Tropical Grasslands-Forrajes Tropicales (2021) Vol. 9(3):383–390
doi: 10.17138/TGFT(9)383-390

Short Communication

The effects of increasing concentrations of *Trichanthera gigantea* leaves in pellets on the nutritive value and short-term intake of diets of grass plus pellets offered to lambs reared under tropical conditions in the Caribbean

Efectos de las concentraciones crecientes de hojas de Trichanthera gigantea *en pélets sobre el valor nutritivo y la ingesta a corto plazo de dietas de pasto más pélets ofrecidas a corderos criados en condiciones tropicales en el Caribe*

H.A. JACK[1,2], L.M. CRANSTON[1], J.L. BURKE[1], M. KNIGHTS[3] AND P.C.H. MOREL[1]

[1]*School of Agriculture and Environment, Massey University, Palmerston North, New Zealand.* massey.ac.nz
[2]*Caribbean Agricultural Research and Development Institute, St Augustine, Trinidad and Tobago.* cardi.org
[3]*Biosciences, Agriculture & Food Technologies, University of Trinidad and Tobago, Centeno, Trinidad and Tobago*. utt.edu.tt/baft

Abstract

There is currently limited information on the benefits of increasing the concentration of *Trichanthera gigantea* leaves in pelleted diets offered to lambs reared under tropical conditions in the Caribbean. Twelve crossbred Barbados Blackbelly rams aged 5 months were used to determine the effects of increasing the concentrations of *T. gigantea* in pelleted diets, on the nutritive value and intake of grass forage plus pellets offered to lambs. Animals were randomly assigned to a basic diet (4 kg) of chopped *Cenchrus purpureus* plus 1 of 6 pelleted diets (500 g) comprised of either 100% intact commercial pellets or a pelleted mixture of ground commercial pellets and ground (dry fallen) *T. gigantea* leaf in the following ratios (*T. gigantea* leaves:ground commercial pellets): 20:80 (T20); 40:60 (T40); 60:40 (T60); 80:20 (T80); and 100:0 (T100). Total intakes of forage and pellets (TPI) were measured at the end of each day during a period of 7 days, and the average daily nutrient intakes of the different treatment diets were calculated. Overall, there was no significant difference in the intakes of pellets containing 0 to 80% *T. gigantea* leaves (P>0.05) but intakes of pellets comprising 100% *T. gigantea* leaves were significantly lower (P<0.0001). Both CP and soluble protein intakes declined progressively as the percentage of *T. gigantea* leaves in the pellets increased. While level of *T. gigantea* leaves in pellets fed to lambs did not generally affect total intakes of pellets, grass, or grass+pellets, animal performance on these various rations cannot be assumed to be similar until longer-term feeding studies have been performed, as reduced protein and energy concentrations in the pellets could significantly lower weight gains as level of leaf in the pellets increased.

Keywords: Barbados Blackbelly sheep, multi-purpose trees, pellet feeding.

Resumen

Actualmente, existe información limitada sobre los beneficios de aumentar la concentración de hojas de *Trichanthera gigantea* en las dietas peletizadas que se ofrecen a los corderos criados en condiciones tropicales en el Caribe. Se utilizaron doce carneros Barbados Blackbelly mestizos de 5 meses de edad para determinar los efectos del aumento de las concentraciones de *T. gigantea* en dietas peletizadas, sobre el valor nutritivo y la ingesta de forraje de pasto más pélets ofrecidos a los corderos. Los animales fueron asignados aleatoriamente a una dieta básica (4 kg) de *Cenchrus purpureus* picado más 1 de 6 dietas peletizadas (500 g) compuestas por pélets comerciales 100% intactos o una mezcla peletizada

Correspondence: Heidi Jack, School of Agriculture and Environment, Massey University, Private bag 11-222, Palmerston North, New Zealand. E-mail: h.jack@massey.ac.nz

de pélets comerciales molidos y hojas secas de *T. gigantea* en las siguientes proporciones (hojas de *T. gigantea*:pélets comerciales molidos): 20:80 (T20); 40:60 (T40); 60:40 (T60); 80:20 (T80); y 100:0 (T100). Se midieron las ingestas totales de forraje y pélets (TPI) al final de cada día durante un período de 7 días, y se calcularon las ingestas promedio diarias de nutrientes de las diferentes dietas de tratamiento. En general, no hubo diferencias significativas en la ingesta de pélets que contenían de 0 a 80% de hojas de *T. gigantea* ($P > 0.05$), pero la ingesta de pélets compuestos 100% de hojas de *T. gigantea* fue significativamente menor ($P < 0.0001$). Tanto la ingesta de proteína cruda como la de proteína soluble disminuyeron progresivamente a medida que aumentaba el porcentaje de hojas de *T. gigantea* en los pélets. Si bien el nivel de hojas de *T. gigantea* en los pélets dados como alimento a los corderos generalmente no afectó la ingesta total de pélets, pasto o pasto+pélets, no se puede suponer que el rendimiento de los animales en estas diversas raciones sea similar hasta que se hayan realizado estudios de alimentación a más largo plazo, ya que las concentraciones reducidas de proteína y energía en los pélets podrían reducir significativamente las ganancias de peso a medida que aumenta el nivel de hojas en los pélets.

Palabras clave: Alimentación con pellets, árboles polivalentes, oveja de Barbados Blackbelly.

Introduction

Trichanthera gigantea is a common non-leguminous multi-purpose tree species (MPT) used in small ruminant production systems in the Caribbean (Heuzé et al. 2017). The nutritive value of fresh intact *T. gigantea* leaves is attributed to its high protein concentration, which ranges between 150 and 220 g/kg DM (Rosales 1997; Rosales and Rios 1999). In addition, the presence of hydrolyzable tannins in *T. gigantea* may increase rumen undegradable or bypass protein, which can be a direct benefit to ruminants when consumed (Rosales 1997; Edwards et al. 2012). Compared with other MPTs at the same stage of maturity, *T. gigantea* is typically higher in non-structural and storage carbohydrates and lower in structural carbohydrate, which results in its high rumen degradability (Rosales and Rios 1999). Further, *T. gigantea* has cystoliths on leaf and stem surfaces, which result in high ash concentration and a large percentage of calcium, which is typically greater than 20% DM (Benton and Benton 1963; Barahona 1999). The higher ash concentration may be used to improve the mineral concentrations in the diets of livestock in the tropics, where mineral deficiencies in tropical pastures often occur (McDowell and Arthington 2005).

Apart from fresh leaves, leaf fall may be a potential dry season feed for animals, despite the possible lower nutritive value relative to intact *T. gigantea* leaves as a result of senescence (Charlton et al. 2003). During periods of prolonged drought, there is often an abundance of biomass available as leaf fall (Wright and Cornejo 1990). This may be significant, particularly in the Caribbean, where prolonged severe dry periods are frequent and are predicted to become more common (Lallo et al. 2017). Though there are several studies focused on the use of fresh intact *T. gigantea* leaves, there is no known study on the use of fallen leaves as a prospective feed ingredient for lambs. Further, there is currently no information on the nutritive value of dry fallen leaves of *T. gigantea* and effects of feeding them to lambs in the Caribbean. Therefore, the objective of this study was to determine the effects on nutritive value and intake of pellets of increasing concentrations of dry fallen *T. gigantea* leaves in pellets offered to lambs with grass forage.

Materials and Methods

The effects of including dry ground fallen *T. gigantea* leaf in commercial pellets at 0 (T0), 20 (T20), 40 (T40), 60 (T60), 80 (T80) and 100% (T100) fed with a fresh grass forage basal diet on intake by lambs were examined over 2 periods: Period 1 (10–15 May 2019) and Period 2 (22–28 May 2019). Due to limitations with the facilities (spacing), all 6 treatments could not be compared at the same time so intakes of treatments T0, T20 and T40 were measured during Period 1 and intakes of Treatments T60, T80 and T100 were measured during Period 2. The study was conducted at the Eastern Caribbean Institute for Agriculture and Forestry (ECIAF) – University of Trinidad and Tobago (10.56° N, 61.32° W).

Harvesting and pelleting material

Dry fallen *T. gigantea* leaves (mature flowering stage; approximately 88% DM) were collected one week prior to the study period from the plantation at the "Up the Hill Farms", which is located in Moruga, Trinidad (10.11° N, 61.29° W).

Dry leaves and a commercial ration were the primary ingredients used to produce the pellets examined in this study. On the Control diet (T0, i.e. 100% commercial pellets) intact commercial pellets made of 80% (DM basis) wheat middlings, 20% (DM basis) corn and a vitamin and mineral mix were fed with fresh grass forage (see below). Pellets fed in the other treatments included mixtures of ground commercial pellets and ground dry fallen *T. gigantea* leaves in the following ratios (*T. gigantea* leaves:ground commercial pellets): 20:80 (T20); 40:60 (T40); 60:40 (T60); 80:20 (T80); and 100:0 (T100). Firstly, the commercial pellets and dry *T. gigantea* leaves were ground separately to pass through a 0.635 cm screen (screen was initially 2.54 cm and modified to 0.635 cm) of a Craftsman shredder-hammer mill (Model 247.776380). The ground materials were weighed according to the ratios for the different pellet treatments. After weighing the respective ratios for the different treatment groups, the ground materials were mixed manually for 10–15 minutes and pelleted using a Changchai-ZS1115 Pellet Mill (22 Horse-Power Diesel Engine) with a die length and diameter of 2.54 and 1.27 cm, respectively. Prior to Periods 1 and 2, a single batch of pellets for each treatment group was produced and fed to the respective treatments throughout the respective periods.

In addition to the pellets, mature (6–8 weeks regrowth and 1.5 m high) *Cenchrus purpureus* (syn. *Pennisetum purpureum*) grass was manually harvested with a machete each day from the Eastern Caribbean Institute for Agriculture and Forestry Campus – University of Trinidad and Tobago (ECIAF-UTT) according to Gemeda and Hassen (2014). *C. purpureus* was used as the basal diet for both Periods 1 and 2. Once harvested, the *C. purpureus* (including leaves and stem) was manually chopped to lengths of about 5–10 cm according to Schnaider et al. (2014), for daily feeding.

Animals and diets

The same 12 crossbred (Barbados Blackbelly × West African) intact rams, aged 5 months, were used in both periods (Periods 1 and 2) to measure the intakes of the treatment diets. Mean live weight at the commencement of Period 1 was 22 ± 2.2 kg and for Period 2 was 27 ± 2.4 kg. Before Period 1 commenced, the lambs were subjected to a 19-day adaptation period, where they were examined, treated for internal parasites, fed a diet of 4 kg of chopped *C. purpureus* (including leaves and stem) plus 500 g of commercial pellets and allowed to become familiar with their enclosures. The 12 lambs were randomly assigned on the basis of live weight to 3 groups of 4 animals, which were allocated to 1 of 3 diets (T0, T20 and T40) and intakes were recorded for 7 days. Lambs were then returned to the same diet as fed prior to Period 1 for 5 days. Period 2 then commenced, where the concentrations of *T. gigantea* in pellets were 60, 80 and 100%. Groups of lambs fed T0, T20 and T40 diets in Period 1 were assigned to dietary treatments T60, T80 and T100, respectively. This was done to minimize between-lamb variation within treatment groups. During the experiment, all lambs were confined to well-ventilated individual pens (1.22 × 1.22 m) and had unrestricted access to water and a mineral block (Alphablock), which contained: 55,000 IU Vitamin A; 27,500 IU Vitamin D3; 300 IU Vitamin E; 30,000 mg calcium; 5,000 mg magnesium; 1,800 mg iron; 2,500 mg manganese; 50 mg cobalt; 1,500 mg zinc; 10 mg selenium; and 35 mg iodine per kg DM.

Experimental procedure and design

Animals were fed twice daily at 09:00 h (4 kg forage) and 15:00 h (500 g pellets). Total forage and total pellets offered and refused for each animal were recorded daily to calculate intake of each component of the diet. At 06:30 h daily, both total forage intake (TFI) and total pellet intake (TPI) were recorded. Total dry matter intake (TDMI) was calculated as the sum of TPI and TFI.

Sampling and analytical procedures

Feed samples (forage and pellets) were collected at the end of each week for DM determination and chemical analysis. The pellet samples included 2 subsamples from a total of 2 batches used for feeding. Forage on offer during the week was consistent and a representative sample was selected to determine nutritive value. The total nutrient concentration in the diets was calculated by determining the concentrations of each nutrient (on a DM basis) in both forage and pellets fed, from which total daily intakes on the various treatments were calculated.

Chemical analysis

Samples were dried at 60 °C for 72 h and ground to pass through a 2 mm sieve using a Thomas Scientific mill. These were then packaged (package included Export permit no. 139517 for Research) and exported to Cumberland Valley Analytical Services (CVAS;

Waynesboro, PA, USA) for further analysis. Dry matter of *C. purpureus* (modified method) was determined by drying samples at 105 °C for 3 h (National Forage Testing Association 2002). Dry matter concentrations for pellets and *T. gigantea* were determined by drying samples at 35 °C for 2 h (method no. 930.15, AOAC 2000). ADF was determined using a Whatman 934-AH glass micro-fiber filter with 1.5 µm particle retention in place of a fritted glass crucible (modification of method no. 973.18, AOAC 2000). NDF was obtained using Whatman 934-AH glass micro-fiber filters with 1.5 µm particle retention used in place of a fritted glass crucible (a modification of Van Soest et al. 1991). Ash was determined using 0.35 g sample, which was ashed for 4 h at 535 °C (a modification to method no. 942.05, AOAC 2000).

Statistical analysis

Statistical analysis was conducted using R environment for statistical computing and visualization (R Core Team 2013). Intake measurements obtained from each lamb at different times were treated as repeated measures. Package nlme (Pinheiro et al. 2018) was used to apply a linear mixed effect model to the intake data. The model consisted of treatment, day and day × treatment interaction as fixed effects and animal as the random effect. An analysis of variance (Anova) from Package car (Fox and Weisberg 2011) and Agricolae (de Mendiburu 2019) was used to obtain the P-value for the model differences. Means and superscripts were generated using the R package emmeans (Lenth et al. 2019) and multcomp (Hothorn et al. 2016), which helps in separating significantly different means using Tukey's multiple comparison test. Differences were considered statistically significant if $P<0.05$.

Results

Chemical composition of the dry fallen *T. gigantea* leaves used, *C. purpureus* and all pelleted feeds offered to lambs in the current study is presented in Table 1. The crude protein (CP) concentration of commercial pellets (181 g/kg DM) and *C. purpureus* (150 g/kg DM) was higher than those reported for *T. gigantea* pellets (98–145 g/kg DM) and *T. gigantea* leaves (81 g/kg DM). Actual CP% in feed consumed could be higher than these data suggest as only about 75% of the grass offered was eaten. Since sheep are very selective and chopped material of whole plants was offered, one could assume that the lambs selected for leaf and rejected the stem, which would have much lower CP concentration than the average figures quoted for the grass. Unfortunately we did not analyze the forage rejected by the lambs to clarify this point. Soluble protein of *C. purpureus* was up to 20 g/kg DM more than that of the commercial pellets and more than twice the average value of 21.4 g/kg DM, reported for the pellets containing *T. gigantea* leaf. ADF and NDF concentrations of the feed components ranged between 109 and 425 g/kg DM and 302 and 660 g/kg DM, respectively, for all feeds. *Cenchrus purpureus* had the highest concentrations of both ADF and NDF.

The average feed and nutrient intakes for the different treatment groups are presented in Table 2. Total forage intake (TFI) and total dry matter intake (TDMI) were comparable across all treatment groups ($P>0.05$), ranging between 0.770 and 0.795 kg DM/hd/d for TFI and 1.13 and 1.21 kg DM/hd/d for TDMI, while total pellet intake (TPI) of the T100 group was lower ($P<0.0001$) than that of all other treatments.

Treatment had a significant effect on intakes of nutrients (Table 2). CP intake declined progressively from 194 g CP/hd/d for T0 group to 148 g CP/hd/d for T100 group ($P<0.0001$). Similarly, intake of soluble protein (SP) declined from 55 g SP/hd/d for T0 to 45 g SP/hd/d for T100 ($P<0.0006$). The average ADF intake for Groups T0, T20 and T40 (380 g/hd/d) was less than that for Groups T60, T80 and T100 (448 g/hd/d) ($P<0.0001$).

Total pellet intake/day (TPI) did not vary throughout the study for T0, T20, T40, T60 and T80, nor did it vary between these treatments ($P>0.05$) but increased from Day 1 to Day 5 for T100, before declining again (Table 3). TPI on T100 was lower ($P=0.0001$) than on other treatments on all days except Days 3 and 5.

Table 1. Chemical composition (g/kg DM) including crude protein, soluble protein, acid detergent fiber, neutral detergent fiber, ash and organic matter for *Cenchrus purpureus*, dry fallen *Trichanthera gigantea* leaves (TGL) and pellets fed in various treatments (T0, T20, T40, T60, T80 and T100).

Parameter	*C. purpureus*	TGL[1]	T0[2]	T20	T40	T60	T80	T100
Dry matter (g/kg)	270	878	870	876	871	854	843	833
Crude protein	150	81	181	145	143	103	109	98
Soluble protein	53	19	33	25	28	21	20	13
Acid detergent fiber	425	308	109	142	152	295	287	340
Neutral detergent fiber	660	430	351	302	316	365	432	459
Ash	132	194	64	85	88	151	159	159
Organic matter	138	684	806	791	783	703	684	674

[1]TGL: *Trichanthera gigantea* (ground dry fallen leaves of *T. gigantea*).

[2]Commercial pellets were offered intact with grass forage for the Control group (T0). Other treatments (T20, T40, T60 and T80) comprised ground commercial pellets mixed with increasing proportions of ground dry fallen *T. gigantea* leaf; T100 represents pellets with ground *T. gigantea* leaves as the sole ingredient.

Table 2. Average daily feed and nutrient intakes for the different treatment groups (n=4 lambs per treatment).

Parameter	T0[1]	T20	T40	T60	T80	T100	s.e.	P-value
Forage intake (kg DM/hd/d)	0.770	0.738	0.762	0.764	0.767	0.795	0.023	0.678
Pellet intake (kg DM/hd/d)	0.435a	0.438a	0.435a	0.423a	0.417a	0.330b	0.013	<0.0001
Total intake (kg DM/hd/d)	1.21	1.18	1.20	1.19	1.18	1.13	0.028	0.4049
Crude protein (kg/hd/d)	0.194a	0.179ab	0.172bc	0.162cd	0.161cd	0.148d	0.003	<0.0001
Soluble protein (kg/hd/d)	0.055a	0.052ab	0.051ab	0.051ab	0.049bc	0.045c	0.001	0.0006
Acid detergent fiber (kg/hd/d))	0.374a	0.389a	0.378a	0.459b	0.447b	0.439b	0.010	<0.0001
Neutral detergent fiber (kg/hd/d)	0.660	0.640	0.621	0.673	0.689	0.659	0.015	0.0707
Ash (kg/hd/d)	0.129a	0.139a	0.135a	0.168b	0.168b	0.154b	0.003	<0.0001

[1]T: *Trichanthera gigantea* (ground dry fallen leaves); T0: Commercial pellets (Control group fed grass forage + 100% commercial pellets); T20 group fed forage + pellets comprised of 20% ground dry fallen *T. gigantea* leaf and 80% commercial; T40 group fed forage + pellets comprised of 40% dry fallen *T. gigantea* leaf and 60% commercial; T60 group fed forage + pellets comprised of 60% dry fallen *T. gigantea* leaf and 40% commercial; T80 group fed forage + pellets with 80% dry fallen *T. gigantea* leaf and 20% commercial; and T100 fed forage + pellets comprised of 100% dry fallen *T. gigantea* leaf.
Means within rows with the same letters are not significantly different (P>0.05).

Table 3. Total pellet intake (TPI) (kg DM/day) of lambs fed rations made up of *Cenchrus purpureus* forage plus commercial pellets or forage plus pellets made of a mixture of ground commercial pellets and ground dry fallen leaves of *Trichanthera gigantea* in varying proportions (n=4 lambs per treatment).

	Treatment						P value			
Day	T0[1]	T20	T40	T60	T80	T100	s.e.	Treatment	Day	Treatment × Day
1	0.435ax[2]	0.438ax	0.435ax	0.402ax	0.418ax	0.319bx	0.0179	0.0001	0.6092	0.8518
2	0.435ax	0.438ax	0.435ax	0.426ax	0.421ax	0.316bx				
3	0.435ax	0.438ax	0.435ax	0.427abx	0.421abx	0.354bxy				
4	0.435ax	0.438ax	0.435ax	0.427ax	0.419ax	0.322bxy				
5	0.435ax	0.438ax	0.435ax	0.427ax	0.411ax	0.376ay				
6	0.435ax	0.438ax	0.435ax	0.427ax	0.412ax	0.316bx				
7	0.435ax	0.438ax	0.435ax	0.427ax	0.414ax	0.309bx				

[1]T: *Trichanthera gigantea* (ground dry fallen leaves); T0: Grass forage + commercial pellets (Control group fed pellets comprised of 100% commercial ingredients); T20 group fed grass forage + pellets comprised of 20% ground dry fallen *T. gigantea* leaf + 80% commercial; T40 group fed grass forage + pellets comprised of 40% ground dry fallen *T. gigantea* leaf and 60% commercial; T60 group fed grass forage + pellets comprised of 60% ground dry fallen *T. gigantea* leaf and 40% commercial; T80 group fed grass forage + pellets with 80% ground dry fallen *T. gigantea* leaf and 20% commercial; and T100 fed grass forage + pellets comprised of 100% ground dry fallen *T. gigantea* leaf.

[2]Means followed by the same letters (a,b,c,d) within rows are not significantly different (P>0.05) and means followed by the same letters (x,y,z) within columns are not significantly different (P>0.05).

Discussion

The inclusion of MPTs above 50% in ruminant diets is often associated with reduced intake as a result of anti-nutritional factors inherent to these species (Reed 1995; Min et al. 2003). However, in the current study, the total intakes of pellets with up to 80% *T. gigantea* (T80) were comparable with that of the commercial pellets which lambs were accustomed to being fed. Unlike many other multi-purpose tree species, there is no known report of anti-nutritional factors that limit the intake of *T. gigantea* (Barahona 1999; Wanapat 2009). This may explain the comparable intakes of pellets comprising up to 80% *T. gigantea* leaves.

Trichanthera gigantea is typically reported as having a moderate to low palatability because of the hirsute nature of its leaves (Mejía and Vargas 1993); however the TPI was generally high for all pellet treatments except T100. This may be as a result of the pelleting process, which is often associated with higher levels of palatability and the presentation of a more favorable form of the feed (Wallace et al. 1961; Dobie 1975). For instance, the smaller unit size of pellets makes it more prehensile and easier to ingest compared with the bulkier form of unprocessed forage. This smaller denser form of feed is also associated with more rapid flow of feed through the gastro-intestinal tract resulting in characteristically higher intakes when compared with bulkier unprocessed forage (Blaxter and Graham 1956; Minson 1963). In addition, the pelleting process involves the drying, grinding, mixing and compression of leaves with more favorable ingredients, which is often associated with reduced selection and increased intake (Wanapat et al. 2013). There are no current studies on the impact of pelleting on the intake *T. gigantea* leaves in small ruminants; however according to Beardsley (1964), pelleting can increase intake of forage feeds by up to 25%. Therefore, pelleting may provide an opportunity for improving the intake of and therefore performance on *T. gigantea*.

Daily CP intake by the Control group barely satisfied the CP requirement for finishing lambs (4–7 months of age) weighing 30 kg and growing at a daily rate of 295 g/d (191 g CP/d) (NRC 1985), while those of groups fed pellets containing *T. gigantea* leaf would not support gains of this magnitude. According to Hoover and Miller (1996) the amount of soluble protein (SP), that fraction of the rumen degradable protein that is immediately available for utilization by rumen microbes, should represent about 35% of feed protein in order to optimize rumen function. SP in this study was less than 35% of CP consumed and, based on CP intakes, the daily intakes of SP barely reached the minimum required amounts for growing lambs (0.05–0.07 kg SP/h/d) in all treatment groups. An adequate supply of degradable and bypass protein from diets is associated with increased efficiency of microbial fermentation; improved digestion; increased throughflow from the rumen; and therefore increased intake and improved performance (Lazzarini et al. 2009; Sampaio et al. 2009).

While total intakes of dry matter were not affected by amount of *T. gigantea* leaves included in the pellets, performance of animals on the different rations could vary substantially as CP concentrations in the different rations were quite different. Before any conclusions are drawn about appropriate levels of *T. gigantea* leaves to incorporate in pellets, longer-term feeding studies with animals where liveweight gains are recorded need to be conducted.

Acknowledgments

The authors are thankful to the Caribbean Agricultural Research and Development Institute (CARDI) and the School of Agriculture and Environment (SAE), Massey University for providing the funding support required to undertake the research. The authors are also thankful to the University of Trinidad and Tobago (UTT) for donating animals, granting access to housing facilities, forage banks and the provision of technical support and access to laboratory equipment required to conduct the studies. The donation of animals and forage from the Trinidad and Tobago Goat and Sheep Society is also gratefully acknowledged.

References

(Note of the editors: All hyperlinks were verified 26 August 2021).

AOAC. 2000. Official Methods of Analysis. 17th Edn. Association of Official Analytical Chemists, Gaithersburg, MD.

Barahona R. 1999. Condensed tannins in tropical forage legumes: their characterisation and study of their nutritional impact from the standpoint of structure-activity relationships. Ph.D. Thesis. University of Reading, UK. bit.ly/3myY4k3

Beardsley DW. 1964. Symposium on forage utilization: Nutritive value of forage as affected by physical form. Part II. Beef cattle and sheep studies. Journal of Animal Science 23(1):239–245. doi: 10.2527/jas1964.231239x

Benton W; Benton H. 1963. Encyclopaedia Britannica. University of Chicago Press.

Blaxter KL; Graham NM. 1956. The effect of the grinding and cubing process on the utilization of the energy of dried

grass. The Journal of Agricultural Science 47(2):207–217. doi: 10.1017/S0021859600040132
Charlton JFL; Douglas GB; Wills BJ; Prebble JE. 2003. Farmer experience with tree fodder. Using trees on farms. Grassland research and practice series 10:7–16. doi: 10.33584/rps.10.2003.2989
De Mendiburu F. 2019. Package 'agricolae'. R package version, 1-2. cran.r-project.org/package=agricolae
Dobie JB. 1975. Cubing tests with grass forages and similar roughage sources. Transactions of the ASAE 18(5):864–866. doi: 10.13031/2013.36697
Edwards A; Mlambo V; Lallo CHO; Garcia GW; Diptee MD. 2012. *In vitro* ruminal fermentation parameters of tanner grass (*Brachiaria arrecta*) supplemented with leaves from three forage trees. Livestock Research for Rural Development 24, Article #102. lrrd.cipav.org.co/lrrd24/6/edwa24102.htm
Fox J; Weisberg S. 2011. An R companion to applied regression. 2nd Edn. SAGE Publications, Thousand Oaks, CA, USA. bit.ly/2WrdyeO
Gemeda BS; Hassen A. 2014. *In vitro* fermentation, digestibility and methane production of tropical perennial grass species. Crop and Pasture Science 65(5):479–488. doi: 10.1071/CP13450
Heuzé V; Tran G; Boudon A; Bastianelli D. 2017. Nacedero (*Trichanthera gigantea*). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. Last updated on June 26, 2017. feedipedia.org/node/7270
Hoover WH; Miller TK. 1996. Feeding for maximum rumen function. Mid-South Ruminant Nutrition Conference Proceedings, Texas Animal Nutrition Council. p. 33–46. bit.ly/3topAlI
Hothorn T; Bretz F; Westfall P; Heiberger RM; Schuetzenmeister A; Scheibe S. 2016. Package 'multcomp'. Simultaneous inference in general parametric models (Version 1.4-6). cran.r-project.org/package=multcomp
Lallo CHO; Smalling S; Facey A; Hughes M. 2017. The impact of climate change on small ruminant performance in Caribbean communities. In: Ganpat W; Isaac W, eds. Environmental Sustainability and Climate Change Adaptation Strategies p. 296–321. doi: 10.4018/978-1-5225-1607-1.ch011
Lazzarini I; Detmann E; Sampaio CB; Paulino MF; Valadares Filho SC; Souza MA de; Oliveira FA. 2009. Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. Revista Brasileira de Zootecnia 38(10):2021–2030. doi: 10.1590/S1516-35982009001000024
Lenth RV; Buerkner P; Herve M; Love J; Riebl H; Singmann H. 2019. emmeans: Estimated Marginal Means, aka Least-Squares Means (Version 1.3.4). cran.r-project.org/package=emmeans
McDowell LR; Arthington JD. 2005. Minerals for grazing ruminants in tropical regions. 4th Edn. University of Florida, Gainesville, FL, USA.
Mejía CE; Vargas JE. 1993. Análisis de selectividad de ovejas africanas con cuatro tipos de forrajes. Livestock Research for Rural Development 5, Article #22. lrrd.org/lrrd5/3/mejia.htm
Min B; Barry T; Attwood G; McNabb W. 2003. The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: a review. Animal Feed Science and Technology 106(1–4):3–19. doi: 10.1016/S0377-8401(03)00041-5
Minson D. 1963. The effect of pelleting and wafering on the feeding value of roughage—a review. Grass and Forage Science 18(1):39–44. doi: 10.1111/j.1365-2494.1963.tb00324.x
National Forage Testing Association. 2002. Method 2.2. 2.5: Dry matter by oven drying for 3hr at 105° C. National Forage Testing Association, Omaha, NE, USA.
NRC (National Research Council). 1985. Nutrient requirements of dairy cattle 6. National Academy Press, Washington, DC, USA.
Pinheiro J; Bates D; DebRoy S; Sarkar D. 2018. nlme: linear and nonlinear mixed effects models. (Version 3.1-137). cran.r-project.org/package=nlme
Reed JD. 1995. Nutritional toxicology of tannins and related polyphenols in forage legumes. Journal of Animal Science 73(5):1516–1528. doi: 10.2527/1995.7351516x
Rosales M. 1997. *Trichanthera gigantea* (Humboldt & Bonpland.) Nees: A review. Livestock Research for Rural Development 9, Article #37. lrrd.org/lrrd9/4/mauro942.htm
Rosales M; Rios CI. 1999. Research into variation in nutritive value of provenances of *Trichanthera gigantea*. Proceedings of the FAO Electronic Conference on Agroforestry for animal production in Latin America. (In Spanish). fao.org/livestock/agap/frg/agrofor1/rosale17.htm
Sampaio CB; Detmann E; Lazzarini I; Souza MA de; Paulino MF; Valadares Filho SC. 2009. Rumen dynamics of neutral detergent fiber in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. Revista Brasileira de Zootecnia 38(3):560–569. doi: 10.1590/S1516-35982009000300023
Schnaider MA; Ribeiro-Filho HMN; Kozloski GV; Reiter T; Orsoletta ACD; Dallabrida AL. 2014. Intake and digestion of wethers fed with dwarf elephant grass hay with or without the inclusion of peanut hay. Tropical Animal Health and Production 46(6):975–980. doi: 10.1007/s11250-014-0594-5
R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL. r-project.org.
Van Soest PV; Robertson JB; Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74(10):3583–3597. doi: 10.3168/jds.S0022-0302(91)78551-2
Wallace JD; Raleigh RJ; Sawyer WA. 1961. Utilization of chopped, wafered, and pelleted native meadow hay by weaned Hereford calves. Journal of Animal Science

20(4):778–781. doi: 10.2527/jas1961.204778x
Wanapat M. 2009. Potential uses of local feed resources for ruminants. Tropical Animal Health and Production 41:1035. doi: 10.1007/s11250-008-9270-y
Wanapat M; Kang S; Polyorach S. 2013. Development of feeding systems and strategies of supplementation to enhance rumen fermentation and ruminant production in the tropics. Journal of Animal Science and Biotechnology 4:32. doi: 10.1186/2049-1891-4-32
Wright SJ; Cornejo FH. 1990. Seasonal drought and leaf fall in a tropical forest. Ecology 71(3):1165–1175. doi: 10.2307/1937384

(Received for publication 3 November 2020; accepted 13 August 2021; published 30 September 2021)