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Partial replacement of cottonseed cake with *Gliricidia sepium* foliage improves growth performance and economic efficiency in growing Bunaji bulls

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ABSTRACT: The hypothesis that *Gliricidia sepium* (GS) foliage can partially replace cottonseed cake (CSC) without compromising growth, health, or nutrient utilisation was tested in a feeding trial using twenty 15-month-old growing Bunaji bulls with a mean live weight of 110.5 kg. The animals were randomly assigned to four dietary treatments in which GS replaced CSC at 0, 25, 50, and 75% (w/w). Concentrate was offered at 2% of body weight, while *Brachiaria decumbens* hay and water were provided *ad libitum* over a 90-day period. Feed intake, growth performance, and feeding costs were evaluated. Concentrate intake, total dry matter intake, and average daily gain increased ($P < 0.05$) with GS inclusion up to 50% and declined at 75%. Average daily gain ranged from 220 to 350 g/day, with the highest values recorded at the 50% replacement level. Feed conversion efficiency improved ($P < 0.05$), while feed cost per unit of weight gain decreased with increasing GS inclusion. In conclusion, GS foliage can replace CSC up to 50% in the diets of growing Bunaji bulls without adverse effects on performance, and its use is recommended as a cost-effective alternative feed resource for farmers.

Keywords: Bunaji cattle, cottonseed cake, growth, haematology, rumen pH, tropical legumes

Highlights

- *Gliricidia sepium* as a tropical legume supplement contained higher protein and lower fibre than cottonseed cake
- The replacement of cottonseed cake with 50% *Gliricidia sepium* maximised weight gain and feed efficiency
- The inclusion of *Gliricidia sepium* in cottonseed cake diets reduced feed cost and improved economic returns

1.0 Introduction

Livestock production plays a critical role in the livelihoods of rural households in developing countries, where more than 70% of the poor reside in rural areas and approximately two-thirds of the population depend on livestock for income, food security and resilience (Alders et al., 2021; Erdaw, 2023). Improving the productivity of these livestock systems would not only enhance household livelihoods, but also increase the availability of animal protein at the national level (Adesogan et al., 2025). In Nigeria, ruminant production is largely dependent on natural pastures, which are characterised by low quantity and poor nutritional quality during the prolonged dry season. Seasonal feed scarcity results in reduced feed intake, poor live-weight gain and depressed reproductive performance, manifested as delayed age at first calving and prolonged calving intervals (Lamidi and Ologbose, 2018). Under such conditions, achieving early slaughter weight or breeding indigenous cattle within optimal reproductive cycles is difficult. Improving the nutritional plane of indigenous cattle, particularly during the dry season, is therefore essential for enhancing productivity (Terry et al., 2020).

Protein supplementation is a well-established strategy for improving the utilisation of low-quality forages by stimulating rumen microbial activity and increasing voluntary intake (Figueiras et al., 2016). However, conventional protein supplements such as cottonseed cake (CSC) are often unavailable or unaffordable to smallholder farmers due to declining national cotton production and rising market prices (Barman et al., 2018). This situation underscores the need to identify locally available, cost-effective and nutritionally adequate alternative protein sources.

Tropical browse legumes offer considerable potential as dry-season supplements due to their deep root systems, perennial growth habit and relatively stable nutrient composition compared with grasses (Aguilar et al., 2025). Among these, *Gliricidia sepium* is widely adapted to tropical environments, produces substantial leaf biomass and contains moderate to high levels of crude protein. (Silva et al., 2024). Although several secondary plant compounds have been reported in *G. sepium*, conclusive evidence of toxicity under normal ruminant feeding conditions remains limited (Molina-Botero et al., 2019).

Gliricidia (*Gliricidia sepium* [Jacq.] Kunth ex Walp.) is a perennial arboreal legume indigenous to Mexico and Central America, whose importance in forage-based animal feeding systems has increased considerably in recent decades (Castro Filho et al., 2016; Alamu et al., 2023). The species is now widely naturalized across tropical regions, including South America, Africa and Southeast Asia, and demonstrates good adaptability to environments characterized by low and irregular rainfall (365–800 mm annually). Under such conditions, *Gliricidia* can produce between 70 and 105 t ha⁻¹ year⁻¹ of total biomass, while its leaves may contain crude protein concentrations as high as 230 g kg⁻¹ DM. Owing to its high protein yield and year-round availability, *Gliricidia* represents a viable alternative to conventional protein supplements, such as soybean meal, thereby contributing to reductions in feed costs (Gurgel et al., 2021). *Gliricidia* is a medium-sized tree, typically attaining heights of 10–15 m and stem diameters of 30–40 cm (Alamu et al., 2023). It can be established either by seed or vegetative propagation using stakes and is commonly utilised by smallholder farmers in cut-and-carry feeding systems, where it is offered fresh to livestock. However, due to the presence of secondary plant compounds including polyphenols, condensed tannins, alkaloids, flavonoids and particularly coumarins; fresh *Gliricidia* may exhibit reduced palatability for some animal species (Purba et al., 2022; Suong et al., 2022). In this context, conservation methods such as haymaking and ensiling have been shown to improve acceptability and feeding value. Ruminant species differ in their tolerance to fresh *Gliricidia*, with cattle generally more sensitive to its anti-nutritional factors, whereas sheep and goats tend to adapt more readily to its use as a roughage source (Rusdy et al., 2019). Given its availability, ease of establishment and nutritional attributes, GS foliage represents a promising alternative protein source for ruminant feeding in the tropics. This study therefore evaluated the effects of replacing CSC with GS foliage in concentrate diets on growth performance, nutrient digestibility, nitrogen retention and economic efficiency in growing Bunaji bulls. It was hypothesised that partial replacement of cottonseed cake with GS foliage would improve growth performance and reduce feed cost in growing Bunaji bulls.

2.0 Materials and methods

2.1. Study site

The study was conducted at the Beef Research Programme's experimental pens at the National Animal Production Research Institute (NAPRI), Shika (11°12'N, 7°33'E), Zaria. The area falls within the Northern Guinea Savannah Zone at an elevation of 640m above sea level with an average annual rainfall of 1100mm which starts from late April/early May and ends in late September/ early October. The experimental protocol was reviewed and approved by the Ahmadu Bello University Animal Care and Use Committee (Approval No. ABUCAUC/2022/016). The feeding trial lasted for ninety days.

2.2 Forage and concentrate feed collection

Brachiaria decumbens hay was sourced at NAPRI. Cottonseed cake was purchased from ABJ Ginnery in Katsina. *Gliricidia sepium* forage was harvested around Bomo village, Samaru-Zaria. The leaves and succulent portions were chopped to a length of 4cm and air dried for 3 days.

2.3 Experimental animal management

The growth study utilised 20 growing Bunaji bulls, approximately 15 months of age, with an initial liveweight ranging from 109 to 113 kg with an average of 110.5 kg. Each bull used in the experiment was obtained from a separate dam within the research herd, with a single male offspring chosen per dam to minimize potential genetic relatedness among animals. All calves were born and reared on the same farm under uniform management and environmental conditions, thereby maintaining consistency in early-life feeding practices, health care, and general husbandry. Prior to the commencement of the experiment, the animals were subjected to a 14-day adaptation period to acclimatize them to the experimental diets, housing conditions and general management practices. During this adjustment period, the bulls were dewormed with albendazole at a dosage of 1 ml per 10 kg body weight to control endoparasites and treated against ectoparasites using Triatix® at the rate of 1 ml per 4 litres of water. Throughout the adaptation phase, the animals were fed the experimental concentrate diet at 1% of their body weight, while *Brachiaria* hay, clean drinking water and mineral salt lick were provided ad libitum. At the end of the adjustment period, the feeding trial commenced and lasted for 90 days. The bulls were randomly allocated to four dietary treatment groups, with five animals per treatment, in a completely randomized design. Each animal served as an experimental replicate. The animals were housed in open concrete stalls under uniform management conditions. Experimental diets were formulated such that *Gliricidia sepium* (GS) foliage replaced cottonseed cake (CSC) in the concentrate on a weight-for-weight basis. Other concentrate ingredients included maize offal, poultry litter (from deep litter layer pen), rice offal, bone meal and salt. During the experimental period, the concentrate was offered daily at 2% of the animals' body weight, while hay, water, and mineral salt lick were provided ad libitum.

2.4 Data collection

Initial body weight of the animals was taken at the commencement of the experiment and subsequently fortnightly using a walk-in weigh bridge. The treatments were adjusted accordingly to maintain treatment effect at 2% body weight. Feed and water intake were determined by the difference between quantity offered and the orts. Evaporative loss was subtracted from water provided in determining actual water intake.

2.5 Economic analysis

An economic analysis was conducted to assess the cost-effectiveness of replacing CSC with GS foliage. The major cost components considered included:

1. Feed Costs: Calculated from prevailing market prices of feed ingredients during the study year multiplied by daily intake per animal.
2. Total Feed Cost per Bull: Cost per kg of feed x daily feed consumed x 90 days.
3. Cost per kg Weight Gain: Total feed cost / Total live weight gain.
4. Labour Cost: One Attendant was employed and paid a wage of \$35/month; \$105 for 3 months hence an equivalent of \$5.25/animal
5. Benefit-Cost Ratio (BCR): $BCR = \text{Total Revenue} / \text{Total Production Cost}$,
where:

Revenue = Animals were sold on hoof. Sale price was based on \$4.71/kg liveweight.

As at the end of this study, the price of beef per kg was sold for \$18.82/kg, it is the usual practice to sell well finished feedlot bulls on hoof for half the price of a kilogram of beef in Nigeria. The prevailing price per kg of liveweight, therefore, was \$9.41. Since the experimental animals were young bulls not matured finished bulls for slaughter, they were sold for half of this price; hence \$4.71/kg liveweight)

Production cost = Initial purchase (\$211.76) + Feed costs + Labour (\$26.82)

Animals were sold to smallholder farmers around the Institute.

2.6 Chemical analysis

Fresh and dried samples of GS were taken to the Food Science Technology Laboratory, IAR to determine the presence of anti-nutritional factors while dry samples were taken to the Central Laboratory NAPRI for proximate analysis (AOAC, 2000). Samples of the concentrate, Brachiaria hay and GS (leaves and top portions of stems) and left overs were oven-dried to constant weight at 105°C to determine Dry Matter (DM) and later ground to pass through 1 mm sieve for further analysis. Crude Protein (CP), Ether Extract (EE), Crude Fibre (CF) and Ash content of the fodders were determined (AOAC, 2000). Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) were analyzed (Van Soest et al., 1991).

2.7 Statistical analysis

All data were analysed using the Statistical Analysis System (SAS, version 9.0; SAS Institute Inc., Cary, NC, USA). Prior to analysis, data were checked for normality and homogeneity of variance using the Shapiro–Wilk test and Levene’s test, respectively. Data from the growth trial and economic analysis were analysed as a completely randomized design (CRD) using one-way analysis of variance (ANOVA). Dietary treatment (level of *Gliricidia sepium* replacing cottonseed cake: 0, 25, 50 and 75%) was considered the fixed effect, while individual animals served as the experimental units.

When significant treatment effects were detected ($P < 0.05$), differences among treatment means were separated using Duncan’s Multiple Range Test (Duncan, 1955). Results are presented as means with their corresponding standard errors of the mean (SEM). All residuals were tested for normality and homogeneity of variance prior to analysis. Treatment means were separated using appropriate post-hoc procedures when significant effects were detected. Statistical significance was declared at $P < 0.05$.

The statistical model used is: $Y_{ij} = \mu + T_i + e_{ij}$ where:

Y_{ij} = observed value of the dependent variable for the j^{th} animal receiving the i^{th} dietary treatment

μ = overall mean

T_i = fixed effect of the i^{th} dietary treatment (0, 25, 50, 75%)

e_{ij} = random error associated with the j^{th} animal, assumed to be independently and normally distributed with mean zero and constant variance.

3.0 Results

3.1. Chemical composition and anti-nutritional factors

Table 1 shows the result of chemical analysis for GS and CSC. The values obtained for CP (26.38%) and Ash (7.62%) for GS was higher than that of CSC (21.75% and 4.32% respectively). *Gliricidia sepium* had lower values for CF (8.52%) and NDF (27.40%) as compared to CSC with a CF and NDF contents of 17.62% and 49.08% respectively. These values from proximate analysis result indicate a higher nutrient profile in *Gliricidia* as compared to CSC.

Table 1. Chemical composition (%) of CSC and *Gliricidia sepium* leaves*

	DM	ASH	EE	CF	NDF	ADF	CP
GS	93.56	7.62	8.52	8.52	43.19	26.38	26.38
CSC	97.91	4.37	16.15	17.62	34.21	21.75	21.75

*GS = *Gliricidia sepium*, CSC = Cotton seed cake, DM = Dry matter, EE = Ether extract, CF = Crude fibre, NDF = Neutral detergent fibre, ADF = Acid detergent fibre

The result of anti-nutritional factors in GS is presented in Table 2. The levels of tannins, oxalate, phytates, saponin and trypsin inhibitors showed a higher concentration of these factors in the dried samples than in the fresh leaves may be due to moisture loss and concentration in dry matter.

Table 2. Levels of anti-nutritive factors in *Gliricidia sepium* (mg/100g)

Anti-nutritive factor	Fresh sample	Dry sample
Tannin	0.28	0.42
Oxalates	1.04	1.46
Phytates	0.46	0.48
Saponin	1.08	1.64
Trypsin inhibitor	0.24	0.40

3.2 Nutrient composition of experimental diets

Proximate analysis of individual feed ingredients was carried out before use (Table 3). The composition of experimental diets is shown in Table 4, while the nutrient composition of experimental diets is presented in Table 5. Dry Matter content of diets containing 50 % and 75 % GS replacement levels were the same while 0 % and 25 % GS replacement levels had DM values of 95.74% and 94.45%, respectively (Table 4). Although diets were formulated to be isonitrogenous (12%), proximate analysis revealed that the diets had CP of 13 %. The CF and EE values ranged between

17.58 and 19.59. The mean Ash content was highest in 75 % while the lowest value was in 0%. The NDF values of 0, 25 and 50% were higher than that of 75 %. The 0% had the highest ADF value while 75 % had the lowest.

Table 3. Proximate analysis of feed ingredients and *Brachiaria decumbens* hay*

Nutrients	Maize offal	Rice offal	Poultry litter	CSC	Brachiaria hay
DM	97.01	97.20	97.39	97.91	98.86
ASH	5.16	16.29	23.96	4.37	6.41
EE	12.21	11.74	15.39	16.15	11.20
CF	18.21	17.96	11.48	17.62	46.68
NDF	32.68	51.68	53.73	49.08	71.65
ADF	17.00	32.06	29.27	34.21	48.94
CP	9.88	5.33	20.88	21.75	2.88

*DM = Dry matter, EE = Ether extract, CF = Crude fibre, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, CP = Crude protein, CSC = Cotton seed cake

Table 4. Ingredient composition of experimental diets*

Feed stuff	Level of <i>Gliricidia sepium</i> inclusion (%)			
	0	25	50	75
Cotton seed cake	10	7.5	5.0	2.5
<i>G. sepium</i>	0	2.5	5.0	7.5
Maize offal	40	40	40	40
Poultry litter	17	19	22	25
Rice offal	30	28	25	22
Bone meal	2	2	2	2
Salt	1	1	1	1
Total (kg)	100	100	100	100
Calculated analysis:				
Crude protein	12.36	12.22	12.21	12.20

Table 5. Nutrient composition of experimental diets*

Nutrients (%)	Level of <i>Gliricidia sepium</i> inclusion (%)			
	0	25	50	75
DM	95.74	94.45	98.84	98.84
ASH	11.91	12.51	11.97	13.01
EE	18.33	19.59	17.97	18.66
CF	19.69	20.08	19.88	17.58
NDF	40.15	42.41	40.79	35.02
ADF	23.75	22.83	20.77	21.53
CP	13.18	13.26	13.31	13.30

*DM = Dry matter, EE = Ether extract, CF = Crude fibre, NDF = Neutral detergent fibre, ADF = Acid detergent fibre, CP = Crude protein

Table 5 shows results of the water intake of animals. Intake of animals on 0 and 50% (20.59L) were significantly ($P<0.05$) different and higher than animals on 25 and 75% (19.33L). The feed conversion efficiency showed no significant ($P>0.05$) difference across the treatments. However, animals on 75% inclusion level had the best Feed Conversion Efficiency (FCE) with the control group having the least.

3.3 Effect of experimental diets on animal performance

The performance of growing bulls fed various levels of GS as replacement for CSC showed that live weight gain increased with increase in the levels of GS leaves in the diets up to a point. It was highest at 50% GS inclusion level and declined after wards (Table 6).

Table 6. Effect of diet on animal performance

Parameter	Level of <i>Gliricidia sepium</i> inclusion (%)				SEM	LOS
	0	25	50	75		
Initial body weight (kg)	113	109	111	109	6.31	NS
Final body weight (kg)	133	138	142	138	9.14	NS
Total weight gain (kg)	20 ^b	28 ^a	31 ^a	29 ^a	5.70	*
Average daily gain (g)	220 ^b	320 ^a	350 ^a	330 ^a	0.06	*
Daily water intake (l)	20.39 ^a	19.62 ^b	20.59 ^a	19.33 ^b	0.24	*
Daily concentrate intake (kg)	2.54 ^c	2.70 ^{ab}	2.78 ^a	2.68 ^b	0.03	*
Daily hay intake (kg)	2.26 ^b	2.21 ^b	2.42 ^a	2.13 ^c	0.02	*
Total daily feed intake (kg)	4.80 ^b	4.91 ^b	5.20 ^a	4.81 ^b	0.08	*
Total daily DMI (kg)	4.59 ^b	4.64 ^b	5.14 ^a	4.75 ^b	0.08	*
FCE kg feed/kg gain	45.39 ^c	18.62 ^b	17.56 ^b	15.78 ^a	10.87	*

a, b, c, d: Means within the same row with different superscript differ significantly ($P<0.05$), * = $P<0.05$

SEM = Standard error of means, LOS = Level of significance, NS = Not significant, DMI = Dry matter intake.

There was however no significant difference ($P>0.05$) in the Total Weight Gain (TWG) and Average Daily Weight Gain (ADWG) of the animals on diets containing 25%, 50% and 75% GS inclusions. Concentrate intake was highest with animals on diets containing 50% and lowest with animals on diets with 0% replacement levels. There was however no significant ($P>0.05$) difference in the concentrate intake of animals on 25 and 75% replacement levels.

For hay intake, animals on 50% replacement level had significantly ($P<0.05$) higher intake compared to all other treatments. No significant ($P>0.05$) difference was observed between animals on diet containing 25% replacement and those on the control diet. Hay intake of animals on 75% replacement level was lowest and significantly ($P<0.05$) different from others. Total Feed Intake (TFI) and Dry Matter Intake (DMI) followed similar trend. Animals on 50% replacement level had significantly ($P<0.05$) higher feed intakes compared to intakes of animals on 0, 25 and 75% replacement levels that had statistically similar values this could be attributed to a better palatability of diet at that level of replacement.

3.3 Effect of experimental diets on economic evaluation

As depicted in Table 7, the feed cost per unit showed only slight variation among treatments, ranging from \$ 0.048 in the 75% GS diet to \$ 0.051 in the 25% GS diet. Daily feed intake was highest in bulls fed 50% GS (5.20 kg), while the lowest intake was observed at 0% GS (4.80 kg). Consequently, the cost of feed and labour was greatest in the 25% and 50% GS diets (\$ 28.04 and \$ 28.00, respectively) and lowest at 75% GS (\$ 26.03). The cost of bulls remained constant across treatments (\$ 211.76), resulting in similar total production costs, which ranged narrowly from \$ 237.79 to \$ 239.76. Sale value increased with higher GS inclusion, with the highest revenue recorded at 50% and 75% GS (\$668.82 and \$ 649.98, respectively), compared with \$ 626.43 in the control diet. Cost per kilogram gain was lowest in the control group (\$ 1.04) but increased slightly with GS inclusion, peaking at \$ 1.65 in the 50% GS diet. Despite this, net profit improved with GS supplementation, reaching the highest value at 50% GS (\$ 429.06), followed by 75% GS (\$ 412.19) and 25% GS (\$ 411.18), while the control group recorded the lowest profit (\$ 387.86). Similarly, the benefit–cost ratio (BCR) increased with GS inclusion, with the highest efficiency observed at 50% GS (2.79), indicating superior economic returns compared to other treatments. Overall, the partial replacement of CSC with GS at 50% inclusion level, enhanced economic profitability of bull fattening.

Table 7. Economic analysis of replacing CSC with GS foliage

Parameter	Feed cost per kg of diet (USD)	Feed intake (kg)	Cost of Feed and Labour (USD)	Cost of bull (USD)	Total cost (USD)	Sale value (USD)	Cost per kg of gain (USD)	Net profit (USD)	BCR
0% GS	0.050	4.80	26.81	211.76	238.57	626.43	1.04	387.86	2.63
25% GS	0.051	4.91	28.04	211.76	238.80	649.98	1.51	411.18	2.72
50% GS	0.049	5.20	28.00	211.76	239.76	668.82	1.65	429.06	2.79
75% GS	0.048	4.81	26.03	211.76	237.79	649.98	1.55	412.19	2.73

* BCR = cost benefit ratio, USD = US\$ (\$1.00 = 100 cents)

4.0 Discussion

4.1 Chemical composition and anti-nutritional factors

The chemical composition of GS observed in the present study confirms its classification as a high-quality tropical legume forage suitable for ruminant nutrition. The crude protein (CP) concentration recorded aligns with earlier reports describing GS as a valuable protein supplement for cattle consuming low-quality basal diets (Tahuk et al., 2022; Aguilar et al., 2024). The comparatively higher ash content further indicates a superior mineral contribution relative to cottonseed cake (CSC), supporting previous findings that GS can enhance dietary mineral supply in ruminant production systems (Gonçalves Junior et al., 2025). The relatively low neutral detergent fibre (NDF) concentration of GS suggests improved rumen degradability and potential for increased voluntary intake, as reduced cell wall fractions are commonly associated with faster rumen passage rates and enhanced feed intake. Conversely, the moderate acid detergent fibre (ADF) concentration may impose some limitation on fibre digestibility, particularly of cellulose-bound fractions, as previously reported by Silva et al. (2024) and Schroeder (2010). Nonetheless, the overall fibre profile of GS reflects a favourable balance between intake stimulation and maintenance of rumen function.

The anti-nutritional factors detected in GS leaves were present at concentrations comparable to those previously reported in tropical legumes (Molina-Botero et al., 2019; Silva et al., 2024). Although GS has been associated with growth depression and toxicity in non-ruminant species such as poultry and rabbits (Edoh et al., 2019), ruminants possess effective ruminal microbial systems capable of detoxifying many secondary plant metabolites. Notably, the tannin levels observed in this study were considerably lower than concentrations reported to impair ruminal fermentation. This finding agrees with report of Rira et al. (2022). It is also in agreement with the findings reported by Guerreiro et al. (2021) who evaluated the effect of increasing doses of CT extract from *C. ladanifer* on rumen fermentation and BH when an oil-supplemented high-concentrate substrate was used and discovered that increasing doses of *C. ladanifer* CT extract (0, 25, 50, 75 and 100 mg/g kg DM) using oil-supplemented high-concentrate substrate led to a moderate decrease in VFA production and to a very pronounced depression of odd and branched-chain fatty acids (OBCFA) and dimethyl acetals (DMA) production, without affecting the biohydrogenation (BH) or the BH products yield. Our findings therefore, suggest that the levels observed are unlikely to compromise nutrient utilization. Under practical feeding conditions, GS has consistently been reported as non-toxic to ruminants (Silva et al., 2024). Although palatability issues related to volatile compounds on the leaf surface have been documented (Molina-Botero et al., 2020), the absence of depressed intake in the present study indicates adequate animal adaptation to GS-based diets, even at higher inclusion levels.

4.2 Nutrient composition of experimental diets

The progressive increase in dietary dry matter content with increasing GS inclusion indicates enhanced nutrient density of the experimental diets. Although the diets were formulated to be isonitrogenous, the slightly higher analysed CP concentrations across treatments ensured that protein supply exceeded the minimum requirement for growing cattle, estimated at approximately 12% CP (Rutherglen, 1995; NRC, 1996). Consequently, dietary protein was unlikely to be a limiting factor for growth performance. The higher ash content observed in *Gliricidia Sepium*-based diets reflects the superior mineral profile of the legume compared with CSC. This characteristic may reduce the need for additional mineral supplementation, particularly during periods of forage scarcity such as the dry season (Rusdy et al., 2021). Ether extract concentrations remained relatively consistent across treatments, indicating comparable dietary energy contributions among diets. A reduction in both NDF and ADF contents was observed with increasing GS inclusion,

reflecting partial replacement of CSC with a less fibrous protein source. This reduction in structural carbohydrate concentration is expected to improve rumen fermentation efficiency and nutrient availability, thereby contributing to improved animal performance. This finding is in conformity with that of Cruz-Matías et al. (2026) who used tropical legume tree and coffee pulp to reduce enteric methane emission by cattle fed a low-quality forage diet and concluded that supplementation with *G. sepium*, alone or in combination with COP, could be used as part of a strategy to reduce enteric CH₄ production in tropical cattle production systems in tropical regions of southern Mexico, where both additives are available.

4.3 Effect of experimental diet on animal performance

The improved performance of animals receiving GS-based diets is consistent with earlier reports demonstrating the beneficial effects of legume supplementation on ruminant productivity (Silva et al., 2024). Concentrate intake increased progressively with GS inclusion up to the 50% replacement level, suggesting improved palatability and reduced dietary bulkiness. This response may also be attributed to the lower fibre concentration of GS compared with CSC thereby ascertaining the findings by (Dama et al., 2025) which stated that substituting concentrate with gamal (*Gliricidia sepium*) leaf meal at graded levels in a corn straw-based complete diet improved crude protein content, organic matter digestibility, ruminal ammonia concentration and microbial protein synthesis *in vitro*, indicating adequate nutritional support for beef cattle. The optimal response was observed with the P3 formulation (50% corn straw, 20% concentrate, and 30% gamal leaf meal), highlighting the effectiveness of gamal leaf meal in enhancing feed quality and nutrient utilization. The reduced hay intake observed in animals fed CSC-based diets may be linked to increased dietary fibre content and bulk density, which can limit rumen fill and voluntary intake. This is similar to the report by Izadbakhsh et al. (2024) that lower DM and crude protein digestibility in calves fed the high-forage diet compared with the medium-forage diet likely resulted from replacing highly digestible, low-fiber ingredients with a less digestible medium-quality forage that exceeded the capacity of the immature rumen and its microbial population. Diets containing small particle size alfalfa hay improved NDF and ADF digestibility, probably due to increased surface area that enhanced attachment and activity of ruminal cellulolytic bacteria. Average daily weight gains recorded in this study exceeded those reported for calves supplemented with GS under extensive grazing conditions in Venezuela (González Villalobos et al., 2010), but were lower than gains observed in crossbred steers fed GS alongside high-quality Napier grass in Indonesia (Rusdy et al., 2019). These discrepancies likely reflect differences in genetic potential, basal diet quality and management systems. Improvements in feed conversion efficiency with increasing GS inclusion further indicate enhanced nutrient utilization, whereas poorer efficiency in CSC-based diets may be attributed to reduced digestibility and lower ruminal synchrony of energy and nitrogen supply. This agrees with Chacko Kaitholil et al. (2024), who reported that sheep feed efficiency is influenced by genetics, feeding strategies and management systems in a review of Insights into the influence of diet and genetics on feed efficiency and meat production in sheep.

4.4 Effect of experimental diet on feed cost

Feed cost analysis indicated that GS was a less expensive feed resource (USD0.06/kg) compared with cottonseed cake (USD0.09/kg). This difference was reflected in the cost of feed per kilogram, which was higher for animals fed the control diet based entirely on CSC compared with those receiving a 50% replacement of CSC with GS. This finding negates the report by Shem et al. (2003) who fed GS as an alternative protein supplement to cottonseed cake for smallholder dairy cows fed on Napier grass in Tanzania and found out that the replacement level of 23.4% is more profitable than the other treatments. For resource-poor livestock producers, adopting a diet in which CSC is replaced

by GS at 50% would result in substantial cost savings, representing a meaningful percentage reduction in feeding expenses relative to a wholly CSC-based diet. However, it is in agreement with the work of Tahuk et al. (2022) who also fattened bulls with GS based diet.

5.0 Conclusion

The study showed that GS has a higher crude protein and mineral content and lower fibre levels than cottonseed cake (CSC), with anti-nutritional factors occurring at low concentrations that did not impair feed intake or animal performance. Inclusion of GS in the diets reduced fibre content while maintaining adequate crude protein levels. Animal performance improved with increasing GS inclusion up to 50%, as shown by higher weight gain, feed intake, and better feed utilization, while performance declined slightly at the 75% level. Diets containing GS also reduced feed cost per kilogram of weight gain compared with the CSC-based control. Based on these findings, farmers can replace up to 50% of cottonseed cake with GS in concentrate diets for growing bulls to improve growth performance and reduce feeding costs without adverse effects. In addition to its lower cost, GS offers agronomic advantages over cotton. The plant can be easily established using stem cuttings and requires minimal inputs after establishment. Moreover, GS is adaptable to a wide range of agro-ecological zones, making it more readily available and accessible than CSC for smallholder farmers. Further studies evaluating long-term effects, meat quality attributes, and breed or regional variations are warranted.

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