INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 29, Issue: 4, p. 48-59, 2026

RESEARCH PAPER OPEN ACCESS

Effects of different levels of dried Savannah mahogany (*Khaya senegalensis* (Desr.) A. Juss.) leaves as a supplement for Djallonké sheep in Burkina Faso: Identifying the optimal incorporation level

Sanou Sita[*1], Nitiema Assètou Wahiba[2], Sanon Hadja Oumou[1]

[1]*Centre National de Recherche Scientifique et Technologique/Institut de l'Environnement et de Recherches Agricoles (INERA), Laboratoire de Recherche en Production et Santé Animales, Ouagadougou, Burkina Faso*
[2]*Centre d'Excellence Régional sur les Productions Pastorales (CERPP), Faculté d'Agronomie, Université Abdou Moumouni de Niamey, Niamey Niger*

Key words: Woody forage, Incorporation rate, Djallonké sheep, Zootechnical performance, Burkina Faso

Received: September 19, 2026 **Accepted:** September 29, 2026 **Published:** October 07, 2026

DOI: https://dx.doi.org/10.12692/ijb/29.4.48-59

ABSTRACT

Browse species are underutilized due to the low availability and poor quality of herbaceous forages during the dry season. The incorporation's levels of these browse fodder into animal diets are poorly documented. This study aimed to determine the optimal incorporation's rate of dried *Khaya senegalensis* leaves in the diet of Djallonké sheep. The trial was conducted with 20 rams aged 20 to 38 months. They were divided into five groups and fed diets containing 0, 15, 30, 70 or 100 % dried *K. senegalensis* leaves. The animals were fed a base diet of dried *K. senegalensis* leaves, combined with *Pennisetum pedicellatum* hay. The measured parameters included voluntary feed intake, apparent nutrient digestibility, average daily gain (ADG) and feed conversion ratio (FCR). The results showed the diet containing 100% of dried *K. senegalensis* leaves recorded the highest voluntary intake of dry matter (83.11 g/ kg $BW^{0.75}$) and crude proteins intake (12 g/ /kg $BW^{0.75}$). In contrast, the best dry matter digestibility (65.19%) and crude proteins digestibility (63.39%) were obtained with T70. Moreover, the most efficient utilization of the diets was observed at this integration level, which resulted in an ADG of 36.72 g/day and a FCR of 19.64. The FCR values observed at 30% rate, were similar to those at 70% and the ADG value (31.21 g/day) were also close to those of T70. These results suggest that the incorporation rate of 30% into diets could be the most recommended for the rational and optimized management of dried *K. senegalensis* leaves.

***Corresponding author:** Sanou Sita ✉ zouwiss@yahoo.fr

INTRODUCTION

In Burkina Faso, ruminant feeding is severely constrained during the dry season due to the scarcity of natural pastures and the low nutritional value of the available herbaceous residues. During this long forage scarcity period, the animals rely mainly on low-quality forage, such as parched pastures, bush straw and cereal straw. A diet consisting exclusively of these forage resources, without adequate supplementation, leads to weight loss in the animals (Adogla-Bessa *et al.*, 2022). These low-quality forages often provide less than 80 g/ kg DM of crude protein, a threshold considered necessary for maintaining optimal ruminal microbial activity (Preston and Leng, 1987; Antwi *et al.*, 2014). As nitrogen is the main limiting factor in these forages, their utilization requires supplementation with protein sources.

In this respect, browse species constitute a strategic resource. Their relative availability during the dry season and their high nitrogen content make them particularly suitable feed supplements for extensive livestock systems. The use of woody forage plants is a common practice that is widely adopted worldwide (Idan *et al.*, 2023; Ertan, 2025). The proportion of woody forages voluntarily ingested varies according to the plant species and ruminant species. It is estimated at 10–30% of the total ration in cattle, approximately 50% in sheep, and 80–100% in goats (Sanon *et al.*, 2007; Klein *et al.*, 2019). Among these species, *Khaya senegalensis* (Desr.) A. Juss. (Savannah mahogany) plays a significant role in local pastoral practices (Ouédraogo-Koné *et al.*, 2008; Traoré *et al.*, 2023).

On pasture, livestock directly consume the leaves and twigs of forage trees that have fallen to the ground or are accessible on the trees, or those made available to them through felling. In stall-fed animals, these forages are harvested by farmers and offered to the animals in the trough (Klein *et al.*, 2019). Overall, forage trees are therefore mainly consumed when they are still green. However, climate change is altering the leaf phenology of certain tree species, with shifts in the timing of leaf emergence and leaf fall depending on the species and rainfall patterns (Brandt *et al.*, 2019; Gusain *et al.*, 2026). This greater variability may result in periods of lower foliage availability, justifying the preservation of these resources as hay to provide reserves during the most critical periods of the year (Abbacha and Adane, 2020). However, drying can reduce intake and digestibility, depending on the plant species and storage conditions. Indeed, the intake and digestion of certain species are significantly reduced when they are presented in the form of hay (Abbacha and Adane, 2020). It is therefore necessary to ensure proper drying to minimize its adverse effect on the nutritional value of forage tree leaves.

Furthermore, the effect of woody forage on the nutritional value of the ration depends on their level of incorporation. Previous studies have shown an increase in digestibility as the proportion of foliage in the total diet rises. However, this effect varies quadratically, suggesting the existence of inclusion thresholds beyond which marginal benefits diminish, particularly depending on the fiber and secondary compound content of the foliage, as well as the nutritional value of the base ration (Kongmanila and Ledin, 2009). High proportions of leaves can reduce feed intake, inhibit some digestive enzymes and, consequently, have negative effects on zootechnical performance (Brouckaert, 2024). The incorporation rate therefore, appears to be an important factor to consider when formulating diets based on woody forage (Fall-Touré *et al.*, 1997). Consequently, for the optimal use of woody forage, it is essential to determine the optimal incorporation level in rations, in order to reconcile their utilization as a local feed resource with the maintenance of satisfactory voluntary intake, digestibility and performance. However, the levels of incorporation of these browse fodder into animal diets are poorly documented. This study therefore aims to determine the optimal incorporation rate of dried *K. senegalensis* leaves in the diet of Djallonké sheep in Burkina Faso. More specifically, it seeks to i) Assess the effects of different incorporation rates of dried *K. senegalensis* leaves on voluntary intake and the apparent digestibility of dry

matter, organic matter and crude protein in Djallonké sheep; ii) Determine the influence of these incorporation rates on growth performance (average daily gain, feed conversion ratio) and iii) To determine the level of inclusion that optimizes the utilization of dried *K. senegalensis* leaves whilst maintaining satisfactory voluntary intake, digestibility and zootechnical performance.

MATERIALS AND METHODS

Experimental design

The study was conducted in Burkina Faso at the Research station of the Regional Directorate for Environmental and Agricultural Research of Saria (DRREA Centre), under the Institute of Environment and Agricultural Research (INERA). The trial was conducted using a completely randomised design with twenty (20) Djallonke rams, divided into five (5) groups of four (4) animals each, based on live weight homogeneity. All treatment groups were similar in terms of mean live weight. The animals were housed in different pens within the same building. Feed rations were randomly allocated to the different treatment groups. The trial was conducted over 74 days, comprising an adaptation phase and a period for measuring voluntary intake and digestibility. Feed was distributed every morning at 9.30 am and in the afternoon at 3.00 pm. The total daily diet distributed was calculated on the basis of the animals' live weight at a rate of 3.5% of live weight. The quantities of the various feedstuffs in the diet were determined based on their inclusion rates in the total diet. The animals had free access to drinking water and salt licks.

Experimental animals

The trial was conducted under controlled conditions on sheep (*Ovis aries* L.) of the Djallonké breed, Mossi variety (Mossi breed). Twenty (20) uncastrated male sheep aged between 18 and 36 months were used. They had an initial average live weight of 23.18 ± 3.27 kg, ranging from 17.25 kg to 30.75 kg.

The animals were purchased from livestock markets (Yilou, Kamboinsé, and Saria). They were vaccinated against pasteurellosis and pest of small ruminant and were dewormed. The animals were then divided into five groups of four animals each. To discard the animals' weight effect on the results, the groups were established based on live weight homogeneity. The animals were placed in different compartments within the same building. Each compartment accommodated four animals for the same treatment. The feed diets were randomly allocated to the different groups by drawing lots.

Diets

The animals were fed five (05) different diets over a period of 60 days, corresponding to five (05) levels of dried leaves of *K. senegalensis*. The diets were dried leaves of *K. senegalensis*, combined with *Pennicetum pedicellatum* hay and cotton seed cake. For the study, fresh *K. senegalensis* leaves were harvested, pre-wilted in the sun for 24 hours, and dried in the shade for 7 days, then stored in airtight bags until they were fed to the animals. This method was adopted to avoid prolonged exposure of the leaves to the sun, as ultraviolet rays can lead to nutrient losses. In this study, five (05) incorporation rates of dried *K. senegalensis* leaves were tested: 0, 15, 30, 70 and 100 % (Table 1). These rates were selected based on the 30% rate of dried *K. senegalensis* leaves used by some authors (Ouedraogo-Koné *et al.*, 2008; Gninkplékpo *et al.*, 2024) as a reference, in order to test a lower rate (15%) and a much higher rate (70%). The 100% rate was chosen to address a concern raised by producers who wished to know whether sheep could be fed exclusively on *K. senegalensis* leaves. The quantities of the basic rations (hay + leaves) were calculated at a rate of 3.5% of live weight. The various feeds were weighed daily using an electric balance with a capacity of 3 kg and an accuracy of 1 g before being placed in the feeders. The diets were supplemented with 100 g of cottonseed seed cake to prevent animals' weight loss, because of the poor quality of the hay used. A diet based exclusively on low-quality forage can lead to significant weight loss in sheep (Adogla-Bessa *et al.*, 2022). Each animal had free access to water and a commercial mineral lick block. The study examined the voluntary feed intake, the apparent digestibility and the animals' weight gain.

Table 1. Experimental diets

Rations	Composition of the base diet (%)		Supplement (g)
	P. pedicellatum hay	Dried leaves *of K. senegalensis*	Cotton seed cake
To	100	0	100
T15	85	15	100
T30	70	30	100
T70	30	70	100
T100	100	0	100

Voluntary intake

To measure the quantities of feed voluntarily ingested, the refusal rate was set between 10 and 30% (Klein *et al.*, 2019). Foliage, hay and cotton seed cake offered and refused were recorded separately and daily during the data collection period and weighed for each animal. Voluntary intake, expressed as Dry Matter Intake (DMI), was calculated as the difference between the quantity offered and that rejected, based on dry matter (DM). Samples were taken daily and pooled to an individual sample for each period for chemical analysis.

$$VI = Qof - Qrf$$

Where IV: Voluntary Intake, Qof: Quantity offered, Qrf: Quantity rejected

Apparent digestibility coefficients

After the voluntary intake trial, digestibility was measured. The digestibility assessment was conducted over 13 days, comprising an 8-day adaptation phase and a 5-day data collection phase (Matumuini *et al.*, 2013). The 8-day adaptation phase was observed to allow the animals to become accustomed to the wearing the digestibility harness.

To calculate the apparent digestibility coefficient, daily faecal output of each animal was collected and weighed each morning before feed was distributed.

From each animal, 20% of the daily faecal output was sampled and weighed to obtain the initial weight (P1). The sample was then dried in the shade for one week before being weighed again to obtain the dry weight (P2). After drying, the samples were stored in plastic bags for bromatological analysis, as well as the samples of *P. pedicellatum*, *K. senegalensis* and cotton seed cake. Feed refusals were also collected and weighed daily, by component and per animal. All samples of distributed and refused feed were retained for bromatological analyses, focusing in particular on dry matter (DM), mineral matter (MM), organic matter (OM), crudem protein (CP) and crude fiber (CF). The digestibility of the ration (dR) was calculated using the following formula:

$$dR = \frac{(I - F)}{I} * 100$$

Where dR = ration digestibility, I = quantity of DM ingested and F = quantity of DM in faeces excreted

Growth performance

To assess growth performance and weight gain, the rams were weighed at the start and the end of the experiment, as well as once a week. An electronic scale with a capacity of 99 kg and an accuracy of 50 g was used for this operation. The difference between the final weight and the initial weight was calculated to determine weight gain. This weight gain was then divided by the number of days in the trial to obtain the average daily gain (ADG), which is an indicator of growth performance. The ADG was calculated using the following formula:

$$ADG\ (\frac{\text{g}}{\text{day}}) = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Number of days}}$$

Feed conversion ratio (kg DM/kg gain)

The feed conversion ratio (FCR) corresponds to the quantity of feed required to achieve a given weight gain. The FCR is an important parameter in animal husbandry as it measures the feed efficiency of the diets. It assesses how efficiently an animal converts feed into final products. The lower the FCR, the more efficiently the animal converts its feed. The FCR is calculated by dividing the total amount of feed

consumed by the body weight gain over a given period. The FCR, like the ADG, plays a key role in optimizing animal production.

$$FCR = \frac{Amount\ of\ feed\ ingested\ (Kg\ of\ DM)}{Final\ live\ weight - Initial\ live\ weight)}$$

Chemical analyses

Samples of the distributed and rejected feeds and samples of feaces collected daily were subjected to bromatological analysis. The dry matter (DM) was determined after oven-drying 2 g of the sample for 24 hours at 103°C (Afnor, 1982; Bastianelli and Hervouet, 1998). After drying, the sample was weighed to determine DM. For crude ash (CA), samples were weighed and placed in an electric muffle furnace at 550°C for 4 hours, and the products obtained were weighed and expressed as relative dry matter values for each sample (Afnor, 1977). Organic matter (OM) was obtained by subtraction: 100 – CA. Nitrogenous content was determined using the Kjeldahl method which involves mineralizing the samples with sulfuric acid (95%) at 480°C for 167 min in the mineralizer, distilling using a distillation apparatus and titrating the distillates (Iso, 1997). The crude protein (CP) contents were estimated from the nitrogen content of the samples and a factor based on the average nitrogen content of plants, which is 16%, using the formula (N × 6.25). Crude cellulose (CC) was measured using fibersac (Afnor, 1993). It is based on the Weende method.

The chemical composition of the rations was determined by taking into account the nutrient content of the constituent ingredients and their proportion in the rations.

Statistical analysis

The data collected were used to create a database using Microsoft Excel 2021, then exported to R software version 4.4.1 for statistical analysis. Descriptive analyses included means, standard deviations, and frequencies. The Shapiro-Wilk test and Bartlett's test were used to check the normality of the distributions and the homogeneity of the variances, respectively. Data that met the conditions of normality and homogeneity were subjected to a one-way analysis of variance (ANOVA), followed by Tukey's test to compare means. However, for nonparametric data, the Kruskal-Wallis test was used. Differences between means were compared at the 5% significance level ($p < 0.05$).

RESULTS

Chemical composition of feed

Chemical analyses in Table 2, showed that the dried leaves of *K. senegalensis* had a high crude protein content (13.25% DM) than that of *P. pedicellatum* hay (4.36% DM). Their dry matter content was 93.63%. Furthermore, the crude fiber content of the dried leaves of *K. senegalensis* was 28.01% DM, lower than that of *P. pedicellatum* hay (41.63%).

Table 2. Chemical composition of the feeds used (%)

Feed	DM	OM	Crude fiber	CP	CF
P. pedicellatum hay	94.95±0.16^a	89.88±0.15^a	10.12±0.15^a	4.36±0.18^a	41.63±0.14^a
Dried leaves of *K. senegalensis*	93.63±0.25^b	93.89±0.02^b	6.11±0.02^b	13.25±0.02^b	28.01±0.37^b
Cotton seed cake	95.44±0.45^c	94.51±0.15^c	5.50±0.15^c	24.98±0.12^c	25.07±0.12^c
p-value	0.001019	0.02732	0.02732	0.02732	0.02732

DM: dry matter; OM: organic matter; CA: crude ash; CP: crude proteins; CF: crude fiber.

Voluntary intake

The results showed that voluntary dry matter (DM) and crude protein (CP) intake increased gradually with the proportion of dried *K. senegalensis* leaves in the diets (Table 3). The amounts ingested rose from 62.16 g/ kg $BW^{0.75}$ for the control diet to 83.11 g/kg $BW^{0.75}$ for the diet containing 100%t dried *K. senegalensis* leaves. Similarly, crude protein intake increased as the proportion of dried *K. senegalensis* leaves in the rations increased. The high DM and CP intake values were obtained with diet T100 (83 g/ kg $BW^{0.75}$ and 12 g/ kg $BW^{0.75}$ respectively) followed by diet T70 (74.92 g/ kg $BW^{0.75}$ and 9.59 g/ kg $BW^{0.75}$ respectively). The CP intake was significantly different among the diets, except diet To et T15 which similar value (4.68 and 6.04 g/ kg $BW^{0.75}$ respectively).

Table 3. Intake of rations according to the inclusion rate of dried *K. senegalensis* leaves, g/kg BW 0.75

Rations	DM	OM	CA	CP	CF
To	62.16 ±4.47^{a}	56.31 ±3.99^{a}	5.85±0.48^{a}	4.68 ±0.35^{a}	24.30 ±1.96^{a}
T15	69.89 ±3.43^{ab}	63.44 ±3.07^{ab}	6.45 ±0.36^{a}	6.04±0.11^{ab}	25.89 ±1.46^{a}
T30	65.52 ±4.78^{ab}	59.71 ±4.32^{ab}	5.81 ±0.47^{a}	6.90±0.28^{b}	22.45 ±1.99 ^{a}
T70	74.92 ±1.80^{ab}	68.58 ±1.60^{ab}	6.34 ±0.20^{a}	9.59±0.01^{c}	22.80 ±0.77^{a}
T100	83.11 ±17.14^{b}	76.32 ±15.67^{b}	6.80 ± 1.47^{a}	12.00±2.20^{d}	23.03 ±4.82^{a}
p-value	2.276e-07	0.3573	0.01902	0.01382	0.3259

DM: dry matter; OM: organic matter; CA: crude ash; CP: crude proteins; CF: crude fiber.

Table 4. Nutrient digestibility of rations containing dried leaves of *K. senegalensis*

Rations	dDM (%)	dOM (%)	dCA (%)	dCP (%)	dCF (%)
To	53.94±2.81^{a}	54.46±3.04^{a}	41.64±3.15^{a}	22.02±1.37^{a}	59.62±1.85^{a}
T15	55.08±8.35^{a}	56.70±8.47^{a}	31.93±9.27^{a}	22.67±9.43^{a}	52.85±1.73^{b}
T30	52.94±9.10^{a}	53.94±9.02^{a}	33.56±12.3^{a}	32.23±0.61^{a}	47.14±1.38^{c}
T70	65.19±3.12^{a}	65.84±3.21^{a}	50.28±3.33^{a}	63.39±1.81^{b}	60.62±0.45^{a}
T100	57.74±15.07^{a}	58.66±14.80^{a}	31.42±27.82^{a}	59.10±3.80^{b}	25.10±1.83^{d}
p-value	0.3425	0.3581	0.1397	0.01321	0.01177

dDM: digestibility of dry matter; dOM: digestibility of organic matter; dCA: digestibility of crude ash; dCP: digestibility of crude proteins; dCF: digestibility of crude fiber.

Table 5. Growth performance and feed conversion ratio

Rations	Initial weight (kg)	Final weight (kg)	Weight gain (kg)	ADG (g/day)	FCR (kg of DM/ kg of gain)
To	22.43±5.41^{a}	23.62±5.25^{a}	1.20±0.94^{a}	15.62±3.62^{a}	53.82±3.85^{a}
T15	22.01±0.80^{a}	22.62±0.75^{a}	0.61±0.13^{a}	13.07±2.78^{a}	64.03±4.78^{b}
T30	22.50±2.71^{a}	23.76±2.89^{a}	1.26±0.42^{a}	31.21±1.33^{b}	22.91±1.13^{c}
T70	23.58±2.33^{a}	24.54±1.69^{a}	1.36±0.74^{a}	36.72±2.13^{c}	19.64±2.02^{c}
T100	25.39±3.88^{a}	26.18 ± 4.03^{a}	0.80±0.15^{a}	16.94±3.18^{a}	49.23±4.58^{a}
p-value	0.6398	0.6201	0.3338	0.004309	0.001703

ADG: average daily gain; FCR: feed conversion ratio.

Apparent digestibility

The apparent digestibilities of dry matter (dDM), organic matter (dOM) and crude ash (dCA) was not affected by the addition of dried *K. senegalensis* leaves into the diets (p>0,05) (Table 4). However, the incorporation of dried *K. senegalensis* leaves had a positive effect on crude protein digestibility (dCP), which increased gradually with the levels of incorporation, reaching a maximum value of 63.39% at an incorporation rate of 70%. Beyond 70% of dried *K. senegalensis* leaves in the diets, a decrease in digestibility was observed. The T100 ration recorded a digestibility of 59.10%. Furthermore, the incorporation of dried *K. senegalensis* leaves at a rate of 70% had no negative effect on cellulose digestibility, unlike the rates of 15, 30 and 100%.

Growth performance

Growth performance showed significant differences between treatments (Table 5). Average daily gain (ADG) fluctuates with the incorporation levels of dried *F. sycomorus* leaves, with the best results obtained using the T30 and T70 rations (31.21 and 36.72 g/day respectively). For the other rations ADG values were similar: 13.27 g/ day, 15.62 g/day and 16.94 g/ day respectively for the T15 diet, To and T100 diets. When the proportion of leaves in the diet exceeded 70%, ADG decreased. The feed conversion ratio (FCR) also varied significantly between the diets ($p < 0.05$). The best feed efficiency, as indicated by the lowest FCR values, was achieved with the T70 and T30 diets, with no significant difference between these two treatments.

DISCUSSION

Chemical composition

The chemical composition of the dried *K. senegalensis* leaves is characterized by a relatively high CP content (13.25% DM) and a moderate crude fiber content (28.01% DM), compared with *P.*

pedicellatum hay, which has values of 4.36% DM and 41.63% DM respectively. CP content of *K. senegalensis* leaves exceeds the 8% threshold required for good microbial activity in the rumen (Idan *et al.*, 2023). The CP content of dried *K. senegalensis* leaves was similar to that of fresh leaves of the same species (13.07%), as reported by Sanou *et al.* (2026a), suggesting that drying conditions in this study did not result in a significant reduction in this component. Buthelezi *et al.* (2019), reported that drying conditions strongly affect the quality of dried forage. In their study, *Cajanus cajan* leaves conserved their CP content when dried in the shade, whereas exposure to high temperatures led to a reduction in CP. Dried leaves of *K. senegalensis* also had a higher CP content than those of *Acacia karroo* (12.7 %) and *Ficus sycomorus* (8.9%) (Brown *et al.*, 2018; Sanou *et al.*, 2026b), thereby confirming their potential as a feed supplement to low-quality forage in extensive livestock systems in Burkina Faso.

These observations corroborate the findings of Yeboah *et al.* (2024), who noted that the leaves of *C. cajan*, *Spondias mombin* and *Leucaena leucocephala* are rich in CP and low in CF.

However, the chemical composition of *K. senegalensis* leaves varies significantly throughout the grazing season, as reported by Ouedraogo-Koné *et al.* (2008). Similar variability in foliage composition throughout the growing season has also been observed for plant species of the Mediterranean region in northern Morocco (Chebli *et al.*, 2021). Also, Traoré *et al.* (2026) reported that CP content of *K. senegalensis* leaves tends to increase from the rainy season (10.4% DM) to the dry season (16.2% DM).

Voluntary intake

The increase in voluntary intake observed with the gradual incorporation of dry leaves of *K. senegalensis* indicates that this woody fodder is well accepted by sheep. Supplementing low-quality roughage with foliage from forage trees improves total dry matter intake (DMI) in sheep, following a generally quadratic response related to the level of incorporation (Patra, 2009). Incorporating leaves increased intake, likely due to their higher crude protein and lower NDF contents relative to hay (Kronqvist *et al.*, 2021). Recent studies confirm that the use of woody plant leaves can stimulate intake in small ruminants. In Djallonké sheep in Benin, the incorporation of 30% dried leaves of *K. senegalensis* or *Mangifera indica* in the diet led to high levels of DMI compared with the control diet (Gninkplékpo *et al.*, 2024).

These results confirm that tree fodder can be incorporated into ruminant rations as a partial substitute for concentrates (Brown *et al.*, 2018), although it cannot replace them entirely. Indeed, a high inclusion of woody leaves can reduce total DMI when it replaces a significant proportion of the concentrate. In sheep fed hay, the gradual replacement of a concentrate mixture with dried leaves of *Chamaecytisus palmensis* thus led to a significant reduction in total DMI (Hailecherkos *et al.*, 2021).

In the present study, voluntary DMI was higher for T100 diet, where 100% of the diet consisted of dried *K. senegalensis* leaves. This intake was also higher than that of *Afzelia africana* leaves fed to Djallonké sheep as the sole feed (Ouédraogo-Koné, 2008), indicating that this resource is highly palatable to animals. The result obtained is consistent with the work of Traoré *et al.* (2026), who demonstrated that *K. senegalensis* leaves are well appreciated by sheep. The dried *K. senegalensis* leaves are however less consumed than those *of Entada africana*, *Ficus sycomorus*, *Pterocarpus lucens* or *Pterocarpus erinaceus* (Coulibaly *et al.*, 2025; Traoré *et al.*, 2026), suggesting that the acceptability of browse species depends heavily on the feeding context, the physiological state of the animals and the level of incorporation. In our study, the incorporation of cotton seed cake likely helped to balance the ration and stimulate overall intake.

CP intake also increased with the level of incorporation of dried *K. senegalensis* leaves. Rations containing 70% and 100% dried *K. senegalensis* leaves recorded the highest levels of CP intake, at 9.59

and 12.0 g/kg $BW^{0.75}$respectively. This high CP intake is attributable both to the higher levels of leaves incorporation in these diets (Brown *et al.*, 2018).

It should also be noted that the animals were able to be fed exclusively on dried *K. senegalensis* leaves with any adverse effects being observed. Previous studies have also demonstrated the possibility of using *A. africana* leaves as a sole feed source (Ouedraogo-Koné *et al.*, 2008). However, there are some woody forage species that cannot be fed to sheep as the sole source of feed. This is the case with oak leaves (*Quercus infectoria*), the feeding of which resulted in the death of lambs receiving 150 g of leaves per day for 10 to 13 days (Eroksuz *et al.*, 2013).

In this study, the young age of the lambs and the high tannin concentration in the oak leaves (approximately 200 g/ kg) were cited as explanations for the observed deaths.

Digestibility

The inclusion of dried *K. senegalensis* leaves significantly improved the digestibility of CP, with a maximum observed at a rate of 70%. This improvement can be attributed to the high CP content of dried *K. senegalensis* leaves and their lower CF content compared with *P. pedicellatum* hay. Studies conducted on other woody plants in West Africa have also shown that supplementation with tree leaves improves digestibility when combined with low-quality feeds, particularly straw and hay from tropical grasses (Aschfalk *et al.*, 2008).

However, increasing the incorporation rate beyond 70% did not result in a proportional improvement in digestibility, suggesting that an excess of dried leaves may limit the optimization of nutrient utilization. This finding is consistent with the meta-analysis by Patra (2009), based on 36 studies involving sheep fed low-quality roughage supplemented with tree foliage. This review demonstrates an improvement in the digestive utilization of nutrients, particularly the digestibility of OM and CP, at moderate levels of incorporation. The extent of the response depends on the level of leaves incorporation, their CP and CF content, and the quality of the basal forage (Patra, 2009).

The reduction in digestibility, particularly of CP, observed when dried *K. senegalensis* leaves were sole component of the diet, indicates that the CP in these leaves become poorly biodegradable, probably due to the presence of condensed tannins. Indeed, *K. senegalensis* leaves contain condensed tannins at often high levels, reaching 8.2% DM depending on the harvest season. When these leaves are fed in large quantities, tannin intake increases and their concentration is likely to exceed the tolerable limit (4 % DM) for ruminants (Mekuriaw *et al.*, 2024), thereby reducing protein degradation and digestibility (Arrigo and Scharenberg, 2010; Besharati *et al.*, 2022). However, the digestibility of dried *K. senegalensis* leaves fed as the sole feed was higher than that of hay for all parameters. Similarly, dried *K. senegalensis* leaves were better digested than dried *F. sycomorus* leaves fed ad libitum to sheep (Sanou *et al.*, 2026a). Furthermore, the digestibility of the T100 diet was higher than that of the leaves of *Ficus racemosa*, *Artocarpus heterophyllus* and *Ziziphus jujuba* offered ad libitum to goats (Kongmanila and Ledin, 2009).

Growth performance

In terms of weight gain, the highest average daily gains were obtained with diets containing 30% and 70% of dried *K. senegalensis* leaves, with values of 31.21 and 36.72 g/day respectively. The ADG recorded in this study are higher than those reported by Adogla-Bessa *et al.* (2022) for Djallonké sheep fed *ad libitum* on rice straw and supplemented with 100 g of fresh leaves of *Albizzia lebbek*, *Moringa oleifera*, *Ficus exasperata* and *Spondias mombin*, despite the high crude protein content of these leaves (15.9 and 31.4% DM). This result could be explained by the small quantities of leaves distributed, which were insufficient to correct the nitrogen deficit in the rice straw. However, the ADG obtained in our study is lower than the value of 51 g/day reported by Hailecherkos *et al.* (2021) for

sheep fed *ad libitum* on *P. pedicellatum* hay and supplemented with dried leaves *of Chamaecytisus palmensis*.

The best feed conversion ratios (FCR) were also obtained with incorporation rates of 30% and 70% of dried *K. senegalensis* leaves, with values of 22.91 and 19.64 respectively. These values are lower than those reported by Adogla-Bessa *et al.* (2022), which ranged from 26 to 71.5 for diets based on rice straw and supplemented with various woody forage. This demonstrates that incorporation at these levels allows for a balance between growth and feed efficiency. The FCR recorded with incorporation rates of 30% and 70% of dried *K. senegalensis* leaves confirm that these diets performed best, indicating that moderate use of dried *K. senegalensis* leaves can improve sheep productivity whilst limiting the amount of dry matter required to achieve the same weight gain. When the leaves were fed to the sheep as the sole roughage, despite high levels of intake and digestion, this diet did not result in good weight gain. The ADG and FCR recorded with the T100 diet are comparable to those of the To diet, which likely indicates a less efficient utilization of ingested nutrients, probably linked to an inadequate synchronization between energy and nitrogen intake. Previous studies have shown that a higher degree of synchronisation between energy and nitrogen release increases microbial protein synthesis (Zhang *et al.*, 2020; Bezerra *et al.*, 2026).

CONCLUSION

The results of this study show that the dried leaves of *K. senegalensis* constitute a valuable forage resource for feeding Djallonké sheep during the dry season. Although dried, they conserve crude protein levels above the 8 % DM threshold required for good microbial activity in the rumen. Their incorporation in diets based on low-quality forage improved feed intake and digestibility, as well as the animals' weight gain. Average daily gains increased from 16 g/day for a diet based solely on *P. pedicellatum* hay to 31 g/day and 37 g/day, respectively, for incorporation rates of 30% and 70% of dried *K. senegalensis* leaves. This study has shown that *K. senegalensis* leaves can be incorporated into sheep diets at levels exceeding 30% with promising zootechnical results. However, given the availability of *K. senegalensis* leaves, the 30% incorporation rate, seems to be the most practical option for incorporating dried *K. senegalensis* leaves into sheep production systems in Burkina Faso. Future research should extend to other browse species and investigate alternative methods for conserving forage tree leaves, particularly ensiling, to evaluate their palatability and digestibility.

ACKNOWLEDGEMENTS

We express our gratitude to the European Union for the financial support provided under the Horizon 2020 program (H2020-SFS-2019-2), SustainSahel project (grant number 861974).

REFERENCES

Abbacha I, Adane D. 2020. L'utilisation des arbres fourragers dans l'alimentation animale (Mémoire de Master en Production et Nutrition Animale). Université Mouloud Mammeri de Tizi-Ouzou (UMMTO), Algérie.

Adogla-Bessa T, Sarkwa FO, Adjorlolo LK, Timpong-Jones EC, Idan F, Nyarko Gyimah A, Tudeka CK. 2022. Performance indicators of sheep fed rice straw supplemented with browse leaves. African Journal of Food, Agriculture, Nutrition and Development **22(5),** 20401-20414. https://doi.org/10.18697/ajfand.110.21925

Afnor (Association Française de Normalisation) 1977. Animal feeding stuffs-Determination of crude ash (NF V18-101).

Afnor (Association Française de Normalisation) 1982. Animal feeding stuffs-Determination of moisture content (NF V18-109).

Afnor (Association Française de Normalisation) 1993. Agricultural and food products—Determination of crude fibre—General method (NF V03-040).

Antwi C, Osafo ELK, Donkoh A, Adu-Dapaah H. 2014. Chem ical composition, gas production and degradation characteristics of haulms of improved dual-purpose Cowpea (*Vigna unguiculata* L. walp) cultivars. Livestock Research for Rural Development **26**, 194.
http://www.lrrd.org/lrrd26/11/antw26194.htm

Arrigo Y, Scharenberg A. 2010. Effets des tanins condensés sur la dégradabilité et la digestibilité de la matière azotée chez le ruminant. Agroscope Changins-Wädenswil ACW Produire de la viande au pâturage Journée d'information du 5 février 2010, 26 février 2026. Liebefeld-Posieux.

Aschfalk A, Steingass H, Müller W, Drochner, W. 2008. Acceptance and Digestibility of Some Selected Browse Feeds with Varying Tannin Content as Supplements in Sheep Nutrition in West Africa. Journal of Veterinary Medicine Series A. **47,** 513-524.
https://doi.org/10.1046/j.1439-0442.2000.00313.x.

Ertan A. 2025. Seasonal variation of feeding values, minerals and vitamins of field elm (*Ulmus minor* Mill.) and blackthorn (*Prunus spinosa* L.) leaves grazed by small ruminants in Thrace region of southeast Europe. Range Management and Agroforestry **46(2),** 324-332.
https://doi.org/10.59515/rma.2025.v46.i2.19

Besharati M, Palangi V, Salem AZM, De Palo P, Lorenzo JM, Maggiolino A. 2022. Substitution of raw lucerne with raw citrus lemon by-product in silage: *In vitro* apparent digestibility and gas production. Frontiers in Veterinary Science **9**.

Bezerra LR, de Oliveira JPF, de Oliveira Soares de Lucena KH, de Melo Vaz AF, de Souza Barros L, de Andrade Fortunato YM, Neto SG, Pereira ES, Oliveira RL, Filho JMP. 2026. Nitrogen Source–Carbohydrate Synchronization in Ruminant Nutrition: A Systematic Review. Animals **16,** 239.
https://doi.org/10.3390/ani16020239

Brandt M, Hiernaux P, Rasmussen K, Tucker CJ, Wigneron JP, Diouf AA, Herrmann SM, Zhang W, Kergoat L, Mbow C, Abel C, Auda Y, Fensholt R. 2019. Changes in rainfall distribution promote woody foliage production in the Sahel. Commun Biol **2,** 133.
https://doi.org/10.1038/s42003-019-0383-9

Brouckaert C. 2024. Valorisation des fourrages ligneux en élevage bovin. Travail de fin d'études Présenté en vue de l'obtention du grade de Médecin Vétérinaire, année académique 2023/2024. Liège Université, Faculté de Médecine Vétérinaire.

Brown D, Ng'ambi JW, Norris D. 2018. Effect of tanniniferous Acacia karroo leaf meal inclusion level on feed intake, digestibility and live weight gain of goats fed a Setaria verticillata grass hay-based diet. Journal of applied animal research **46(1),** 248–253.
http://dx.doi.org/10.1080/09712119.2017.1289939

Buthelezi LS, Mupangwa JF, Muchenje V, Nherera-Chokuda FV. 2019. Influence of drying technique on chemical composition and ruminal degradability of subtropical *Cajanus cajan* L. Animal Nutrition **5(1),** 95–100.
https://doi.org/10.1016/j.aninu.2018.03.001

Chebli Y, El Otmani S, Chentouf M, Hornick JL, Cabaraux JF. 2021. Temporal Variations in Chemical Composition, *In Vitro* Digestibility, and Metabolizable Energy of Plant Species Browsed by Goats in Southern Mediterranean Forest Rangeland. Animals **11(5),** 1441.
https://doi.org/10.3390/ani11051441

Cissé SM. 2015. Study of the palatability of woody forage and its influence on the weight changes of sheep in Mali [Master's thesis, Université Laval]. Library and Archives Canada.

Coulibaly M, Coulibaly D, Roessler R, Coulibaly H, Cissé B, Schlecht E. 2025. Preference of ligneous forages by sheep in South-East Mali. Animals **15(8),** 1102. https://doi.org/10.3390/ani15081102

Eroksuz Y, Dabak M, Eroksuz H, Baydar E, Turkoglu I, Yilmaz I. 2013. Acute oak (*Quercus infectoria*) toxicosis in lambs. Revue Méd Vét. Published online 2013.

Fall-Touré S, Traoré E, N'Diaye K, N'Dèye S. N'Diaye, Baye MS. 1997. Utilisation des fruits de Faidherbia albida pour YaIimentation des bovins #embouche paysanne dans le bassin arachidier au Sénégal. LivestOck Research for Rural DeveloDment **9(5),** 17 p.

Gninkplékpo ELR., Koura BI, Lesse PDA, Yaoïtcha A, Accalogoun J, Hornick JL, Cabaraux JF, Houinato MRB. 2024**.** Forage preference, voluntary intake, and *in vivo* digestibility of six tropical tree leaves by sheep in semi-arid areas in Benin Republic (West Africa). Sustainability **16(6),** 2270.
https://doi.org/10.3390/su16062270mdpi

Gusain K, Gautam K, Bhatt M, Singh H, Singh M, Barthwal S. 2026. Climate-driven shifts in tree phenology: global patterns, trends, and ecological implications. Environmental Science Advances **5(3),**
726-752.
https://doi.org/10.1039/d5va00292c

Hailecherkos S, Asmare B, Mekuriaw Y. 2021. Evaluation of tree lucerne (*Chamaecytisus palmensis*) dried leaves as a substitution for concentrate mixture on biological performance and socioeconomic of Washera sheep fed on desho grass hay. Veterinary Medicine and Science **7,** 402–416.
https://doi.org/10.1002/vms3.376

Idan F, Adogla-Bessa T, Sarkwa FO, Frimpong YO, Antwi C. 2023. Effects of supplementing rice straw with two fodder tree leaves and their combinations on voluntary feed intake, growth, and nitrogen utilization in sheep. Translational Animal Science 7.
https://doi.org/10.1093/tas/txad004

Iso (International Organization for Standardization). 1997. Animal feeding stuffs-Determination of nitrogen content and calculation of crude protein content—Kjeldahl method (ISO 5983:1997).

Klein HD, Rippstein G, Huguenin J, Toutain B, Guerin H, Louppe D. 2019. Les cultures fourragères. Éditions Quæ, CTA, Presses agronomiques de Gembloux.

Kongmanila D, Ledin I. 2009**.** Chemical Composition of Some Tropical Foliage Species and Their Intake and Digestibility by Goats. Asian-Australasian Journal of Animal Sciences **22(6),** 803-811.

Kronqvist C, Kongmanila D, Wredle E. 2021. Effects of Replacing Grass with Foliage on Growth Rate and Feed Intake in Goats-A Systematic Review and Meta Analysis. Animals **11,** 3163.
https://doi.org/10.3390/ani11113163

Matumuini FNE, Lemoufouet J, Tendonkeng F, Mboko AV, Miégoué E, Pamo TE. 2013. Ingestion et digestibilité in vivo des chaumes de maïs traités à 5% d'urée associés à différents niveaux de mélasse chez le mouton Djallonké. Livestock Research for Rural Development **26(3)**.

Mekuriaw S, Tsunekawa A, Ichinohe T, Tegegne F, Haregeweyn N, Kobayashi N, Tassew A, Mekuriaw Y, Belete MW, Ali S, Tsubo M, Okuro T, Meshesha D, Abebe G. 2024. Selection and evaluation of promising indigenous fodder trees and shrubs as supplemental diets for ruminant animals across different agroecological environments. African Journal of Range and Forage Science **41(1),** 15-28.
https://doi.org/10.2989/10220119.202 3.2228840

Ouédraogo-Koné S, Kaboré-Zoungrana CY, Inger L. 2008. Intake and digestibility in sheep and chemical composition during different seasons of some West African browse species. Trop Anim Health Prod **40**,155–164.

Patra AK. 2009. A meta-analysis on effects of supplementing low-quality roughages with foliages from browses and tree fodders on intake and growth in sheep. Livestock Science **121(2–3),** 239–249.

Preston TR, Leng RA. 1987. Matching ruminant production systems with available resources in the tropics and sub-tropics, 265 p.

Sanon HO, Zoungrana CI, Ledin I. 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pasture in a Sahelian area. Small Ruminant Research **67,** 64–74.

Sanou S, Djiguemde M, Nitiema AW, Sanon HO. 2026a. Ingestibilité et digestibilité des rations contenant des feuilles fraîches de *Ficus sycomorus* et de *Khaya senegalensis* chez les ovins Djalonké. Journal of Applied Biosciences **222,** 24740–24751.

Sanou S, Kere M, Kaboré M, Delma BJ, Djiguemdé M, Sanon HO. 2026b**.** Effects of Graded Dietary Levels of Dried Sycamore Fig (*Ficus sycomorus* L.) Leaves on the Performance of Djallonké Sheep in Burkina Faso. Journal of Advances in Biology and Biotechnology **29(9),** 1184–1193. https://doi.org/10.9734/jabb/2026/v29i94394

Traoré LCG, Ouattara M, Sanou S, Sanon HO, Bougouma-Yaméogo V. 2023. Ethnobotanical study of woody fodder species in the commune of Guibaré, Burkina Faso. International Journal of Biological and Chemical Sciences **17(1),** 77-93. https://doi.org/10.4314/ijbcs.v17i1.6

Traoré LCG, Sanou S, Sanon HO, Roessler R, Bougouma-Yameogo V, Schlecht E. 2026. Preference and in vitro digestibility of leaves of woody plants by sheep in the Northern Sudanian Zone. Journal of Animal Physiology and Animal Nutrition **110,** 200-212. https://doi.org/10.1111/jpn.70032

Yeboah ED, Adogla-Bessa T, Ayorkor GNQ, Yeboah R, Sarkwa FO. 2024. Effects of supplementation of sole and combined browse leaves on *in vitro* digestibility of rice straw. West African Journal of Applied Ecology **32(1).**

Zhang J, Zheng N, Shen W, Zhao S, Wang J. 2020. Synchrony Degree of Dietary Energy and Nitrogen Release Influences Microbial Community, Fermentation, and Protein Synthesis in a Rumen Simulation System. Microorganisms **8,** 231. https://doi.org/10.3390/microorganisms8020231