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Mature fruits of *Gliricidia sepium* and *Leucaena leucocephala* plants have potential as inexpensive protein and mineral supplements for ruminants

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Abstract Multifunctional leguminous trees like *Gliricidia sepium* Jacq. (Steud.) and *Leucaena leucocephala* Lam. (de Wit) are ideal for sustainable agro-ecological farming systems. They are commonly used in alley cropping to provide a sustainable source of nitrogen to cultivated crops or in silvopastoral systems where the leaves are used as livestock feed. However, these plants produce fruits that are not widely used. This study evaluated the nutritive value of mature fruits from *G. sepium* and *L. leucocephala* plants to determine their potential as supplemental feedstuffs for ruminants. Mature fruits were collected from 15 plants of each species and evaluated for crude protein (CP), total digestible nutrients (TDN), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, non-fiber carbohydrates, total digestible nutrients, minerals, phytochemicals, *in-vitro* ruminal dry matter degradability (IVDMD) and 48-h (h) *in-vitro* ruminal organic matter digestibility (IVOMD). The concentration of CP (242 g/kg DM) was approximately 28% higher in *G. sepium* fruits. The TDN (552 g/kg DM), NDF (560.1 g/kg DM) and 48-h IVOMD (590 g/kg) were superior in *L. leucocephala* fruits. Similarly, *L. leucocephala* fruits had significantly higher minerals (i.e., calcium, magnesium, potassium, among others). However, *G. sepium* fruits had lower concentrations of soluble and insoluble condensed tannins and mimosine. The immediately degradable fraction (265.9 g/kg DM), potential degradability (621.6 g/kg DM), and effective degradability (438.9 g/kg DM) values were higher in *L. leucocephala* fruits. We concluded that mature fruits of *G. sepium* plant may be a better protein supplement for poor quality grass forages than *L. leucocephala* because of higher CP and lower phytochemicals contents.

Keywords Anti-nutritional compounds · Ruminal degradability · Chemical composition · Tree forage

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Introduction

Poor quality and low availability of grass forages particularly in the dry season are major constraints to ruminant livestock farmers in tropical environments (Kronqvist et al. 2021). To offset these deficits, farmers traditionally supplement grass forages with commercial concentrate feeds (Birmingham and Hughes 2023). However, the rising cost of commercial supplements negatively impacts on the profitability of ruminant farms. Commercial supplemental feeds account for approximately 25–50% of variable cost to produce sheep and goat meat (Leon et al. 2022) and approximately 40% to produce milk (Hughes et al. 2011) in the Caribbean. Therefore, inexpensive, and locally growing alternative feedstuffs should be identified to support sustained growth of ruminant production. Leguminous forages have the potential to be incorporated in ruminant rations to achieve economically, environmentally, and socially sustainable livestock production. *Gliricidia sepium* Jacq. (Steud.) and *Leucaena leucocephala* Lam. (de Wit) are important for agroforestry systems, reforestation programmes and soil conservation (Alamu et al. 2023). In particular, *L. leucocephala* has played a critical role in developing sustainable agro-ecological farming systems in Latin America and the Caribbean (Chará et al. 2019). Both *G. sepium* and *L. leucocephala* can contribute to development of agroforestry systems and improve crop productivity and sustain tropical agroecosystem by providing shade, organic matter, control soil erosion, provide a constant supply of nitrogen to the soil through biological N fixation in their roots (Sena et al. 2020; Camelo et al. 2021) and provide a sustainable source of high-quality feed for ruminant livestock (Garcia et al. 1996). In mixed cropping or monoculture cultivation, *G. sepium* and *L. leucocephala* can add approximately 29–87 kg nitrogen/ha to the soil (Jayasundara et al. 1997). As a result, intercropping leguminous trees with grass forage increased biomass yield and nutritive value of the grass forage (De-Oliveira et al. 2017). Further, soil organic carbon sequestration was around 35% higher in intercropping systems with *G. sepium* than in monoculture plantation (Lira Junior et al. 2020).

As forage plants, *G. sepium* and *L. leucocephala* are rich in protein (Edwards et al. 2012) and can significantly improve digestibility, intake, and productivity when used to supplement grass forages (Cudjoe and Mlambo 2014). Indeed, protein supplementation of grass forages has been shown to increase average daily gains and reproductive efficiency in small ruminants (Tshabalala et al. 2013). Similarly, growth rate in small ruminants increased by approximately 10% when *G. sepium* leaves were included in the diet (Fasae et al. 2014). However, leaf biomass yield of these plants is generally low (Edwards et al. 2012) especially in the dry season (Edvan et al. 2014). Leguminous trees produce fruits mainly towards the end of the rainy season that are not used but may have similar potential as the leaves for feeding ruminants (Rubanza et al. 2007). These fruits of the *G. sepium* and *L. leucocephala* plants could provide an additional source of nutrients for livestock making both plants ideal for agroforestry systems in tropical environments characterized by a distinct seasonal variation in forage availability. Previous studies reported that the fruits of multi-purpose forage trees contained as much as 150–400 g crude protein (CP)/kg dry matter (DM) and served as important feedstuffs for goats when forages are in short supply (Rubanza et al. 2007; Rojas Hernadez et al. 2015). Similarly, Zapata-Compos et al. (2020) confirmed high nutritive value of *L. leucocephala* fruits in Mexico. In their report, the concentrations of CP, acid detergent fiber (ADF) and in vitro dry matter digestibility of the mature fruits were 220, 357 and 506 g/kg DM, respectively.

Likewise, CP and ADF contents of *G. sepium* fruits were 132 and 417 g/kg DM, respectively (Pérez-Gil Romo et al. 2014). The fruits of both plants were also a rich source of macro- and microminerals (Zapata-Compos et al. 2020; Pérez-Gil Romo et al. 2014). However, very little is known of the ruminal dry matter degradability (DMD) kinetics of the mature fruits of *L. leucocephala* and *G. sepium* plants. This information is critical to encourage utilization as supplemental feedstuffs for ruminants to increase the contribution of agroforestry systems to livestock development in the Caribbean. Since the nutritional value of leguminous tree forages varies with location and growing conditions, it is important to nutritionally characterize *G. sepium* and *L. leucocephala* fruits within each locality to encourage local and optimal usage. The objective of this study was to examine the chemical composition and in vitro ruminal DMD kinetics of mature fruits of *L. leucocephala* and *G. sepium* plants grown under similar conditions in Trinidad and Tobago.

Materials and methods

Sample collection and preparation

Mature fruits were harvested by hand from *Leucaena leucocephala* and *Gliricidia sepium* trees planted at the University of the West Indies Field Station (Lat 10° 38’ N Lon 61° 23’ W). The University Field Station is situated on a relatively flat topography with an altitude of 15.2 m above mean sea level. Average annual rainfall is 1782.9 mm with an average monthly temperature of 27 °C. The soil type is river estate loam. The soil is free draining with an average pH of 6.6 (Peters et al. 2022). The species were established on separate semi-cambered beds at a spacing of 0.91 × 0.91 m. Approximately fifty (50) mature fruits were manually harvested from each of fifteen (15) plants per species. The fruits collected from every three plants were pooled to produce five (5) replicates per species. The samples were temporarily stored in brown paper bags prior to being transported to the laboratory to be oven dried to constant weight at 65 °C in a force-draft oven. After drying, the samples were milled to pass through a 1 mm sieve using a Wiley hammer mill (Glen Creston Ltd, Middlesex, UK) in preparation for chemical analysis.

Chemical analyses

Proximate components

Milled samples were analyzed for concentrations of DM (AOAC 2005, method no. 934.01) and Kjeldahl Nitrogen (N) (AOAC 2005, method no. 2001.11) which was converted to CP [N × 6.25]. Organic matter (OM) was calculated by difference of DM and ash (AOAC 2005, method no. 942.05). The concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined sequentially with the ANKOM^{2000} Fiber Analyzer following the procedure described by Peters et al. (2022) and expressed inclusive of residual ash. Heat-stable α-amylase was used for NDF analysis. Lignin was determined by treating the ADF residue post fiber extraction with 72% sulfuric acid followed by oven drying and ashing in a muffle furnace at 550 °C for 8 h. Acid detergent-insoluble nitrogen (ADIN) was determined by Kjeldahl N method of residues post ADF extraction of a second set of samples (Licitra et al. 1996). Crude fat was determined by the petrol ether method using the Soxhlet apparatus (AOAC 2005, method no. 92003.05). Mineral contents were assessed by dissolving 0.3 g of milled sample in 5 mL nitric acid (HNO_3) and 0.05 mL hydrogen fluoride in a microwave oven and then diluting to 10 mL with deionized water. Samples were further diluted 20 times to a matrix of 0.1 HNO_3 for analysis of all mineral elements except for iron, for which the samples underwent a second round of dilution to an alkaline matrix (AOAC 2005, method no. 985.35). Diluted samples were analyzed for calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K) and sodium (Na) by the inductively coupled plasma optical emission spectroscopy (ICP-OES) method (SS-EN 14538:2006) using a 3 ICP AAS instrument (Spectro Analytical Instruments GmbH, Kleve, Germany). Samples were also analyzed for contents of copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) using the Perkin-Elmer Analyst 700 atomic absorption spectrometer (Turkekul et al. 2004).

Phenolics

Phenolic compounds (total phenolic compounds, condensed tannin, and insoluble condensed tannins) were estimated using Folin–Ciocalteau reagents, after extraction of 40 mg sample with 10 ml of 70% aqueous acetone for 15 min following standard procedures (Folin and Ciocalteu 1927; Porter et al. 1986). The UV–Vis spectrophotometer (Genesys 10S, Thermos Scientific) was used to measure and record absorbance parameters at 675 nm wavelengths. Analysis of mimosine was done according to the HPLC method (Wu et al. 2012).

In vitro ruminal dry matter degradability

In vitro ruminal DMD was assayed by slight modification of the Daisy^{II} Incubator method (ANKOM 2001, method no. 3) for in vitro true digestibility. Filter bags were not rinsed with NDF solution after incubation with buffered rumen inoculum. A non-lactating fistulated cross-bred Holstein cow weighing approximately 450 kg was used to source the inoculum. Management of this animal was consistent with the recommendations of the National Research Institute (2011) for care of experimental terrestrial animals. Ethical clearance was obtained from the Research Ethics Committee of the University of the West Indies, St Augustine Campus, Trinidad and Tobago (Ref: CREC-SA.0410/06/2020). The donor cow was fed a diet consisting of unrestricted amounts of *Brachiaria arrecta* grass forage supplemented with approximately 2 kg (as fed) commercial concentrate feed and 3 kg (as fed) of each fruit from *L. leucocephala* and *G. sepium* plants for 10 days prior to the start of the experiment. Inclusion rate of the fruits was to achieve minimum concentrate use while ensuring the cow was offered a diet with approximately 12–15% CP needed to support a typical heifer or dry cow (NRC 2001). Both fruits were wilted for 12–24 h, chopped in a mechanical forage chopper prior to feeding. *Brachiaria arrecta* grass forage was harvested and fed fresh daily. Rumen inoculum was collected in the morning prior to feeding. Digesta was manually removed from multiple sites in the reticulo-rumen, squeezed through 2 layers of warm muslin cloth into a pre-warmed thermos flask and transported immediately to the laboratory. Approximately 500 g digesta was taken to the lab and blended at high speed to dislodge tightly adhering microbes for inclusion into the final inoculum.

The inoculum was again strained through muslin cloth and maintained at 39 °C under constant flushing with CO_2. Approximately 0.5 g milled sample was heat-sealed into ANKOM F57 filter bags and placed in the digestion jars containing approximately 1600 ml of buffer. The buffer solution was prepared as described by ANKOM (2001, method no. 3). About 400 ml inoculum was added to each Daisy^{II} jar. A total of 54 filter bags inclusive of blanks (2 per incubation interval) were prepared per treatment (plant species) and distributed equally between the jars. Filter bags were withdrawn at 2, 4, 6, 8, 12, 24, 36, 48, and 72 h post-inoculation, rinsed in cold water until filtrate becomes clear. Jars were purged with CO_2 each time they were opened. In vitro ruminal organic matter digestibility (IVOMD) assay was subsequently done using a second set of prepared samples following modifications to the ANKOM Daisy ^{II} method previously described. After 48 h of incubation, the samples were washed in cold distilled water, dried and ashed to determine IVOMD (Smith et al. 1971).

Statistical analysis and calculations

Data normality was confirmed by the Shapiro–Wilk test. One-way analysis of variance (ANOVA) was used to examine the effect of plant species on chemical compositions and in vitro ruminal fermentation parameters of the fruits. Incubation time was included as the main effect for DMD. All analysis was performed in SAS 9.3 (2010). Significance was declared at $p \leq 0.05$. In vitro ruminal DM fermentation data was fitted to the Ørskov and McDonald (1979) nonlinear model using SAS 9.3 to estimate DMD parameters. The nonlinear model was as follows:

$$P = a + b\left(1 - e^{-ct}\right)$$

where, P = DMD at time 't', a = immediately degradable DM, b = slowly degradable DM (insoluble fraction), c = degradation rate constant for the insoluble fraction b, l is lag time and t = incubation time (hours). Potential degradability (g/kg DM) was calculated as fraction $a+b$ (Moya 2021). Effective degradability (ED) was estimated as follows (Cudjoe and Mlambo 2014):

$$\mathrm{ED} = a + (b \times c)/(c + k)$$

where k (outflow rate of solids) was assumed to be 5%/ h.

Total digestible nutrients were determined by multiplying the digestion coefficient for organic matter, D, by a conversion factor: $F = M(100 + 0.000125E)$. Where: M = % organic matter in feed DM, E = ether extract as % organic matter as follows (Lofgreen and Meyer 1956):

$$\mathrm{TDN} = D\mathrm{x}\ \mathrm{F} = M(100 + 0.000125E)$$

The concentrations of non-fiber carbohydrates (NFC) was calculated using as follows (Naseri 2020):

$$\mathrm{NFC} = \mathrm{OM} - (\mathrm{NDF} + \mathrm{EE} + \mathrm{CP})$$

Table 1 Chemical composition (g/kg DM unless otherwise stated) of mature fruits of *Gliricidia sepium* and *Leucaena Leucocephala*

Parameters	*G. sepium*	*L. leucocephala*	SEM	*p*-value
Macro-constituents				
Dry matter (g/kg)	923	922	12.5	0.338
Crude protein	242^{a}	174^{b}	4.50	0.027
Organic matter	891^{a}	885^{b}	2.03	0.001
Non-fiber carbohydrates	272	261	11.2	0.230
Neutral detergent fiber	460^{a}	560^{b}	73.7	0.003
Acid detergent fiber	421^{a}	373^{b}	68.2	0.008
Lignin	154	159	10.6	0.822
Acid detergent insoluble N	1.43	1.15	0.35	0.122
Macro-minerals				
Calcium	1.10^{a}	8.60^{b}	5.40	0.041
Phosphorous	1.80	2.90	2.03	0.543
Magnesium	0.90^{a}	2.20^{b}	1.02	0.045
Potassium	18.8^{a}	24.5^{b}	3.50	0.024
Sodium	1.00	0.30	1.90	0.555
Micro-minerals (ppm)				
Iron	76.0^{a}	136^{b}	30.5	0.019
Manganese	13.0^{a}	22.0^{b}	7.7	0.033
Zinc	23.0^{a}	34.0^{b}	9.4	0.022
Copper	4.00^{a}	14.0^{b}	10.0	0.049
Phytochemicals				
Total phenolic compounds (mgGAE/g)	24.2^{a}	75.3^{b}	15.7	0.040
Soluble condensed tannins (AU_{550nm})	0.05^{a}	0.21^{b}	0.01	0.015
Insoluble condensed tannins (AU_{550nm})	1.50^{a}	1.87^{b}	0.02	0.035
Mimosine (%)	0.004^{a}	2.76^{b}	1.51	0.009

SEM Standard error of the mean, *AU* Absorbance units, *mgGAE/g* Milligrams of gallic acid equivalents per 100 g

^{a,b}; Means on the same row with different superscripts are statistically ($p < 0.05$) different

Results

Chemical constituents

Plant species did not influence the DM, CF, NFC, lignin, and ADIN concentrations of pods (Table 1). *Gliricidia sepium* fruits had higher CP content than *L. leucocephala* fruits. The concentration of NDF was lower in *G. sepium* while ADF was lower in *L. leucocephala* fruits. The *L. leucocephala* fruits had significantly higher concentrations of calcium, magnesium, potassium, iron, manganese, zinc and copper while phosphorus and sodium were similar (Table 1). Further, *L. leucocephala* fruits had significantly higher concentrations of total phenolic compounds, soluble and insoluble condensed tannins and mimosine compared to *G. sepium* fruits (Table 1).

Total digestible nutrients and in vitro organic matter digestibility

The concentration of TDN in *L. leucocephala* fruits was 11.5% higher than in *G. sepium* fruits (Fig. 1). Further, the 48-h IVOMD of *L. leucocephala* fruits was 17% higher compared to those of *G. sepium*.

In vitro ruminal dry matter degradability (DMD) kinetics

The fruits of the two plants did not differ in the slowly degradable fraction of DM (*b*) or the degradation rate of this fraction (*c*). However, the immediately degradable fraction of DM *(a)* was significantly higher in *L. leucocephala* fruits. *Leucaena leucocephala* fruits also had higher potential degradability and

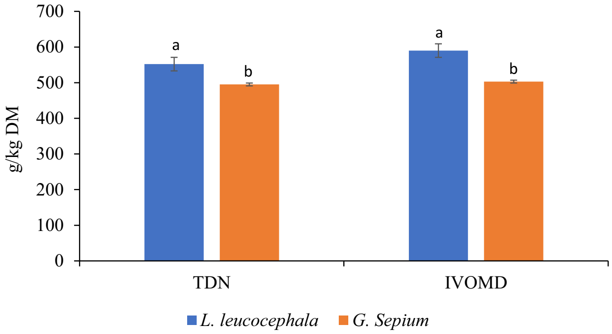

Fig. 1 Total digestible nutrients (TDN) and 48-h in vitro ruminal organic matter digestibility (IVOMD) of *Leucaena leucocephala* and *Glircidia sepium* mature fruits. ^{a,b}; columns with different superscripts are statistically ($p < 0.05$) different

Table 2 In vitro ruminal dry matter degradability kinetics of mature green fruits from *Glirdidia sepium* and *Leucaena leucocephala* plants

Parameters	*G. sepium*	*L. leucocephala*	SEM	*p*-value
a (g/kg DM)	190^b	266^a	8.07	0.006
b (g/kg DM)	341	356	14.5	0.435
c (%/h)	4.30	4.80	0.34	0.344
PD (g/kg DM)	531^b	622^a	18.9	0.008
ED (g/kg DM)	346^b	439^a	8.55	0.039

Parameters: *a* = immediately degradable fraction, *b* = degradable part of the insoluble fraction, *c* = degradation rate of fraction *b*

PD = Potential degradability and *ED* = Effective degradability, *SEM*: Standard error of mean

^{a,b}: Means within rows with different superscripts are significantly ($p < 0.05$) different

effective degradability of the DM than *G. sepium* fruits (Table 2).

Discussion

Agroforestry systems are important for their ecological services, contribution to food production and efficient use of natural resources (Domiciano et al. 2020). Leguminous plants like *Glirdidia sepium* and *Leucaena leucocephala* are critical to agroforestry development, especially in silvopastoral systems where their leaves provide a source of high-quality nutrients for livestock. This preliminary study demonstrated that the mature fruits of the *G. sepium* and *L. leucocephala* plants could also be important sources of nutrients for ruminant livestock which corroborates with previous studies (Zapata-Campos et al. 2020; Ngwa et al. 2000). The high CP contents of the mature fruits of *G. sepium* and *L. leucocephala* plants are characteristic of tropical multipurpose browse forages (Solvia et al. 2008). This highlights the potential of *G. sepium* and *L. leucocephala* plants to supply an additional source of nutrients, which makes these plants more valuable to agroforestry systems. The difference in CP content of *G. sepium* and *L. leucocephala* fruits may be an indication that both species differs in nitrogen fixing efficiencies since they were grown on the same soil under similar condition. The ratio of seed to husk could have also contributed to the variation in CP content because the CP content of seeds is usually higher than husk (Krenz et al. 2023). Indeed, this can account for the significantly higher CP content of *L. leucocephala* fruits that comprised of 60% seeds reported by Ngwa et al. (2000). Other factors such as stage of maturity could have contributed to the differences in chemical constituents such as the fiber contents. Therefore, careful considerations must be given to the stage of harvesting to optimize nutritive value of each species.

The fruits were harvested at the same time, but it is not certain that flowering and fruit development occur at similar rates in both species. Indeed, the higher NDF and lower CP contents could suggest that *L. leucocephala* fruits matures faster than *G. sepium* fruits. It is worth highlighting that the mature fruits for both species contained significantly more CP than the 150 g/kg DM recommended for optimum productivity in fattening sheep and goat (Bernard et al. 2020). Therefore, the high CP contents of *G. sepium* and *L. leucocephala* fruits could justify their use as protein supplements for grass forages that are deficient in protein during the dry season (Anele et al. 2009). However, the quality of the protein for ruminants is not clear. Garcia et al. (1996) reported total apparent digested CP of *L. leucocephala* leaves between 65 and 78%, with 48% of the undegradable protein available for post rumen absorption. Like the leaves, it may be reasonable to assume the CP of the mature fruits may be of high quality because of a high proportion of rumen undegradable protein (Garcia et al. 1996; Cudjoe and Mlambo 2014). Despite high CP contents and generally low NDF, the IVOMD of both fruits were relatively low, especially those from the *G. sepium* plant. The presence and deleterious effects of insoluble fiber and phenolic compounds such as condensed tannins may contribute to the generally low digestibility (Getachew et al. 2000; Hatew et al. 2016). However, lower insoluble fiber like cellulose, higher TDN and a more favorable balance between energy and protein in *L. leucocephala* fruits (Mizubuti et al. 2014) are likely more influential factors for the significantly higher IVOMD of *L. leucocephala* fruits. Indeed, significantly higher potential and effective degradability of *L. leucocephala* fruits can provide support for the latter. Similar to TDN, the NFC composition is an indication of the potential energy value of the feedstuff. Tylutki et al. (2008) suggested that the diet of a high productive ruminant must contain about 350–400 g/kg DM NFC. Therefore, lower amounts of supplementation with energy-rich commercial feedstuffs may be required to support high productivity ruminants on diets inclusive of *G. sepium* and *L. leucocephala* fruits. This may be an indication that the fruits of these species could improve the contribution of agroforestry systems to environmental and economic sustainability of livestock production. Lignin could also be a contributing factor for the higher degradability parameters of *L. leucocephala* fruits despite both species having similar lignin contents. However, it is possible that the composition and spatial distribution of lignin within the cell wall (Li 2021; Moore and Jung 2001) of *G. sepium* fruits could contribute to between-species variations in ruminal degradability.

Genetic variations in fruit compositions and rate of maturity could account for differences in the mineral profiles of *G. sepium* and *L. leucocephala* fruits. The mineral composition, especially in *L. leucocephala* fruits, suggest potential as a good source of supplemental minerals. In fact, the concentrations of calcium, potassium, iron, manganese, and copper in *L. leucocephala* fruits are multiple times the requirements of fattening indigenous Canindé goats (Ribeiro et al. 2018), but they fall below the maximum tolerable levels for the typical small ruminant (NRC 2007). However, the concentrations of phosphorus, magnesium, sodium, and zinc were within the required range of the typical small ruminant (NRC 2007). While *G. sepium* fruits may be deficient in calcium, most of the tropical grasses used for feeding ruminants in Trinidad and Tobago are rich in calcium (Jack et al. 2020) which may avert potential problems of calcium deficiencies. Similarly, potential deficiencies in phosphorus, magnesium, and copper from feeding *G. sepium* fruits can be prevented with use of grasses like *Cynodon nlemfuensis* and *Brachiaria arrecta* grown in the Caribbean (Jack et al. 2020). The concentrations of potassium in *L. leucocephala* and *G. sepium* fruits are much higher than the amount required by small ruminants. This can present a nutritional challenge because excessive potassium can hinder the uptake and metabolism of other minerals like sodium, calcium and magnesium (Mirzaei 2012).

Similarly, the iron concentrations of the fruits of both species exceed the normal requirements but is below the maximum tolerable level for ruminants (NRC 2007). The concentrations of manganese and zinc in the fruits of both species are adequate to satisfy requirements for the typical fattening sheep or goat (Ribeiro et al. 2018). Careful considerations must be given to dietary inclusion rates of these fruits to prevent problems associated with toxicity of minerals like potassium and iron and mitigate nutritional encumbrances caused by phenolic compounds. Unlike the leaves (De Angelis et al. 2021; Phimphachanhvongsod and Ledin 2002), the optimum inclusion rates of *G. sepium* and *L. leucocephala* fruits to avert toxicity issues and promote high animal productivity is unclear. However, up to 50% substitution of mustard seed cake with *L. leucocephala* seeds as the protein source in rations for fattening male lambs had no adverse effects on intake, nutrient utilization and growth (Singh et al. 2002).

The higher phenolic contents in the fruits of the *L. leucocephala* plant may be attributed to genotypic factors controlling physiological synthesis and accumulation of secondary plant compounds (Li 2021). Within species variations in the concentrations of phenolic compounds are associated with growth stage, botanical composition (Li 2021; Rodriguez and Reed 2020), growing conditions (Makkar et al. 2011), and defensive mechanisms against pests, pathogens, and predators (Norouzian and Ghiasi 2012). The low condensed tannin concentrations of *G. sepium* and *L. leucocephala* fruits may be in the desired range, enabling decreased ruminal nitrogen metabolism and increasing the supply of by-pass protein (Besharati et al. 2022). Indeed, diets containing condensed tannins of 2–4% DM can impart additional benefits to ruminants (Hatew et al. 2016) such as preventing frothy bloat, reduce internal parasitic load and improve intake and animal performance (Besharati et al. 2022). Feeding ruminants *G. sepium* and *L. leucocephala* fruits could further benefit the environment because of anti-methanogenic activity of condensed tannins in the rumen resulting in a reduction in methane emission (Besharati et al. 2022). The high concentration of mimosine in *L. leucocephala* fruits may be a cause for concern because of the possibility of mimosine conversion into secondary toxic compounds (Halliday et al. 2014). However, some ruminants like goats can develop bacterial and hepatic detoxification mechanisms to increase tolerate to high mimosine contents (De Angelis et al. 2021; Phaikaew et al. 2012).

Conclusion

The mature fruits of the *Gliricidia sepium* and *Leucaena leucocephala* plants has potential to provide an additional source of nutrients for ruminants managed in silvopastoral systems. This study demonstrated that mature fruits from the *G. sepium* plant may be a superior protein supplement for ruminants compared to *L. leucocephala* fruits because of higher crude protein and lower phytochemicals contents. However, the biological activity of these phenolic compounds and the quality of the protein for ruminants are largely unknown and worth investigating. In addition, the most appropriate management practices to optimize the productivity and contribution of both plants to developing silvopastoral systems is also critical to know. Further, it is imperative that future research addresses the impact of *G. sepium* and *L. Leucocephala* fruits on animal health and production to confirm their value as important nutritional supplements.

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Author contributions A.E - Conceptualization, Formal analysis, Writing – original draft, Investigation, Visualization, Data curation V.M - Conceptualization, Project administration, Writing – review & editing C.K - Formal analysis, Writing – review & editing M.H - Project administration, Writing – original draft, Writing – review & editing

Data availability Data available on request.

Declarations

Competing interests The authors declare no competing interests.

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