradation potentielle la plus élevée des protéines crues (DPC) a été enregistrée à 12 SAP pour T. bracteolata (75,79 %) et G. arborea (59,68 %). La dégradation potentielle la plus élevée (P<0,05) des fibres détergentes neutres a été enregistrée à 16 SAP pour T. bracteolata (76,77 %) et à 8 SAP pour G. arborea (48,63 %). Cette étude a conclu que T. bracteolate devrait être récolté entre 12 et 16 SAP comme complément protéique tandis que les plantes de G. arborea peuvent être fournies aux ruminants comme compléments alimentaires pendant la saison sèche pour augmenter les aliments de mauvaise qualité disponibles pendant la période.*

Mots clés: Fistulation, Gmelinaarborea, Dégradation des nutriments, Tephrosia bracteolata, ruminants

Introduction

Lack of balance feed for ruminants during the dry season is a major concern to livestock farmers. This is because of the decline in quality and quantity of forages from the natural pastures that supply the bulk of the feed for ruminants. This condition eventually leads to series of ill health on the animals. Legumes are commonly used to overcome the low nitrogen content of ruminant diets in tropical regions which resulted to low protein intake in human diets. Animal protein consumption in developing countries has been put at lower than 10.0 g/per day as against the minimum daily intake of 35 g recommended by Food and Agricultural Organization to be the minimum requirement for the growth and development of the body (Esobhawan *et al*., 2008). This shortage of animal protein intake among the ever-increasing human population in the under developed countries is an issue of concern to researchers and policy makers. Arigbede *et al.* (2002) reported that the role of browse trees in ruminant feeding system cannot be over emphasized. *Tephrosia bracteolata* is a leguminous shrub which is very rich in protein and is abundantly available in the rainy season being an annual plant that completes its life cycle within six months (Babayemi and Bamikole, 2006). *Gmelina arborea* is particularly notable for its fast growth, large green leaves and very high DM yield. It has been reported that the leaves and fruits can serve as feed resources for ruminant feeding (Ramachandran, 1993). Tedonkeng *et al*. (2006) observed that deficiencies in feed quality could be corrected by the addition of herbaceous legumes or multi-purpose trees to the basal diet, since they have more nutrients than most grasses and crop residues available during the dry season. These browse plants are however, low in fibre, high in crude protein and could be available all year round (Babayemi *et al.*, 2004). However, harvesting of forage species at the right stage of growth have been reported to be one of the management practices to improve nutritive values of forages (Valdes *et al.*, 1998). More so, browse plants have time of shedding their leaves in the year, and as a result, there is need to harvest the plants during the period when they have high quality and quantity, then process them, so as to feed them as protein supplements during dry season to improve animal productivity. The nylon bag technique has been identified as a rapid way for evaluation of nutritive values of feedstuffs for ruminants (Orskov *et al.*, 1980). The technique is useful in screening ruminant feeds and forage plants in particular (Arigbede *et al.*, 2002). The present study therefore seeks to evaluate the effects of age at harvest of *T. bracteolata* and *G.arborea* on ruminal degradation of organic nutrients which can be used as a supplementary feed for ruminants during the dearth period.

Materials andmethods

Experimental site

The growth experiment was carried out at the Teaching and Research Farm of the Federal University of Agriculture, Abeokuta, Ogun State (7°58'N; 3°20'E) in the savannah agro-ecology zone of south-western Nigeria. The area is characterized by a bimodal rainfall pattern that typically peaks around June and September with a break of about two to three weeks in August. The area has a mean annual rainfall of 1250 mm. The soil at the experimental site belongs to the Iwo series of the Alfisol soil order. The rumen degradability study was conducted at the International Livestock Research Institute, Ibadan, (7°30'N, 3°54'E), 200 m above sea level.

Land preparation and planting

An area of land was cleared, ploughed and harrowed. The seeds of *T. bracteolata* were scarified in 80°C for 30 seconds and air dried. The seeds of T. bracteolata were later sown at 0.5 m apart. Seedlings of *G. arborea* were transplanted from nursery pots after 28 days post planting at a spacing of two meters between plants. The plots were regularly weeded. The study was conducted in a randomized complete block design with four replicates which included two forage species (*T. bracteolata* and *G. arborea*) and four harvesting times (8, 12, 16 and 20 weeks after planting (WAP)). At every harvesting period, *T. bracteolata* was harvested at 10cm above ground level while four stands of *G. arborea* were sampled for each harvesting time. From each harvest, 300 g of sub-samples of *T. bracteolata* and *G. arborea* at different ages were oven dried at 65 °C to a constant weight for dry matter determination. The dried samples were then ground to pass through a 1 mm screen for chemical composition and 2.5mm mesh sieve for rumen degradation. Chemical composition of the samples were carried out by determination of CP, EE and ash which were determined using the procedure of AOAC (2000), while NDF, ADF and ADL were assessed by the method of Van Soest *et al.* (1991). Cellulose was taken as the difference between ADF and ADL while hemicellulose was calculated as the difference between NDF and ADF.

Rumen degradability measurement

Three adult West African dwarf (WAD) rams fitted with permanent rumen cannulae (75 mm internal diameter) weighing 24 kg, 25 kg and 26kg respectively were used for this study. The rams were kept intensively. The animals were supplemented with concentrate while *Panicum maximum*, salt lick and clean water were given *ad libitum*. The nylon bag technique as described by Orskov*et al.* (1980) was used to determine the dry matter disappearance of the two forage samples, *T. bracteolata* and *G. arborea* harvested at different harvesting stages 8, 12, 16 and 20 weeks after planting. Five grams each of grounded samples were weighed in triplicates into nylon-bag (65 mm × 140 mm) with pore size of 41 mm which were tied with a fistula line twine and were well labelled according to the incubation hour and inserted into the rumen of the rams. The 48hrs degradation bags were inserted first, followed by 24hrs, 12 hrs and 6 hrs incubation periods. At the end of the incubation period, the bags were evacuated from the rumen and rinsed immediately under running cold tap water until the rinsed water was clean to terminate fermentation. The bags were then placed on metal trays, oven dried at 65°C to constant weight to determine the loss of dry matter contents of the residues. To determine degradation characteristic constants, the data of dry matter disappearance were fitted into the exponential equation $p=a+b(1-e^{-ct})$ as reported by Orskov and McDonald (1979) where p = potential degradability in time t; a= rapidly degradable fraction at zero hour; b= insoluble but degradable fraction at time t; c= fractional rate constant at which the fraction described by b will be degraded per hour and t= time of incubation. The cell wall disappearance was estimated by refluxing the nylon bag residue with neutral detergent solution for neutral detergent fibre (NDF).

Data were analysed using two-way analysis of variance and means were compared using Duncan's Multiple Range Test (Duncan, 1955).

Results and discussion

Table 1 shows the chemical composition of *Tephrosia bracteolata* and *Gmelina arborea harvested at different age*s of growth. Significant differences were observed for all the chemical composition except CP for *T. bracteolata*. McDonald *et al.* (1998) reported an increase in DM contents of plants with advancing maturity which is reflected in increased cell wall contents (NDF, ADF, ADL and NFE) and a decrease in cell contents (CP, EE and ash). This is similar with DM contents of plants in this study as DM increased with age of harvest. The crude protein contents for forage legumes investigated in this study were above the proposed minimum requirement for lactation (120 g/kg DM) and growth (113 g/kg DM) as reported by ARC (1980) in ruminant livestock. This value also falls within the range reported for tropical legumes (Norton and Poppi, 1995 and Mupangwa *et al*., 2000). This implies that irrespective of the harvest stage, *T. bracteolata* and *G. arborea* will provide the adequate nitrogen requirement for the rumen microorganisms to maximally digest the main components of dietary fibre leading to the production of volatile fatty acids (Trevaskis *et al.,* 2001; Lamidi and Ogunkunle, 2016) which in turn facilitates microbial protein synthesis in the animal and translate to meat and milk production for human uses. Meanwhile, crude protein values of *G. arborea* fell within the range of 10 - 37.9 % reported for browse plants in Nigeria (Mecha and Adegbola, 1980). This showed that the plants investigated could be used as a source of protein to supplement low quality grasses as well as roughages in ruminant diets especially during dry season. Increase in the fibre fractions of the plants from 8 to 20 WAP have implications for the use of the browse plants produced by contributing to the dilution of the nutrient contents of the forages, as most of the nutrients taken up by the plants from the soil were mobilized for formation of structural and reproductive components, such as cellulose, hemicelluloses and lignin (Butterworth, 1985). The NDF contents of forage plants in this study is comparable to values of 33.9 to 54.5 % except at 20 WAP for *T. bracteolata* (this can be associated with lignification) reported by Topps (1993) for 13 tropical herbaceous legumes. The higher NDF value obtained in this study is an indication that it will be a useful feeding stuff as good energy source in ruminant animal production as NDF is preferred measure for ruminant feeds and dietary balancing programs (Van Soest *et al.*, 1991).

Table 1 :Chemical composition of *Tephrosia bracteolata* and *Gmelina arborea* harvested at different age

	Tephrosia bracteolata Age at harvest (Weeks after planting)					*Gmelina arborea* Age at harvest (Weeks after planting)				
Parameters (%)	8	12	16	20	SEM	8	12	16	20	SEM
DM	25.00^{c}	25.24^{c}	30.63^{b}	64.51^{a}	4.98	32.34^{c}	33.50^{bc}	35.76^{ab}	37.40^{a}	0.27
CP	15.91	15.05	14.30	13.61	0.51	15.95^{a}	15.28^{ab}	13.94^{ab}	13.33^{b}	0.41
EE	3.05^{a}	2.74^{a}	2.21^{b}	1.91^{b}	0.14	11.54^{a}	8.45^{b}	6.01^{b}	5.95^{b}	0.76
Ash	8.43^{a}	6.70^{b}	5.34^{c}	3.11^{d}	0.59	12.35^{a}	10.10^{b}	9.00^{bc}	7.80^{c}	0.56
NDF	40.11^{d}	45.24^{c}	50.17^{b}	67.51^{a}	3.14	36.32^{b}	39.87^{b}	47.44^{a}	49.60^{a}	1.71
ADF	25.00^{c}	28.22^{bc}	30.12^{b}	42.13^{a}	2.00	23.10^{c}	25.90^{bc}	29.38^{ab}	31.54^{a}	1.09
ADL	10.11^{c}	11.84^{bc}	13.60^{ab}	15.11^{a}	0.69	9.50^{c}	1bc0.56^{bc}	12.30^{ab}	13.93^{a}	0.50
Hemicellulose	15.11^{b}	17.02^{b}	20.05^{b}	25.38^{a}	1.36	13.22^{b}	13.97^{ab}	18.06^{a}	18.06^{a}	0.88
Cellulose	14.89^{b}	16.38^{b}	16.52^{b}	27.02^{a}	1.62	13.60	15.34	17.08	17.61	0.90

a, b, c, d Means along the same row with different superscripts are significantly different($P<0.05$).

Table 2 shows the dry matter degradability of browse plants harvested at different ages of growth in the rumen of WAD rams. The DM degradability characteristics patterns in the forage samples were different ($P<0.05$) from each other. Generally, the two plants exhibited high initial DM degradation when the plants were at 8 WAP. This indicated the presence of highly soluble fraction in the two forages as a result of low level of lignification. Generally, the forage plants showed low to medium degradability with higher values from plants harvested at 8 and 12 WAP above the ones harvested at the more advanced stages of growth (16 and 20 WAP). The overall degradability was higher than a range of 29 % to 34 % reported for *Calliandra calothrysus* by Perera *et al*. (1996) but in the same range (41.78-66.54 %) reported by Arigbede *et al*. (2002) for multi-purpose tree species. Moreover, the values of PD of *T. bracteolata* and *G. arborea* were lower than 85.70 to 86.10 % reported by Babayemi *et al*. (2002) and 68 % for Gliricidia (Akinlade *et al*., 2001) respectively. The values of plant species in this study for DM degradation was however, within the range of 25.44 and 69.93 % for Alfalfa (Keyserlingk *et al*., 1996). Variation in the DM degradation could be attributed to differences in fibre contents of the forages. Rapidly degradable fraction (a) of dry matter decrease with increase in age for the two forages from 16-20 WAP. However, the degradable fraction (b) of dry matter, first increased at 12 WAP and started to decrease ($P<0.05$) as the age of harvest increased. The reduction effect on DM degradation could be attributed to increase in lignification of the plants as they increased in age which might have led to reduction in the rate of microbial attachment and colonization of the forages as the plants matures within the rumen which probably reduced the rate of microbial reduction of forage particle size.

Effect of age at harvest on the forage plants on crude protein degradation is shown on Table 3. Highest ($P<0.05$) values were recorded for both plants at 12 WAP for potential degradation(PD). The reduction in CP degradation as age of harvest increases could suggest possible inhibition of rumen microbes to utilize dietary protein. Lignification of the plants as they increase in age could decrease the breakdown of dietary protein in the rumen and lowered microbial synthesis. The plants still however, have high degradation throughout the study period. This could possibly be as a result of high protein contents in them. Lower rates of protein degradation as the plants age increased, indicated that more protein would escape ruminal degradation. Moderate effective degradability (ED) reported in this study could imply that most of the protein might have been protected by other nutrients such as lignin and tannins which might not make it readily available. This is in agreement with Dzowela *et al*. (1995) that tannins have ability to bind protein in browse leaves and thereby reduce its availability to animals. The CP degradability values reported in this trial were consistently higher than values reported by Dzowela *et al*. (1995) and Pererа*et al* (1996), however, it is in the range (47.64-76.05 %) reported by Arigbede *et al*. (2002) for multi-purpose tree species. Tender age might be partly responsible for higher rate of degradability observed at 8-12 WAP. Aderinboye *et al*. (2011) reported that utilization of forages is largely dependent on microbial degradation. As a result, high CP degradation values obtained in the two forages suggests the presence of degradable and fermentable carbohydrates in them, which enabled the microbial contents to degrade the forages well to make nutrients available for animal utilization. It may be concluded that *T. bracteolata and G.arborea had appreciable protein values at 12 WAP.* The highest values of the PD for the plants were recorded at 12 WAP. The CP disappearance in the two forages were comparable with CP degradation of 69 % for Leucaena and 79 % for Gliricidia as reported by Ibrahim *et al.* (1995). The tender age of the plants could have accounted partly for the high rate of protein degradation observed. This is in agreement with Kaitho *et al.* (1993) that low degradation is highly correlated with increased stage of maturity of plants. This implied that less protein would escape ruminal degradation at 12 WAP. Lower rates of protein degradation in other ages of harvest indicated that more protein would escape ruminal degradation.

On Table 4, there was significant difference in NDF of *T. bracteolata* and *G. arborea* at different ages. Effective and potential degradability of NDF were low for the two plants at all stages of harvest investigated except for *T. bracteolata* at 16 WAP for PD, despite high level of NDF contents in their chemical composition. Dzowela *et al*. (1995) reported that condensed tannins precipitate protein to form stable complexes at rumen pH, which adversely affect protein and fibre degradation in the rumen. Presence of condensed tannin in the forages might be responsible for the low NDF degradability in this study. Kamatali *et al*. (1992) however, reported higher degradable NDF than in this study for *Calliandra callothyrsus* (39 %) and *Leucaena leucocephala* (56.50 %) that were harvested from young shoots of 8 weeks old. Forages with cell walls that are degraded rapidly may promote greater rate of ruminal digestion and passage and allow animals to consume more feed (Jung and Allen, 1995).

Table 2: Effect of age at harvest on the forage plants on dry matter degradation

	Tephrosia bracteolata					*Gmelina arborea*				
	Age at harvest (Weeks after planting)					Age at harvest (Weeks after planting)				
Parameters (%)	8	12	16	20	SEM	8	12	16	20	SEM
A	46.37^{a}	21.15^{b}	19.64^{c}	19.10^{d}	1.58	46.17^{a}	45.88^{b}	32.78^{c}	32.70^{c}	2.22
B	10.40^{d}	33.42^{a}	31.07^{b}	17.55^{c}	3.49	10.37^{c}	15.13^{b}	22.67^{a}	11.11^{d}	2.12
C	0.13^{a}	0.03c	0.05b	0.03c	0.01	0.26a	0.07c	0.06c	0.13b	0.02
PD	56.59^{a}	54.57^{b}	50.71^{c}	32.06^{d}	6.27	56.57^{b}	61.01^{a}	55.45^{c}	32.51^{d}	5.75
ED	55.37^{a}	50.89^{a}	41.25^{b}	29.68^{c}	3.61	55.15^{a}	59.94^{a}	50.16^{b}	39.07^{c}	2.87

a, b, c Means along the same row with different superscripts are significantly different(P<0.05).
a = rapidly degradable fraction. b = insoluble but degradable fraction. c= fractional rate constant at which b will be degraded per hour, PD = potential degradation, ED = effective degradation.

Table 3: Effect of age at harvest on the forage plants on crude protein degradation

	Tephrosia bracteolata					*Gmelina arborea*				
	Age at harvest (Weeks after planting)					Age at harvest (Weeks after planting)				
Parameters (%)	8	12	16	20	SEM	8	12	16	20	SEM
A	49.32^{b}	55.17^{a}	50.03^{b}	53.29^{b}	1.19	46.62^{b}	53.40^{a}	45.92^{b}	40.63^{c}	2.27
B	13.58^{b}	20.62^{a}	6.76^{c}	15.45^{b}	2.48	11.66^{a}	6.28^{c}	9.60^{b}	12.76^{a}	1.23
C	0.04^{b}	0.05^{b}	0.08^{a}	0.04^{b}	0.00	0.22^{a}	0.07^{c}	0.09^{c}	0.12^{b}	0.00
PD	62.90^{c}	75.79^{a}	56.79^{d}	68.74^{b}	3.52	58.28^{b}	59.68^{a}	55.52^{c}	53.39^{d}	1.22
ED	57.11^{a}	56.49^{a}	54.73^{b}	51.52^{c}	1.09	56.88^{a}	57.70^{a}	53.02^{b}	50.59^{c}	1.44

a, b, c Means along the same row with different superscripts are significantly different(P<0.05).
a = rapidly degradable fraction. b = insoluble but degradable fraction. c= fractional rate constant at which b will be degraded per hour, PD = potential degradation, ED = effective degradation.

Table 4: Effect of age at harvest on the forage plants on neutral detergent fibre degradation

	Tephrosia bracteolata					*Gmelina* arborea				
	Age at harvest (Weeks after planting)					Age at harvest (Weeks after planting)				
Parameters (%)	8	12	16	20	SEM	8	12	16	20	SEM
A	21.02^{b}	7.83^{c}	44.15^{a}	17.61^{b}	6.66	6.17^{a}	2.68^{b}	6.64^{a}	7.29^{a}	0.89
B	10.86^{d}	27.37^{b}	32.62^{a}	16.47^{b}	4.30	42.46^{a}	40.33^{a}	30.93^{b}	29.99^{b}	2.76
C	0.06^{c}	0.11^{b}	0.25^{a}	0.02^{c}	0.04	0.02^{b}	0.02^{b}	0.11^{a}	0.05^{b}	0.00
PD	31.88^{b}	35.20^{b}	76.77^{a}	34.08^{b}	9.34	48.63^{a}	43.01^{b}	37.57^{c}	37.28^{c}	2.32
ED	28.24^{a}	29.20^{a}	24.48^{b}	24.49^{b}	1.07	25.24^{b}	20.49^{c}	30.76^{a}	25.49^{b}	1.82

a, b, c Means along the same row with different superscripts are significantly different(P<0.05).
a = rapidly degradable fraction. b = insoluble but degradable fraction. c= fractional rate constant at which b will be degraded per hour, PD = potential degradation, ED = effective degradation.

Conclusion

This study concluded that *T. bracteolata* should be harvested at 12 – 16 WAP as protein supplement while *G. arborea* plants may be supplied to ruminants as supplementary diets during dry season to augment poor quality feed available during the period.

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