

Effects of ensiling tropical grass-*Leucaena* mixtures on chemical composition and group dry-matter intake by Barbados Black Belly ewes

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ABSTRACT

This study evaluated the effects of ensiling on the chemical composition of tropical grasses and grass-*Leucaena* mixtures and assessed group dry-matter intake by growing Barbados Black Belly ewes. Tanner, Mulato, and Elephant grasses were ensiled alone or mixed with *Leucaena* at grass-to-*Leucaena* ratios of 50:50, 75:25, and 25:75. Thirty-six replicated pits were used for the grass-only and mixed treatments, and the silages were recovered after 55 days. Dry matter, moisture, organic matter, crude protein, ether extract, ash, crude fibre, and nitrogen-free extractives were determined using AOAC procedures. Ensiling significantly altered several chemical constituents ($P < 0.05$). Crude protein declined across the replicated treatments, with post-ensiling values ranging from 47.6 g/kg DM in tanner grass to 114 g/kg DM in Tanner-*Leucaena* 75:25. Crude fibre generally increased, whereas ether extract and nitrogen-free extractives declined in most treatments. In the feeding evaluation, group dry-matter intake was 4 kg DM/day for Tanner-*Leucaena* 50:50, Tanner-*Leucaena* 25:75, and Mulato-*Leucaena* 50:50, compared with 3 kg DM/day for the other mixtures. Mulato-*Leucaena* 50:50 combined a comparatively favourable nutrient composition with high observed group intake. Further replicated animal studies are recommended to evaluate digestibility, fermentation quality, and productive responses.

Keywords: Barbados Black Belly sheep, forage conservation, *Leucaena*, silage, small ruminants, tropical forage.

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INTRODUCTION

Seasonal variation in forage availability and nutritive value remains an important constraint to ruminant production in tropical and subtropical systems. Livestock contribute substantially to food security, income generation, and rural livelihoods; however, productivity is frequently limited by seasonal shortages of feeds of adequate quantity and quality (Herrero et al., 2013; Thornton, 2010). Under these conditions, conservation of locally available forages is an important strategy for maintaining feed continuity and reducing dependence on purchased feeds.

Among forage-conservation approaches, ensiling preserves moist herbage through anaerobic fermentation. Silage quality is governed by interacting factors, including forage dry matter, fermentable carbohydrate supply,

buffering capacity, compaction, sealing, and microbial activity (Kung et al., 2018; McDonald et al., 1991; Muck et al., 2018). These factors are particularly relevant in tropical systems because grasses may contain limited concentrations of water-soluble carbohydrates, whereas legumes may have comparatively high buffering capacity. Consequently, wilting and complementary grass-legume combinations may improve ensilability and nutritional value by balancing fermentable substrates with protein-rich forage.

Within this context, tree legumes offer a potential source of nutritional complementarity when tropical grasses are mature or deficient in protein. *Leucaena leucocephala* is widely used as a high-protein tropical forage, although its contribution depends on inclusion

level, forage maturity, and conservation method. Associative effects between grass and legume components may therefore influence nutrient preservation and subsequent feed intake. Evidence from tropical ruminant systems indicates that moderate inclusion of legume silage can maintain or improve productive responses, whereas very high inclusion levels may reduce intake or digestibility (Castro-Montoya and Dickhoefer, 2018). Research on Napier grass-*Leucaena* mixtures similarly indicates that the mixing ratio can influence nutritive value and that a 50:50 mixture may provide a favourable nutritional balance (Rakau et al., 2022). More recent evidence from tropical sheep systems shows that *Leucaena* and other fodder-tree foliage can improve nitrogen utilisation and, when used in complementary combinations, support voluntary intake and growth, reinforcing the importance of associative effects among forage components (Idan et al., 2023).

Despite this evidence, information remains limited on the ensiling characteristics of forage combinations commonly available under Caribbean conditions and their acceptance by locally adapted small-ruminant genotypes. Addressing this gap is important because locally conserved grass-legume mixtures could help buffer seasonal feed shortages while promoting greater utilisation of regionally available forage resources. We hypothesised that the inclusion of *Leucaena* would modify nutrient preservation during ensiling and that balanced grass-*Leucaena* mixtures would support comparatively favourable group dry-matter intake. Therefore, the objectives of this study were to determine the effects of ensiling on the chemical composition of selected tropical grasses and grass-*Leucaena* mixtures and to describe group dry-matter intake by Barbados Black Belly ewes offered the mixed silages.

MATERIALS AND METHODS

Study site

The study was conducted at the Eastern Caribbean Institute of Agriculture and Forestry (ECIAF) in Trinidad and Tobago. Three tropical grass species Tanner grass (*Brachiaria radicans*), Mulato grass (*Brachiaria brizantha* × *B. ruziziensis*), and Elephant grass (*Pennisetum purpureum*), were harvested from the ECIAF Farm, while *Leucaena* (*Leucaena leucocephala*) was harvested from an adjacent area. The forages were harvested manually at the early vegetative growth stage using sickles.

Forages and treatment mixtures

The harvested forages were transported to the processing facility and chopped to approximately 5 cm in length using a mechanical forage chopper. The chopped materials were spread evenly on polyethylene sheets

inside a greenhouse for wilting. Samples were turned daily to ensure uniform moisture reduction, while ambient temperature and relative humidity were monitored throughout the drying period. Wilting continued until the forage moisture content reached approximately 30%. Representative pre-ensiling samples were dried in a forced-air oven at 60°C to constant weight for proximate analysis.

The experiment evaluated three grass-only treatments and nine grass-*Leucaena* mixtures in a completely randomized design. The grass-only treatments consisted of three grass species, with three replicate pits per species, giving a total of nine pits. The mixed treatments combined each grass species with *Leucaena* at dry-weight ratios of 50:50, 75:25, and 25:75. Each of the nine mixtures was replicated across three pits, yielding 27 mixed-treatment pits and 36 total experimental units. The specific mixtures comprised Tanner grass-*Leucaena* (50:50, 75:25, and 25:75), Mulato grass-*Leucaena* (50:50, 75:25, and 25:75), and Elephant grass-*Leucaena* (50:50, 75:25, and 25:75).

Forage preparation and ensiling

Laboratory-scale trench silos were prepared by digging earth pits approximately 1.07 m deep and 0.30 m wide. Following wilting, weighed forage mixtures were tightly packed, wrapped securely in heavy-duty polyethylene sheeting to ensure airtight conditions, and buried in the pits. Ensiling was carried out for 55 days under ambient conditions.

After 55 days, the silos were opened, unsealed, and their internal temperatures recorded. Core samples were then collected from each silo. Representative post-ensiling samples were dried and prepared for comparative chemical evaluation against the pre-ensiling materials.

Physical and Chemical Analyses

Pre- and post-ensiling forage samples were ground to pass through a 1-mm screen and analyzed for proximate composition following standard AOAC (1995) procedures. The parameters evaluated included dry matter (DM), moisture content (MC), organic matter (OM), crude protein (CP), ether extract (EE), ash, crude fibre (CF), and nitrogen-free extractives (NFE). All chemical constituents except moisture content were expressed on a dry-matter basis, and NFE was calculated by difference.

Feed-intake evaluation

A feeding trial was conducted using growing Barbados Black Belly ewes with an average live weight of 19.0 ±

1.50 kg. The animals were housed in designated treatment pens and allocated to the experimental silages.. Silage was offered twice daily with a 15% refusal allowance to ensure *ad libitum* intake. The ewes underwent a 7-day preliminary adaptation period to the diets, followed by a data-collection phase. The amount of feed offered and the corresponding refusals were weighed and recorded daily for each treatment group to determine group dry-matter intake (DMI).

Ethical statement

The feeding evaluation relied on standard management practices involving routine feeding and non-invasive intake measurements. Therefore, formal institutional animal ethics committee approval was not required, in accordance with local institutional guidelines for standard livestock feeding trials.

Statistical analysis

Chemical composition and intake data were evaluated using analysis of variance (ANOVA) in IBM SPSS

Statistics (version 21). When significant F-tests were observed ($P < 0.05$), treatment means were separated using Duncan's multiple range test. Results are reported as treatment means with the standard error of the mean (SEM).

RESULTS

Chemical composition before and after ensiling

Ensiling produced treatment-dependent changes in DM and MC (Table 1). The clearest pattern was an increase in DM, accompanied by corresponding reductions in MC, in several treatments, including Elephant grass, Mulato grass-*Leucaena* 25:75, Elephant grass-*Leucaena* 75:25, and the Tanner grass-*Leucaena* mixtures. Other combinations showed comparatively small or non-significant changes. Specific treatment means and significance groupings are presented in Table 1.

Changes in OM were likewise treatment-dependent (Table 1), with increases in some grass-*Leucaena* combinations and decreases in others. Across the replicated treatments, the most consistent compositional response was a significant decline in CP after ensiling.

Table 1. Chemical composition of forage treatments before and after ensiling (g/kg DM).

Treatment	Phase	DM	MC	OM	CP	EE	Ash	CF	NFE
Leucaena	Before	914aA	86aA	888aA	198aA	79.6aA	112aA	163aA	448aA
Leucaena	After	929bA	71aA	895bA	139bA	59bA	121bA	227bA	428bA
Mulato	Before	911aA	83aA	850aB	107aB	65.7aB	150aB	257aB	420aB
Mulato	After	917aB	89aA	863bB	60.2bB	53.8bB	157bB	373bB	355bB
Elephant	Before	912aA	88aA	895aC	104aC	68.3aB	105aC	309aC	413aB
Elephant	After	936bA	64bC	898aA	61.7bB	51.3bB	112bC	382bB	315bC
Tanner	Before	890aB	110aB	886aA	99.8aD	54.7aC	114aA	303aC	469aC
Tanner	After	901aB	99aB	863bB	47.6bC	46.7bB	137bD	374bB	382bD
M/L 25:75	Before	911aAB	89aA	883aA	165aE	70.4aB	138aD	271aB	365aD
M/L 25:75	After	933bA	67bAC	863bB	101bD	62.2bA	117bE	297bC	325aC
M/L 50:50	Before	914aA	86aA	860aD	201aF	69.3aB	151aB	337aD	257aE
M/L 50:50	After	922aA	78aA	860aB	101bD	65.5bAC	140bD	360bB	247aE
M/L 75:25	Before	912aA	88aA	869aE	210aG	85.7aD	131aE	235aB	352aD
M/L 75:25	After	912aB	88aA	879bC	99.8bE	82.1aD	121bA	242aA	332aC
E/L 25:75	Before	933aC	67aA	815aF	171aH	79.6aA	185aF	335aD	250aE
E/L 25:75	After	935aA	65aAC	819aD	101bD	62.3bAC	181aF	343aB	230aE
E/L 50:50	Before	922aAC	78aA	835aG	197aI	95.8aE	166aG	262aB	289aF
E/L 50:50	After	926aA	74aA	845bE	100bD	79.2bE	156bG	274aC	269bF
E/L 75:25	Before	912aA	88aA	837aG	202aF	80.4aA	164aG	285aBD	288aF
E/L 75:25	After	949bAC	51bAC	844bE	105bF	69.2bAC	156bG	297aC	268bF
T/L 25:75	Before	876aBC	124aB	846aD	169aJ	91.8aE	155aB	265aBD	329aG
T/L 25:75	After	935bA	65bAC	854bF	99.7bE	61.7bAC	146bH	272aC	309bC
T/L 50:50	Before	891aBC	119aB	818aF	202aF	79.6aA	183aF	249aB	326aG
T/L 50:50	After	927bA	73bA	846bE	113bF	69.4bAC	154bG	257aA	306bC
T/L 75:25	Before	879aBC	111aB	821aF	197aA	68.3aB	180aF	273aB	302aF
T/L 75:25	After	949bAC	51bAC	833bG	114bF	60.6bA	167bI	290bC	292aF
SEM		13.4	17.0	4.31	1.99	4.73	4.27	16.8	18.9

Abbreviations: DM, dry matter; MC, moisture content; OM, organic matter; CP, crude protein; EE, ether extract; CF, crude fibre; NFE, nitrogen-free extractives; M/L, Mulato grass/*Leucaena*; E/L, Elephant grass/*Leucaena*; T/L, Tanner grass/*Leucaena*. Leucaena-alone values are descriptive because Leucaena was not ensiled in replicated pits. Superscripts indicate the Duncan multiple-range comparisons retained from the original analysis.

Post-ensiling CP values ranged from 47.6 g/kg DM in Tanner grass to 114 g/kg DM in Tanner grass-*Leucaena* 75:25. *Leucaena*-only values are retained in Table 1 for descriptive context because this treatment was not ensiled in replicated pits.

EE generally declined after ensiling, whereas CF tended to increase and NFE tended to decrease (Table 1). These broad shifts indicate a relative loss or utilisation of more readily fermentable fractions compared with structural components, although the proximate-analysis dataset does not include direct measures of fermentation quality. Ash responses varied among treatments.

Feed intake

Group dry-matter intake ranged from 3 to 4 kg DM/day across the silage mixtures (Table 2). The highest observed group intake, 4 kg DM/day, occurred for Tanner grass-*Leucaena* 50:50, Tanner grass-*Leucaena* 25:75, and Mulato grass-*Leucaena* 50:50, whereas the remaining mixtures recorded 3 kg DM/day. These values represent descriptive treatment-group observations and were not interpreted as independent animal-level measurements.

Table 2. Group dry-matter intake of grass-*Leucaena* silages offered to growing Barbados Black Belly ewes.

Treatment	Group DM intake (kg DM/day)
Tanner/ <i>Leucaena</i> 50:50	4
Tanner/ <i>Leucaena</i> 75:25	3
Tanner/ <i>Leucaena</i> 25:75	4
Elephant/ <i>Leucaena</i> 50:50	3
Elephant/ <i>Leucaena</i> 75:25	3
Elephant/ <i>Leucaena</i> 25:75	3
Mulato/ <i>Leucaena</i> 50:50	4
Mulato/ <i>Leucaena</i> 75:25	3
Mulato/ <i>Leucaena</i> 25:75	3

Values are treatment-group dry-matter intake and are presented descriptively; they are not individual-ewe intake values.

DISCUSSION

Nutrient changes during ensiling

Ensiling altered the chemical composition of the tropical forages and grass-*Leucaena* mixtures, although the magnitude and direction of these changes depended on forage type and mixing ratio. Such treatment-specific responses are biologically plausible because silage composition reflects the characteristics of the starting forage, pre-ensiling wilting, microbial fermentation, and differential losses of soluble and structural constituents (Kung et al., 2018; McDonald et al., 1991). The present data therefore support interpretation of changes in

proximate composition but do not permit direct conclusions about fermentation quality because pH, organic acids, and ammonia-N were not measured.

Dry matter and organic matter

Several treatments showed higher DM concentrations after ensiling, accompanied by lower MC. This pattern is consistent with concentration effects associated with pre-ensiling wilting and moisture loss; fermentation-related losses of soluble constituents may also alter the proportional composition of the remaining DM. However, a higher DM concentration alone is not evidence of superior fermentation quality. Fermentation quality is more appropriately evaluated using pH, organic acids, ammonia-N, DM recovery, and aerobic stability (Kung et al., 2018; Muck et al., 2018; Wilkinson and Davies, 2013). The variable responses in OM similarly suggest that the forage combinations differed in the proportional retention or loss of organic constituents.

Crude protein

The consistent decline in CP after ensiling was one of the clearest findings. During ensiling, plant proteases and microorganisms can convert proteins into peptides, amino acids, and ammonia; the extent of proteolysis depends strongly on how rapidly anaerobic conditions are established and the pH is reduced (McDonald et al., 1991; Muck et al., 2018). This process is particularly relevant to grass-legume silages because the relatively high buffering capacity of legumes can slow acidification unless sufficient fermentable carbohydrate is supplied by the grass component. The substantial CP reductions observed in the present study should therefore be interpreted cautiously in the absence of pH and ammonia-N measurements. Nevertheless, the grass-*Leucaena* mixtures generally retained higher CP concentrations than the corresponding grass-only treatments, supporting the potential nutritional complementarity of the legume component (Castro-Montoya and Dickhoefer, 2018; Rakau et al., 2022; Njidda, 2010).

Fibre and soluble carbohydrate fractions

CF increased in several treatments, whereas NFE generally declined. Preferential microbial utilisation of readily fermentable carbohydrates can result in structural carbohydrates representing a greater proportion of the residual DM, thereby producing an apparent increase in fibre concentration. Some cell-wall components may also be modified during fermentation; therefore, proximate CF alone provides only a limited description of changes in

fibre fractions. The decline in NFE is directionally consistent with the utilisation of readily fermentable carbohydrates, but NFE is a calculated fraction and is not a direct measure of water-soluble carbohydrates or fermentation success. Future studies should therefore include neutral detergent fibre (NDF), acid detergent fibre (ADF), and direct measurements of fermentation products.

Grass-*Leucaena* mixtures and feed intake

The group-level intake data suggest that acceptance differed among the grass-*Leucaena* combinations, with Tanner grass-*Leucaena* 50:50, Tanner grass-*Leucaena* 25:75, and Mulato grass-*Leucaena* 50:50 recording the highest observed group DM intake. A balanced grass-legume mixture may provide associative nutritional effects by combining fermentable energy from grass with degradable nitrogen from *Leucaena*, potentially supporting rumen microbial activity, microbial protein synthesis, and fibre digestion. These mechanisms may influence passage rate and voluntary intake, while palatability and the physical characteristics of the silage may also contribute. Because intake was measured at the treatment-group level, however, the present observations cannot quantify individual-animal variation or establish statistically independent differences in intake among treatments. Recent work in goats fed *Leucaena* silage further demonstrates that interventions that improve fibre degradation can increase voluntary intake and the digestibility of DM, OM, CP, NDF, and ADF, highlighting the close relationship between fibre utilisation, rumen microbial activity, and intake of *Leucaena*-based conserved forage (Bureenok et al., 2024).

The comparatively favourable result observed for the 50:50 Mulato grass-*Leucaena* mixture is noteworthy because independent work with Napier grass-*Leucaena* silage also identified a 50:50 mixture as nutritionally favourable (Rakau et al., 2022). Studies of Elephant grass with increasing levels of *Leucaena* inclusion have further shown that *Leucaena* can increase CP and alter fibre characteristics and fermentation losses, although these responses are not necessarily linear (Araújo et al., 2022). Together, these findings support the optimisation of grass-to-legume ratios rather than the assumption that progressively increasing legume inclusion will necessarily improve feeding value or intake.

Practical implications

Grass-*Leucaena* co-ensiling could provide a locally based forage-conservation option for tropical small-ruminant systems, particularly where seasonal forage scarcity limits production. The present findings identify balanced mixtures, particularly Mulato grass-*Leucaena*

50:50, as candidates for further evaluation because this combination provided a comparatively favourable nutrient composition alongside high observed group intake. Confirmation of its feeding value will require adequately replicated animal trials incorporating direct measurements of fermentation quality, detergent-fibre fractions, digestibility, productive performance, and storage stability.

CONCLUSION

Ensiling resulted in forage-dependent changes in nutrient composition, characterised principally by lower CP and NFE concentrations and higher CF concentrations in several treatments. Incorporation of *Leucaena* generally improved post-ensiling protein concentration relative to the grass-only silages, while the highest observed group DM intake occurred with Tanner grass-*Leucaena* 50:50, Tanner grass-*Leucaena* 25:75, and Mulato grass-*Leucaena* 50:50. Among the combinations evaluated, Mulato grass-*Leucaena* 50:50 showed a promising balance between nutrient composition and observed group intake. Strategically balancing tropical grasses with *Leucaena* for co-ensiling may therefore offer a practical approach to improving the utilisation of local forage resources and mitigating seasonal feed shortages in small-ruminant systems. However, this potential should be confirmed through adequately replicated feeding trials incorporating individual-animal intake measurements, digestibility, fermentation-quality parameters, and productive responses.

COMPETING INTERESTS

The authors declare that they have no competing interests.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author on reasonable request.

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