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Research Article

Evaluation of Priority Fodder Trees for Leaf Yield and Nutritional Value at Arba Minch, Ethiopia

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Tree fodder is an important supplement to livestock feed particularly where the shortage of palatable herbaceous biomass affects the animal production in dry seasons. In Arba Minch and nearby semiarid parts of southern Ethiopia, lopping and feeding tree fodder is becoming a common practice to increase livestock productivity. However, knowledge of the fodder species' biomass productive potential and their nutritional content along with their digestibility is limited. Hence, this study investigated leaf yield, nutritional value, and chemical composition including mineral profile and *in vitro* dry matter (DM) and organic matter (OM) degradability of these three browse tree species viz., *Dendrocalamus giganteus*, *Balanites aegyptiaca,* and *Terminalia brownii*. These are commonly used trees for lopping branches and harvesting fodder in Arba Minch, southern Ethiopia. The leaf yield of the trees was assessed based on the uniformity in tree parameters such as height, diameter at breast height, and crown spread. Samples of tree leaves were analysed for chemical composition using standard procedures. The results indicated that fodder yield lopped from all branches was 25.92 kg·DM/five culms for *D. giganteus*, 19.60 kg·DM/tree for *B. aegyptiaca,* and 22.53 kg·DM/tree for *T. brownii*. The crude protein (CP) content was 69.3 g/kg·DM, 113.2 g/kg·DM, 102.6 g/kg·DM, and 122.7 g/kg·DM for the forage hay, *D. giganteus*, *B. aegyptiaca,* and *T. brownii,* respectively. Among the studied browse species, *Terminalia brownii* leaf fodder constitutes greater potential to supply CP, *IVDMD* (48.43%), and *IVOMD* (56.39%) for ruminants. Mineral contents of the trees fodder were also in the suitable optimal range to support ruminant livestock performance except for zinc which was below the recommended level.

1. Introduction

Feed scarcity is a factor responsible for the lower reproductive and growth performance of ruminant livestock especially during the dry season. In many cases, productive pasture areas have changed to cropland in the course of subsistence farming. More attention is now being given to tree leaves for feeding ruminant livestock. Browse species can make a large contribution to livestock nutrition as they can maintain green leaves for a prolonged period during the dry season. Browse fodder is a useful and cheap source of feed for ruminant animals in developing countries where livestock face pressing problems, especially during the dry season when herbaceous pasture grasses and legumes are in senescence. Since trees are able to retain their green leaves and relative nutrient content during the dry season, they bridge the gap normally created by the decline in the nutritive potentials of natural pastures. The potentials of a fodder tree depends on the amount of leaf biomass it produces when lopped or pollarded on annual basis. Leaf life spans vary for trees. In deciduous trees, while some leaves undergo senescence, others remain on the tree for a significant period in the dry season. Accordingly, trees could shade all the leaves or maintain a certain proportion for a longer period in the dry season. The ability of tree foliage to remain green and maintain their protein content makes them potential sources of protein and energy [1]. According to Tolera and Abebe [2], browse species have high crude protein content ranging from 10 to more than 25% which may make them be considered as a more reliable feed resource. Supplying tree fodder in times of feed shortage can help in developing sustainable feeding systems and increase livestock productivity. Therefore, browse tree/shrub species are of great importance in dry-season livestock feeding as they can provide substantial protein and energy [3]. The present research area, Arba Minch is known for its large and small ruminant populations with an average holding of 3-4 cattle per household. The free-roaming livestock in group herds are facing feed shortages during the dry spell. Despite the presence of fodder species in the landscape and the known habit of lopping and feeding to animals, there is limited scientific information regarding the feed values of different fodder trees in the Arba Minch area. Therefore, this study is mainly intended to assess the fodder dry matter (DM) yield of three priority fodder tree species and determine the leaf fodder nutritional potential in terms of chemical composition including *in vitro* digestibility in Woito-Guji goats in the experimental farm of Arba Minch University.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was conducted at the Teaching and Research Farm of the Department of Animal Science, College of Agricultural Sciences, Arba Minch University. It is located in southwestern Ethiopia on the Addis Shashamane Road at about 505 km from Addis Ababa and 275 km from the regional capital, Hawassa in southwestern Ethiopia. It is found in the southern part of the east African rift valley at a specific location of 6°08′N latitude and 37°37′E longitude. According to the station data, the mean annual rainfall of Arba Minch is between 801–1600 mm. Its mean annual average temperature is 29°C. The area receives bimodal rainfall with the main rainy season from March to May and the short rainy season from September to October.

2.2. Data Collection

2.2.1. Fodder Tree Leaf Sampling Procedure. Terminalia brownii and *Balanites aegyptiaca* deciduous trees of relatively similar age, height, and diameter at breast height (dbh) were selected for uniformity in growth. Being deciduous, the trees largely maintain more than 65% of their leaves in the dry season from November to March in the critical period of feed shortage. In short rain, there is always new flash growth from these trees. From the current year (2020), flash grown branches of five trees, from tender and succulent shoots leaves were sampled above the middle portion of the shoots. These are usually the edible fraction, less lignified and palatable when supplied as feed to ruminant livestock. The giant bamboo leaves from *Dendrocalamus giganteus* were collected from branches of young, two years old culm along the nodes. The forage hay in this study was harvested from a succulent grass mixture mainly comprising of scutch grass (*Cynodon dactylon*), green foxtail (*Setaria viridis*), and in about 15% proportion of the native clover (*Trifolium* sp.). The hay grass is maintained at about 2500 m^2 area replicated four times in the experimental farm of Arba Minch University. These are slightly irrigated and regularly harvested in six weeks intervals, dried and used as a control for comparison in the chemical and nutritive value analysis.

The sample leaves, above a kilogram, collected at least from five similar sized trees of the target species, respectively, were taken to the College of Agriculture, Animal Science/Nutrition Laboratory, and washed with tap water to remove dirt and dust. The leaves were placed over a tray, spread on the laboratory bench, and kept for air drying. They were cut into smaller sizes for easy handling and were oven dried at 65°C for 24 hours. These were then removed from the oven, cooled to room temperature, and ground to pass through a 1 mm sieve and placed in an airtight closed container for further proximate chemical analysis at the Holeta Animal Nutrition Laboratory of the Ethiopian Institute of Agricultural Research (EIAR).

2.2.2. Fodder Tree Leaves Biomass Yield Estimation. In order to establish the amount of leaf biomass the three priority fodder tree species in Arba Minch (*D. giganteus*, *B. aegyptiaca,* and *T. brownii*) can produce annually, leaf biomass production potential was estimated from randomly selected five trees with relatively similar dendrometric values (height, diameter at breast height, and crown spread/diameter). The estimates can thus be used for carrying capacity studies on different ruminant livestock and different number of ruminants. The giant exotic bamboo species, *D. giganteus* and the indigenous trees (*B. aegyptiaca* and *T. brownii*) were marked for the leaf biomass study from Arba Minch University experimental farm and the main campus compound, respectively. Leaf biomass for the bamboo species were assessed from randomly selected five individual culms. The culms were carefully bent to collect whole branches with the leaves which were stripped completely and weighed. On the other hand, the other fodder trees for leaf biomass estimation were assessed for the following parameters for uniformity: height (*H*; in meters) was measured as the height from the ground or collar region to the top of the leading shoot [4]. The diameter at breast height (dbh) value was measured at 1.3 m above the ground, and for separate stems an average value was calculated. The crown diameter (CD) for the crown spread was measured in all compass directions from one end to the other using measuring tape and was taken as the average of the perpendicular diameters of the tree canopy in meters [4]. In doing so, trees of similar height, dbh, and crown spread were selected for the foliage biomass estimation.

2.2.3. Analysis of Leaf Nutritional Content. Most of the feed samples were analysed at Arba Minch University, College of Natural Science, Department of Chemistry. The dry matter (DM) was determined by air drying under shade and then oven drying the sample at 65°C for 24 hours till constant weight was obtained. The amount of organic matter (OM) in the feed material was determined by reducing the amount of dry matter from the amount of inorganic matter (crude ash). Total ash was analysed as per AOAC [5] procedure number (942.05) and ether extracts (EE) by the procedure number

(920.39). Crude protein (CP) content was estimated by the automated Kjeldahl technique 976.05. The percentage of leaf nitrogen found using the Kjeldahl apparatus was multiplied with the factor 6.25 ($CP = N \times 6.25$) to obtain the crude protein. Natural detergent fiber (NDF) was determined using techniques described by Van Soest et al. [6]. Acid detergent fiber (ADF) and acid detergent lignin (ADL) were analysed by AOAC procedure number (973.18). Minerals were analysed based on AOAC [5] atomic absorption spectrophotometer procedure number 968.08 and phosphorus by 964.06. Sulphur content in the tree fodder was assessed using the turbidemetric method [7]. The feed sample of *in vitro* dry matter and organic matter digestibility was placed in an airtight closed container and proximate chemical content was analysed at Holeta Agricultural Research Centre, Animal Nutrition Laboratory. It was determined by the method of Tilley and Terry [8]. 0.5 g of the sample was incubated in Erlenmeyer flasks containing rumen fluid-medium mixture for 48 hours at 39°C and further incubated in pepsin solution for another 48 hours at 39°C. Metabolizable energy value was estimated from % *in vitro* organic matter digestibility (*IVOMD*) where the estimated metabolized energy was found to be $(EME) = 0.016^{*}$ % *IVOMD* [9].

2.2.4. Data Analysis. Data recorded in four replications were subjected to the one-way analysis of variance, carried out on proximate chemical composition, mineral content, and in *in vitro* digestibility estimates using the general linear model (GLM) procedure [10]. The trees' leaf fodder biomass production potential estimates followed five replications. Means on the estimated parameters were compared using Fisher's least significance difference.

3. Results and Discussion

3.1. Leaf Fodder Yield Potential of Experimental Trees. The leaf fodder production potential of a browse tree is an important factor to be considered in evaluating its annual fodder yield. As indicated in Table 1, *D. giganteus* has the highest fodder yield (25.92 kg·DM/ five culms) per year at a mean height of 12.5 m, dbh of 14.8 cm, and a crown diameter of 3.2 m. Comparing the other two broad-leaved species, *T. brownii* has slightly lower dendrometric values but produced a higher total leaf fodder than *B. aegyptiaca*. The data on total leaf biomass production potential highlighted the need for a certain number of tree stems to sustain the predetermined number of livestock as per their respective daily intake demand. Based on the amount of daily intake and number of ruminants (5 Woito-Guji goats) in a community, the number of trees to be planted and managed for tree fodder production was estimated for the tree species sought (Table 2). The fodder estimate is supplementary feed in addition to forage hay while the browse species feed on daily basis. Tree stems estimated to sustain the number of ruminants can be planted as fodder lots nearby homesteads. *Dendrocalamus giganteus* bamboo is a clumping type of bamboo which can have about 12 culms per clump. Culms from two years old onwards produce dense leaf biomass for supplementing forage hay every season or particularly in the dry season.

3.1.1. Chemical Composition. The chemical composition of the experimental tree fodder along with the control forage hay investigated in the present study is presented in Table 3. The dry matter (DM) contents of *D. giganteus* and *T. brownii* were statistically at par ($P > 0.05$); however, significantly higher than ($P < 0.05$) the control forage hay and that of *B. aegyptiaca* (Table 3). The dry matter content in the current study trees is higher than the study report for *Ficus sur* 23.52% (235.2 g·DM/kg) by Omoniyi *et al.* [11], for *Newbouldia laevis* 44.95% (449.5 g/kg·DM) and *Ficus exasperata* 19.39% (193.9 g/kg·DM) by Isah et al. [12], and for bamboo (ranging from 45.2% to 65.4% i.e., 452–654 g/kg·DM) by Bhandari et al. [13]. The difference could be ascribed to the variability of the number of leaf constituents among the tree species. The present study findings are, however, comparable to reports on *Acacia* browse tree species DM content ranging from 917.4 to 936.8 g/kg·DM [14].

The ash content of *T. brownii* and *B. aegyptiaca* was lower ($P < 0.05$) than that of *D. giganteus* (Table 3). A similar value of ash content average (92 g/kg·DM) was reported for *Acacia* browse tree species by Rubanza et al. [18]. In another study, significantly lower ash content values (1.98 and 0.039%) for *T. brownii* and *D. giganteus,* respectively, were reported by Agatemor and Ukhun [15]. These differences could definitely arise either from site conditions, analytical methods used, and/or standard procedures followed. Another study conducted on the nutritional status of fodder tree leaves and shrubs in the scarcity zone of Maharashtra, India [16], portrayed an ash content of 8.28% average for 20 browse tree and shrub species.

Organic matter (OM) content of *T. brownii*, *B. aegyptiaca,* and the control forage hay had statistically similar values, that is, (838.2 g/kg·DM), (803 g/kg·DM), and (827.7 g/kg·DM), respectively, whereas *D. giganteus* attained the lowest (722.3 g/kg·DM) OM content. This lower value of OM for *D. giganteus* is related to the higher proportion of Ash content in the dry matter (Table 3). Comparable values of organic matter (OM) content were reported for *Acacia* browse species ranging from 822.9 to 892.2 g/kg·DM [14].

In the present study, *T. brownii* tree fodder contained the highest amount of CP (122.7 g/kg·DM) followed by *D. giganteus* (113.2 g/kg·DM) and *B. aegyptiaca* (102.6 g/kg·DM), whereas the control forage hay (69.3 g/kg·DM) was the lowest in potential crude protein supply to livestock. The browse species were significantly different in CP content between each other and the control forage. Bhandari et al. [13] also reported crude protein content of bamboo leaves averaging 12.3% and ranging from 8.4% to 17.1%. The observed higher CP values of browse trees in the current study (Table 3) were also comparable ($P > 0.05$) to those

Table 1: Sample trees dendrometric parameters and estimated fodder biomass dry matter.

Parameter		Study tree species		
		Dg	*Ba*	*Tb*
Height (m)		12.5 ± 0.0.22	7.2 ± 0.39	6.8 ± 0.37
Diameter at breast height (cm)		14.8 ± 0.37	43.0 ± 0.70	40.6 ± 0.40
Crown diameter (m)		3.2 ± 0.20	6.8 ± 0.37	5.2 ± 0.37
Fodder trees	Mean no of primary branches/ tree and per 5 mature culms per clump	Mean weight (kg) of fresh leaves from single sample branch	Mean weight (kg) of dry leaves from single sample branch	Total leaf yield (kg) dry weight^{-1}tree^{-1} year and per clump
Dg	16* 5 culms	3.08	1.62	25.92
Ba	6.6	5.5	2.94	19.40
Tb	8.6	5.42	2.62	22.53

($n = 5$ for each spp.) *Dg, Dendrocalamus giganteus*; *1 clump = ±12 culms*; *Ba, Balanites aegyptiaca*; *Tb,* and *Terminalia brownii.*

Table 2: Estimate of the tree stems and culms required to sustain five Woito-Guji goats on annual basis in addition to the basal hay forage supply.

Tree species	Monthly tree fodder consumption estimate (kg) dry weight	3 months tree fodder consumption (kg) dry weight	Annual tree fodder consumption estimate (kg) dry weight	Annual fodder production potential of the tree sp. (kg) dry weight per stem/5 mature culms per clump	Number of tree stems/culms estimated to sustain five Woito-Guji goats on annual basis
Dg	87.98	263.94	1055.76	25.92	203.65 ± 9.3
Ba	101.65	304.95	1219.8	19.4	62.87 ± 3.65
Tb	112	336.02	1344	22.53	59.65 ± 6.91

Dg, 1 clump = (±12 culms of all ages).

Table 3: Proximate chemical composition of the trail fodder tree leaves.

Feed type	Proximate chemical composition (g/kg·DM)								
	DM	Ash	OM	CP	NDF	ADF	EE	CF	ADL
Forage hay	923.8^{ab}	96^{ab}	827.7^{b}	69.3^{a}	503.5^{a}	416.3^{a}	7.4^{ab}	53.4^{a}	42.9^{a}
Dg	933.2^{b}	210.9^{c}	722.3^{a}	113.2^{bc}	534.7^{a}	444.2^{a}	6.2^{a}	47.2^{a}	79.9^{c}
Ba	916.7^{ab}	114.6^{b}	803.0^{b}	102.6^{b}	312.6^{a}	183.6^{b}	10.9^{ab}	76.8^{ab}	90.4^{c}
Tb	930.3^{b}	92^{ab}	838.2^{b}	122.7^{c}	430.1^{a}	334.2^{a}	10.3^{ab}	134.6^{c}	63.6^{b}

a, b, and c column means with different superscripts are significantly different ($P < 0.05$); DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber, EE, ether extract; ADL, acid detergent lignin; EE, ether extract; CF. crud fiber; *Dg, Dendrocalamus giganteus*; *Ba, Balanites aegyptiaca*; and *Tb, Terminalia brownii.*

reports of Abdulrazak et al. [17], Rubanza et al. [18, 19], Mtui et al. [20], and Mokoboki [14], where CP in browse species ranged from 11.1% to 30.0%/DM.

There was no difference observed ($P > 0.05$) in NDF and ADF except for *B. aegyptiaca* and EE except for *D. giganteus* content between the tested tree species and the control forage hay (Table 3). However, the highest CF content (134.6 g/kg·DM) was observed ($P < 0.05$) in *T. brownii* than the other fodder species.

The ADF values for the browse and the control forage hay were statistically at par and ranged from 334.2 to 444.2 g/kg·DM except that it was significantly lower (183.6 g/kg·DM) in *B. aegyptiaca* (Table 3). Acid detergent fiber (ADF) in the browse species also portrayed values much lower than what was reported by Mtui et al. [20] for *Gliricidia Sepium* (271 g/kg·DM), *Leucaena leucocephala* (257 g/kg·DM), and *Morus alba* (231 g/kg·DM) sampled in the dry season. Nevertheless, it is higher than the values (16.00%, 16.00% and 17.00%) reported by Uzman et al. [21] for the browse trees *Morus alba, Acacia nilotica,* and *Ziziphus jujuba* leaves, respectively, and lower than that of 145 g/kg·DM reported by Rubanza et al. [18] for *Acacia* browse trees.

The content of ADL in *D. giganteus* and *B. aegyptiaca* is statistically the same but significantly higher ($P < 0.05$) than that in *T. brownii* and the control forage hay. The values differed due to leaf lignification in the growing period. The ADL contents for browse species in the current study (42.9–90.4 g/kg·DM) were comparable to the results of Mtui et al. [20] which ranged from 33 to 110 g/kg·DM for *Morus alba*, *Leucaena leucocephala,* and *Gliricidia Sepium,* respectively, and also to ADL (100 g/

kg·DM) average reported for *Acacia* browse species by Rubanza et al. [18].

3.2. Concentration of Minerals (g/kg Dry Matter) in the Leaf Fodder and Forage Hay. Results from the analysis of both macromineral and micromineral concentrations of the trail feeds are presented in Table 4. Calcium (Ca) varied significantly ($P < 0.05$) in its concentration among the fodder tree species which ranged from 5.8 g/kg·DM (*D. giganteus*) to 16.1 g/kg·DM (*T. brownii*). The control forage hay had the lowest Ca content which, however, was statistically at par with *D. giganteus*. Magnesium content was comparable in the control hay and in the tree species viz., *B. aegyptiaca* and *T. brownii* which, however, was significantly lower in *D. giganteus*. Sulphur concentration was significantly higher ($P < 0.05$) in the control forage hay followed by *B. aegyptiaca*. Phosphorus content was significantly lower ($P < 0.05$) in the control hay than in the other tree species.

T. brownii and *B. aegyptiaca* had a similar ($P > 0.05$) concentration of iron (Fe), but the value was significantly lower ($P < 0.05$) than that of the Fe content in the control forage hay and the *D. giganteus*. Copper (Cu) and zinc (Zn) were significantly higher in the control hay and lowest ($P < 0.05$) in the *D. giganteus* leaf fodder. Manganese (Mn) content was significantly different among the tested species ($P < 0.05$), where it was the lowest in the control forage hay and varied with the maximum value at the *B. aegyptiaca* tree fodder (Table 4).

In the current study, despite the significantly varying levels of Ca in the fodder trees' leaves, its levels are within the range of 8.6–10.2 g/kg·DM reported for most tropical legumes [22] and also comparable with 3.2–14.2 g/kg·DM reported by Abdulrazak et al. [17]. However, Ca concentrations in the current study were slightly lower than those reported by Rubanza et al. [19] and Mtui et al. [20] which ranged from 6.6 to 35.6 g/kg·DM. The leaf contains twice as much Ca as the stem fraction. The stage of growth, fertilizer, and climate has no consistent effect on Ca levels in forage.

Phosphorus (*P*) levels in the current study (2–2.5 g/kg·DM) in tree leaves were higher ($P < 0.05$) than those reported elsewhere for *Acacia* species (0.7–1.6 g/kg·DM) [17]. The *P* levels were within the range of 1.0–5.0 g/kg DM as noted by Rubanza et al. [19], Mtengeti and Mhelela, [23] and Mtui et al. [20]. Phosphorus is an essential nutrient that is deficient in forage grown on soils derived from parent rock low in *P* content. Its deficiency reduces forage intake, estrus, conception rate, milk and wool production, growth rate, and the survival of ruminants. The *P* contents from the current report were lower than the minimum requirements for beef cattle (3.1–4.0 g/kg·DM) but within the range for sheep (1.6–3.2 g/kg·DM) [24].

The species had varying contents of magnesium (Mg) that ranged from 5.89 g/kg·DM in *D. giganteus* to 6.6 g/kg·DM in *B. aegyptiaca*. The tree fodder contents for Mg were within the range consistent with the minimum requirements in the diets of beef cattle (0.5–7.0 g/kg·DM) and higher than that for sheep diets (0.4–0.8 g/kg·DM) [25]. Magnesium concentration in forage varies with available soil Mg and can be increased by fertilizer nitrogen amendments. The contents of Mg in the studied browse species were also comparable to that of legume species (1.3–6.6 g/kg·DM) studied elsewhere [17, 19, 20, 23].

Concentrations of sulphur (*S*) among the browse species (1.91–3.18 g/kg·DM) was much lower than the value in the forage hay. However, the contents were within the minimum requirements of diets for sheep (1.4–2.5 g/kg·DM and goats 1.6–3.2) 56 g/kg·DM [26]. The S contents observed in the species in the current study were consistent with those reported by Abdulrazak et al. [17] for *Acacia* spp.

Most of the studied tree fodder had copper (Cu) concentrations (28–36) mg/kg·DM comparable ($P < 0.05$) to most tropical legumes (15–35 mg/kg·DM) [22]. Copper levels are higher in temperate legumes than in temperate grasses, but tropical forage grasses have a higher level of Cu than legumes. There are no consistent differences in Cu concentration between forage species but there are large differences between cultivars. Likewise, the range of Cu concentrations in fodder tree species in the current study were higher ($P < 0.05$) than the minimum requirements for beef cattle (4–10 mg/kg·DM), sheep, and goat diets (0.1 mg/kg·DM) [24].

The concentrations of iron (Fe) in the fodder trees leaves were lower than those of the normal requirements of ruminants [27] (30–60 mg/kg·DM); and the minimum requirements of beef cattle (50–100 mg/kg·DM) [25].

The manganese (Mn) content in the trees' fodder varied from 22 mg/kg·DM in *T. brownii* to 34 mg/kg·DM in *B. aegyptiaca*. The values are within the range of minimum requirements of the diets for beef cattle (20–50 mg/kg·DM), sheep (20–40 mg/kg·DM), and goats (>5 mg/kg·DM) [26]. Manganese is an essential element required for normal growth, bone development, and reproduction, but there is no evidence that Mn deficiency occurs in grazing ruminants. It is an essential cofactor for many enzymes with a wide range of activities. The Mn concentrations in this study were lower than those reported by Rubanza et al. [19] (44.6–306 mg/kg·DM) and were within the range of 9.4–67.8 mg/kg DM as reported by Abdulrazak et al. [17] and Kakengi et al. [28].

The concentration of zinc (Zn) in the fodder trees of the current study (11–18 mg/kg·DM) had lower levels of Zn than the forage hay and were significantly lower than that of the mean concentration of most forages (36–47 mg/kg·DM) [22]. Zinc (Zn) is required by ruminants to prevent the skin disease parakeratosis and to achieve maximum food intake, growth rate, testicular development, spermatogenesis in rams, and conception in ewes. The recommended requirements of ruminants for dietary Zn are reduced to 16–26 mg/kg·DM following the results of absorption studies with diets deficient in Zn and yield responses to Zn supplements. Zinc deficiency rarely occurs in ruminants fed forage. On the other hand, the species could not meet the minimum requirements for ruminant diets (20–40 mg/kg·DM) [24]. Nevertheless, the contents of Zn were in range with the values (10.2–34.7) mg/kg DM reported by Abdulrazak et al. [17], Rubanza et al. [19], and Kakengi et al. [28].

Table 4: Concentration of macro- (g/kg DM) and microminerals (mg/kg DM) in fodder tree leaves.

Feed type	Ca	Mg	*S*	*P*	Fe	Cu	Mn	Zn
Forage hay	5.71^{a}	6.37^{b}	4.43^{ab}	1.78^{a}	215^{b}	42^{ab}	19^{a}	28^{ab}
D. giganteus	5.8^{a}	5.89^{a}	1.97^{a}	2.5^{ab}	240^{ab}	28^{a}	27^{ab}	11^{a}
B. aegyptiaca	13.4^{b}	6.6^{b}	3.18^{b}	2.0^{b}	198^{a}	37^{b}	34^{d}	13^{b}
T. brownii	16.1^{ab}	6.3^{b}	1.99^{a}	2.5^{ab}	198^{a}	36^{b}	22^{b}	18^{b}

a, b, and c column means with different superscripts are significantly different ($P < 0.05$).

Fodder tree leaves are generally rich in mineral contents which vary among the species possibly due to genotypic differences among the species, variability in mineral uptake, and retention efficiency in plants, stage of foliage maturity, and proportion of leaf samples [22].

3.2.1. In Vitro Digestibility. Results for *in vitro* digestibility of leaves of the selected fodder tree species are presented in Table 4. The difference was observed between fodder species in their potential of *IVDMD and IVOMD. In vitro* dry matter digestibility (*IVDMD*) and *in vitro* organic matter digestibility (*IVOMD*) potential of the fodder tree species leaves from Arba Minch University farm have varied significantly ($P < 0.05$) between species (Table 5).

IVOMD ranged from 48.27% DM in *B. aegyptiaca* to 56.39% DM in *T. brownii* which implies that it was significantly different ($P < 0.05$) in the fodder. Similarly, the *IVOMD* value between *D. giganteus* and *B. aegyptiaca* was also different ($P < 0.05$). However, all the tree fodders had similar ($P > 0.05$) *IVDMD* and EME potentials (Table 5). There were noted variations in terms of *IVDMD* and *IVOMD* potential. The existing variations among species in the current study could be partly associated with the influence of accumulation of fiber fraction as a result of stage of growth, plant maturity, and proportion of tree components taken for analysis of chemical composition. The data reported in this study indicate that the leaves from a range of browse trees in the Arba Minch have a good potential to supply highly digestible feeds for ruminants. A report from Tanzania also indicates that eight browse tree species screened in Kongwa and Kiteto districts (*Acacia mellifera, Acacia senegal, Acacia xanthophloea, Acacia tortilis, Boscia* spp,. *Gliricidia sepium, Leucaena pallida, and Melia azedarach*) could be utilized as protein supplements to ruminant livestock feed on low-quality feeds including hays, stover, and crop residue due to their high levels of crude protein and minerals, low fiber contents as well as high digestibility potential [29].

Results from the present study indicate that the species had high levels of *in vitro* dry matter digestibility potentials. The observed high *IVDMD* in the current study were consistent with the findings of other studies. The *IVDMD* among the fodder tree species (39.13–48.43% DM) is comparable to the findings reported elsewhere (30.0–84.7% DM) [23, 29–32]. Contents of *IVOMD* potentials were also within the range of the findings by Khanal and Subba [33] for other browse species which ranged from 34.4–81.0% DM and Rubanza et al. [19] for *Acacia* species. EME values for the control forage hay and fodder from the studied tree species were statistically similar ($P > 0.05$). Comparable values in the range from 7.2 MJ/kg·DM for *A. seyal* to 9.3 MJ/kg·DM for *A. ehrenbergiana* at the early period and from 7.3 MJ/kg·DM for *A. nubica* to 9.7 MJ/kg·DM for *Z. spina-christi* at the late period were reported by Fadel Elseed et al. [34].

Table 5: *In vitro* digestibility (% DM) of leaf fodder from tested tree species.

Feed ingredients	IVDMD	IVOMD	EME (MJ/kg·DM)
Forage hay	36.28^{a}	44.60^{a}	7.14^{a}
Dg	$44.06a^{b}$	52.91^{c}	8.47^{a}
Ba	$42.13a^{b}$	48.27^{b}	7.7^{a}
Tb	48.43^{b}	56.39^{c}	9.0^{a}

Dg, Dendrocalamus giganteus; *Ba, Balanites aegyptiaca*; *Tb, Terminalia brownii*; IVDMD, *in vitro* dry matter digestibility; IVOMD, *in vitro* organic matter digestibility; and EME, estimated metabolizable energy.

4. Conclusion

The study evaluated the proximate chemical composition including mineral profile and *in vitro* digestibility and leaf biomass yield of *D. giganteus, B. aegyptiaca,* and *T. brownii* compared with a control forage hay in Arba Minch, southern Ethiopia.

The study indicated that with the leaf biomass production potential in dry weight basis number of tree stems/culms estimated to sustain five Woito-Guji goats on annual basis is 203.65 ± 9.3 *D. giganteus* culms, 62.87 ± 3.65 stems of *B. aegyptiaca,* and 59.65 ± 6.91 stems of *T. brownii.*

The three fodder trees constituted leaf crude protein much higher than that of the control forage hay indicating their suitability as a forage supplement. The mineral concentrations in the leaf fodder were also in a suitable range for ruminant livestock feeding except for Zn which requires supplementation in the feed. The browse trees leaf fodder had optimum levels of *IVDMD* and *IVOMD*, where the observed potentials are within the range for productive ruminant livestock.

Data Availability

The data used to support this study are included within the article.

Disclosure

This manuscript is prepared from Master thesis research report (2021) on "Evaluation of Priority Fodder Trees for Leaf Yield and Nutritional Value at Arba Minch, Ethiopia" by the first author at Department of Animal Science, Arba Minch University.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] O. A. Olafadehan, "Feeding value of Pterocarpus erinaceus for growing goats," *Animal Feed Science and Technology*, vol. 185, no. 1-2, pp. 1–8, 2013.

[2] A. Tolera and A. Abebe, "Livestock production in pastoral and agro-pastoral production systems of southern Ethiopia," *Livestock Research for Rural Development*, vol. 19, 2007.

[3] B. Shenkute, A. Hassen, T. Assafa, N. Amen, and A. Ebro, "Identification and nutritive value of potential fodder trees and shrubs in the mid rift valley of Ethiopia," *Journal of Animal & Plant Sciences*, vol. 22, no. 4, pp. 1126–1132, 2012.

[4] M. Balehegn, E. A. Eniang, and A. Hassen, "Estimation of browse biomass of Ficus thonningii, an indigenous multipurpose fodder tree in northern Ethiopia," *African Journal of Range and Forage Science*, vol. 29, no. 1, pp. 25–30, 2012.

[5] Aoac (Association of Official Analytical Chemists), Edited by W. Horwitz, Ed., AOAC, Washington DC, 18th edition, 2005.

[6] P. J. Van Soest, J. B. Robertson, and B. A. Lewis, "Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition," *Journal of Dairy Science*, vol. 74, no. 10, pp. 3583–3597, 1991.

[7] M. A. Tabatabai and J. M. Bremner, "A simple turbidimetric method of determining total Sulfur in plant materials," *Agronomy Journal*, vol. 62, no. 6, pp. 805-806, 1970.

[8] J. M. A. Tilley and R. A. Terry, "A two-stage technique for the in vitro dry matter digestibility of forage crops," *Grass and Forage Science*, vol. 18, no. 2, pp. 104–111, 1963.

[9] P. R. A. McDonald, R. A. Edwards, J. F. D. Greenhalgh, C. A. Morgan, L. A. Sinclair, and R. G. Wilkinson, *Animal Nutrition*, Pearson Education Limited, London, UK, 7th edition, 2010.

[10] Sas, *Statistical Analysis System. User's Guide: Statistics*, SAS Institute. Inc, Cary NC 275513 USA, 1999.

[11] L. A. Omomniyi, O. A. Isah, R. A. Olorunsola et al., "Nutrient and anti-nutritional constituents of Penisetum purpureum and four indigenous tree legume of south-western Nigeria: a potential ruminant feed," *Nigerian Journal of Animal Production*, vol. 40, no. 1, pp. 152–160, 2013.

[12] O. A. Isah, P. O. Fayemi, M. B. Gazaly, and R. Y. Aderinboye, "Nutritional characteristics of four browse plants consumed by free-ranging ruminants in western part of Nigeria," *African Journal of Agricultural Research*, vol. 7, no. 12, pp. 1944–1949, 2012.

[13] M. Bhandari, R. Kaushal, R. L. Banik, and S. K. Tewari, "Genetic evaluation of nutritional and fodder quality of different bamboo species," *Indian Forester*, vol. 141, no. 3, pp. 265–274, 2015.

[14] H. K. Mokoboki, "Effect of species within season on techniques used to measure nutritive value and anti-nutritional factors in browse tree leaves," *Life Science Journal*, vol. 8, no. 2, pp. 112–119, 2011.

[15] C. Agatemor and M. E. Ukhun, "Nutritional potential of the nut of tropical almond (Terminalia Catappia L.)," *Pakistan Journal of Nutrition*, vol. 5, no. 4, 2006.

[16] U. S. Gaikwad, A. B. Pawar, and A. D. Kadlag, "Nutritional status of fodder tree leaves and shrubs of scarcity zone of Maharashtra," *Advances in Life Sciences*, vol. 7, no. 1, pp. 11–14, 2017.

[17] S. A. Abdulrazak, T. Fujihara, T. Ondiek, and E. R. Ørskov, "Nutritive evaluation of some Acacia from Kenya," *Animal Feed Science and Technology*, vol. 85, pp. 89–98, 2000.

[18] C. D. K. Rubanza, M. N. Shem, R. Otsyina, T. Ichinohe, and T. Fujihara, "Nutritive evaluation of some browse tree legume foliages native to semi-arid areas in western Tanzania," *Asian-Australasian Journal of Animal Sciences*, vol. 16, no. 10, pp. 1429–1437, 2003.

[19] C. D. K. Rubanza, M. N. Shem, T. Ichinohe, and T. Fujihara, "Polyphenolics and mineral composition of selected browse tree species leaves native to north western Tanzania traditional fodder banks," *Journal of Food Agriculture and Environment*, vol. 4, no. 1, pp. 328–332, 2006.

[20] D. J. Mtui, F. P. Lekule, M. N. Shem, T. Ichinohe, and T. Fujihara, "Comparative potential nutritive value of grasses, creeping legumes and multipurpose trees commonly in sub humid region in the eastern parts of Tanzania," *Livestock Research for Rural Development*, vol. 21, no. 10, 2009.

[21] B. C. Uzman, I. S. Javed, J. Asif, A. Parvis, and S. Muhammad, "Chemical composition, mineral profile and in situ digestion kinetics of fodder leaves of four native trees," *Pakistan Journal of Botany*, vol. 43, no. 1, pp. 397–404, 2011.

[22] D. J. Minson, "Forage in ruminant nutrition," *Science Direct*, vol. 483, 1990.

[23] E. J. Mtengeti and A. Mhelela, "Screening of potential indigenous browse species in semi-arid central Tanzania. A case of Gairo division," *Livestock Research for Rural Development*, vol. 18, no. 8, p. 1, 2006.

[24] Nrc (National Research Council), *Committee on Animal Nutrition*, National Academy Press, Washington D.C, 1981.

[25] Nrc (National Research Council), *Nutrient Requirements of Domestic Animals, Nutrient Requirements of Beef Cattle*, National Academy of Science, National Research Council, Washington DC, 6th edition, 1984.

[26] Nrc (National Research Council), *Nutrient Requirements of Dairy Cattle*, The National Academies Press, Washington, DC, Fifth revised edition, 1978.

[27] P. R. A. McDonald, R. A. Edwards, J. F. D. Greenhalgh, and C. A. Morgan, *Animal Nutrition*, Longman Group, Harlow, United Kingdom, Fifth edition, 1995.

[28] V. A. M. Kakengi, S. M. Ndabikunze, S. V. Starwatt, and T. Fujihara, "Trace mineral contents of grass and browses in Tanzania and its implication to ruminant feeding and reproduction," *Journal of Food Agriculture and Environment*, vol. 5, no. 1, pp. 210–215, 2007.

[29] Z. Nassoro, "Evaluation of nutritive value of browse tree fodder species indigenous to Kiteto and Kongwa Districts," MSc thesis in Biodiversity Conservation, University of Dodoma, Dodoma, Tanzania, 2014.

[30] C. M. Shayo, B. Ogle, and P. Uden, "Comparison of water melon (Citrullus vulgaris) seed meal, Acacia tortilis pods and sunflower-seed cake supplements in central Tanzania. 1. Nutritive value and influence on the rumen environment," *Tropical Grasslands*, vol. 31, no. 2, pp. 124–129, 1997.

[31] C. M. Shayo and P. Uden, "Nutritional uniformity of neutral detergent solubles in some tropical browse leaf and pod diets," *Animal Feed Science and Technology*, vol. 82, no. 1-2, pp. 63–73, 1999.

[32] O. R. Madibela, O. Seitshiro, and ochankana, "Deactivation effects of polyethylene glycol (PEG) on in-vitro dry matter digestibility of Colophospermum mopane (Mophane) and acacia browse trees in Botswana," *Pakistan Journal of Nutrition*, vol. 5, no. 4, pp. 343–347, 2006.

[33] R. C. Khanal and D. B. Subba, "Nutritional evaluation of leaves from some major fodder trees cultivated in the hills of Nepal," *Animal Feed Science and Technology*, vol. 92, no. 1-2, pp. 17–32, 2001.

[34] A. M. A. Fadel Elseed, A. E. Amin, D. Khadiga et al., "Nutritive evaluation of some fodder tree species during the dry season in central Sudan," *Asian-Australasian Journal of Animal Sciences*, vol. 15, no. 6, pp. 844–850, 2002.