Seasonal variation in Nutritional value of major browse species in North Western, Ethiopia

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Abstract

The experiment was conducted to evaluate effect of season on chemical composition, in vitro dry matter digestibility and in sacco dry matter degradability of browse species. Sample foliage of ten browse trees/shrubs were collected in the field for evaluations in both dry and wet season from five kebeles in Bahir Dar Zuria District. Data were analyzed by statistical analysis system. The chemical composition except dry matter in the wet season, in vitro digestibility and in sacco dry matter degradability except degradation rate significantly (P<0.05) differed between seasons. In the dry season dry matter, acid detergent fiber, acid detergent lignin and ash were highest while organic matter, crude protien and hemi-cellulose were in the wet season. In vitro dry matter digestibility ranging from 282 to 694 g/kg dry matter during the wet season and from 239 to 683 g/kg dry matter during the dry season. For most studied browse trees shrubs, in sacco dry matter degredability were higher in the wet season than in the dry season at different rumen incubation hours. The study revealed that evaluation of nutritional value from different browse trees/shrubs and seasons can be a good indicator for linking nutritional quality and seasonal factors. Further study on individual mineral content, anti-nutritional factors and feeding trial of top quality browse species are important.

keywords: Bahir Dar Zuria, browse species, chemical composition, digestibility, season

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Introduction:

The potentials of indigenous browse trees and shrubs remain vital in the support of rural livelihoods and food security [1]. The potential of browse trees/shrubs can be gauged in their multipurpose nature and their ease of integration into existing farming systems through soil fertility and improvement of both crop and livestock production. Natural browse is advantageous over exotic species because they are adapted to the local environment and planting material is abundant. Cultivated forages are land and labour intensive, hindering possible adoption by resource poor farmers. Moreover, there are limited species appropriate to different agro-ecological zones, forage seeds are not available adequately and that farmers lack knowledge and skills needed to grow them [2].

As reported by Takele et al.[3] indigenous browse trees are used as feed resource during the dry season of the year. According to Aynalem and Taye [4], browses have considerable potential for use in the mixed crop-livestock production system for sustainable agriculture and to complement low quality basal feed as they are rich in protein, minerals, and vitamins for rumen microbes and the host animal[5].

Bahir Dar Zuria District (BDZD) production system is characterized as a mixed crop-livestock farming system. Crop production and livestock rearing are means of the farmers' livelihoods. In the study area, there is feed shortage problem due to shrinkage of grazing lands which are changed in to crop lands and expansion of urbanization and the available natural pasture are highly degraded due to overgrazing. Crop residues are not enough to feed livestock year-round and are low in nutritional value. Therefore, in this regard indigenous browses can be an alternative supplement since they are cheap source of protein. The area has remnant indigenous trees/shrubs, which are found in the homestead, cropland, hilly tops, and communal grazing land and watershed areas as reported by Getachew and Mesfin[6]. The availability and quality of the different browse species vary from season to season due to seasonality in rainfall distribution that affects the growth and development of the browse species [7]. For smallholder farmers to efficiently use this indigenous Browse Trees/Shrubs (BTSs) as a source of feed for ruminants' important browse species should be identified and their potential as fodder in the localities should be well understood. However, in the study area browse trees/shrubs are not well identified, seasonal variations in nutritive value and availability are not evaluated and documented. Therefore, we evaluated effect of season on chemical composition, in vitro dry matter digestibility and in sacco dry matter degradability of selected major browse species in Bahir Dar Zuria District.

Materials and Methods

Location and description of the study area

The study was conducted in Bahir Dar Zuria District (BDZD) in Amhara Regional state of Ethiopia. It is situated at an altitude ranging from 1700-2300 meters above sea level and has area coverage of 151,119 hactare (ha). Its extension is between 11°25′N - 11°55′N latitude and 37°04′E - 37°39′E longitude. The District falls within tepid moist agro-climatic zone. The mean annual temperature is about 20 ºC, with a maximum temperature slightly above 28.3 ºC and the minimum about 10.2 ºC. The annual rainfall ranges from 800 – 1250 mm, with a long period of summer rain from May to September [8].

Browse foliage sample collection and preparation for chemical analysis

The major browse species in the study area were identified and prioritized by farmers based on abundance and preference by livestock mainly cattle. Among fifteen species identified the top ten were selected on the basis of priority by farmers for herbage biomass yield estimation, chemical composition analysis, in vitro dry matter digestibility, and in sacco dry matter degradability. Sample foliage (leaves) of these species was collected both in the wet and dry season on August and January, respectively. In both seasons the collection was done from three randomly selected browse trees/shrubs for each species and a composite sample was done. The samples were air dried in a well-ventilated room, then the sample transported to Haramaya University Animal Nutrition Laboratory. The samples were dried in an oven for 72 hours at 60 0C and ground in a Willy mill to pass through 1 and 2 mm sieve for chemical composition analysis and IVDMD, and in sacco dry matter degradability, respectively.

Chemical composition analysis

Leaves of Cordia africana, Ficus sycomorus, Ficus vasta, Ficus thonningii, Vernonia amygdalina, Sapium ellipticum, Stereospermum kanthianum, Grewia ferruginea, Piliostigma thonningii and Carissa edulis were analyzed for dry matter (DM). It was determined by drying 2g sample in forced draft oven at 105 0C overnight. Ash was determined by complete burning of 2g feed samples in a muffle furnace at 550 0C overnight, and Nitrogen (N) was determined following the procedure of Kjeldahl methods by AOAC[9]. Crude protein was estimated as N x 6.25. Organic matter was determined by deducting ash content of browse sample from 100. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were analyzed by using the detergent extraction method by Van Soest et al. [10]. Hemi-cellulose and cellulose were calculated as NDF minus ADF and ADF minus ADL, respectively.

In vitro dry matter digestibility

In vitro dry matter digestibility (IVDMD) of foliage of selected browse species was determined by the method of Tilley and Terry [11] as modified by Van Soest and Robertson[12], in which the second stage (pepsin digestion) is substituted with neutral detergent solution. Rumen liquor was taken in the morning before animals were offered feed. About 0.5 g of the sample was incubated in 125ml Erlenmeyer flasks containing rumen fluid-medium mixture for 48 hours in incubator at 39 0C. The rumen fluid was obtained from three rumen fistulated Boran x Holstein Friesian steers at Holetta Agricultural Research Center (HARC), Ethiopia.

In Sacco dry matter degradability

Rumen degradability of the samples was determined by incubating about 3g of sample in nylon bag (41µm pore size and 6.5 ×14 cm) in rumen fistulated steers kept at, HARC, Ethiopia. Browse samples were incubated for 0, 6, 12, 24, 48, 72 and 96 hours. Replicated nylon bags containing the sample were incubated in three rumen fistulated animals for different length of hours. After incubation for respective length of hours bags were removed and washed with tap water until the rinsing water looks clean. Zero-hour wash losses were rinsed and cleaned by tap water similar to that of the incubated bags. The washed bags were dried in an oven at 65 0C for 72 hours. The dried bags were taken out of the oven and cooled and weighed immediately. The percentage disappearance of DM was determined by using the following formula.

Dry matter degradability (DMD) = (DM in browse species - DM in residue) x 100

(DM in browse species)

The DMD data was fitted to the equation described by Ørskov and McDonald (13). The nonlinear parameters a, b, and c were estimated using non-linear procedures of PROC NLIN of SAS (14) .

$Y = a+b\,(1-e^{-ct})$, where

Y= the potential disappearance of DM at time ta= rapidly degradable fraction

b = the potentially, but slowly degradable fraction

c = the rate of degradation of b

e = the natural logarithm

t = time

Effective degradability (ED) was calculated following the method of Ørskov and McDonald(13), a passage rate of 4% /h.

The potential degradability (PD) was calculated as follow

PD = a+b

ED = a+b*(c/k+c), where

k = passage rate

Statistical analyses

The data were analyzed using ANOVA of the general linear model procedure of SAS(14). Mean differences were tested using least significant difference (P≤0.05). The model used for analysis was as follow:

$Y_{ij} = \mu + B_i + S_j + e_{ij}$

Where;

Yij= response variable

µ= overall mean

Bi= browse species i=1-10

Sj= season effect j=1-2

eij = random error

Results and discussion

Chemical composition of browse species

The chemical compositions of BTSs are indicated in Table 1 for wet and Table 2 for dry season. In the wet season chemical composition except in the DM content were significantly (P<0.05) different between species. High ash content in F. vasta indicates it is a rich source of minerals for livestock feeding. The ash content was within the range reported by (Solomon et al.; Muleta) [15, 16] the organic matter of BTSs was highest in the wet season which could be attributed to higher amount of nutrient availability to the livestock.

Table 1. *Chemical composition (g/kg DM) and in vitro dry matter digestibility (g/kg DM) of browse species during wet season*

Browse spp.	DM	Ash	OM	CP	NDF	ADF	ADL	HC	Cellulose
C. africana	907	121^{b}	879^{e}	141^{bcd}	664^{a}	450^{b}	212^{d}	214^{bc}	238^{b}
F. sycomorus	887	122^{b}	878^{e}	144^{bcd}	567^{cd}	411^{c}	114^{g}	157^{dc}	297^{a}
F. vasta	898	134^{a}	866^{f}	157^{abc}	598^{bc}	376^{d}	278^{b}	222^{bc}	98^{d}
F. thonningii	895	115^{bc}	885de	137^{bcd}	549^{cd}	305^{e}	151^{f}	245^{b}	153^{c}
V. amygdalina	890	120^{b}	880^{e}	177^{a}	535^{d}	295^{e}	253^{c}	240^{b}	41^{e}
S. ellipticum	887	82^{e}	918^{b}	177^{a}	517^{d}	253^{f}	174^{e}	264^{b}	79de
S. kanthianum	889	112^{c}	888^{d}	99^{e}	634^{ab}	486^{a}	321^{a}	148^{d}	166^{c}
G. ferruginea	894	91^{d}	909^{c}	165^{ab}	636^{ab}	305^{e}	126^{g}	331^{a}	179^{c}
P. thonningii	908	72^{f}	928^{a}	132^{cd}	637^{ab}	385^{cd}	117^{g}	252^{b}	268^{ab}
C. edulis	896	72^{f}	928^{a}	116de	588^{bc}	354^{d}	116^{g}	234^{b}	238^{b}
SEM	2.00	5.01	5.01	5.97	11.46	16.31	16.56	12.33	18.80
P-value	*0.1110*	<.0001	<.0001	0.0029	0.0008	<.0001	<.0001	0.0039	<.0001

ADF = acid detergent fiber; ADL= acid detergent lignin; CP = crude protein; DM = dry matter; HC= hemi-cellulose; NDF = neutral detergent fiber; OM= organic matter; SEM = standard error of the means; Means with different letters within column are different at P≤0.05

Table 2. *Chemical composition (g/kg DM) of browse species during dry season*

Browse spp.	DM	Ash	OM	CP	NDF	ADF	ADL	HC
C. africana	921^{c}	155^{c}	845^{g}	133^{abcd}	752^{a}	487^{a}	236^{bc}	265^{bc}
F. sycomorus	922^{c}	158^{bc}	842^{gh}	127^{bcd}	585^{e}	439^{c}	247^{ab}	147^{e}
F. vasta	922^{c}	112^{e}	887^{e}	139^{abc}	579^{e}	487^{a}	258^{a}	92^{f}
F. thonningii	913^{c}	161^{b}	839^{h}	121^{cde}	657^{c}	400^{d}	228^{c}	257^{bc}
V. amygdalina	934^{b}	127^{d}	873^{f}	163^{a}	614^{d}	478^{a}	201^{d}	136^{e}
S. ellipticum	955^{a}	70^{h}	930^{b}	158^{a}	557^{f}	366^{e}	192de	190^{d}
S. kanthianum	954^{a}	204^{a}	796^{i}	96^{e}	655^{c}	411^{d}	178^{ef}	244^{c}
G. ferruginea	955^{a}	101^{f}	900^{d}	154^{ab}	667^{c}	358^{e}	189de	309^{a}
P. thonningii	947^{a}	88^{g}	912^{c}	122^{cde}	722^{b}	446^{bc}	167^{f}	277^{b}
C. edulis	952^{a}	62^{i}	938^{a}	103de	626^{d}	465^{ab}	241^{bc}	162^{e}
SEM	3.73	9.92	9.92	5.39	13.66	10.57	7.05	15.84
P-value	<.0001	<.0001	<.0001	0.0075	<.0001	<.0001	<.0001	<.0001

ADF = acid detergent fiber; ADL= acid detergent lignin; CP = crude protein; DM = dry matter; HC= hemi-cellulose; NDF = neutral detergent fiber, OM= organic matter; SEM = standard error of the means; Means with different letters within column are different at P≤0.05

The CP content was lowest (99 g/kg DM) in S. kanthianum while highest (177 g/kg DM) in S. ellipticum. Crude protein content was slightly higher in the wet season because of increased photosynthesis and plant maturity is not advanced. Inter species variation in CP content indicated that S. ellipticum had the highest while S. kanthianum the lowest in both seasons. The CP values measured in this study lie within the ranges reported for other browse species in Ethiopia (Aster et al.; Ahmed et al.) [7,17]. The CP content was lower than reported by Solomon et al. [15], this might be variation of location, soil type and browse species. In general, all the ten trees/shrubs leaves had an excellent CP concentration (more than 70 g/kg DM) even in the dry season. Below 60-80 g/kg DM CP appetite and forage intakes are supposed to be depressed [18]. All except S. kanthianum browse species fulfill CP content of (110-120 g/kg DM) required for moderate level of ruminant production (ARC; Kazemi et al.; Nassoro et al.) [19, 20, 21]. V. amygdalina, S. ellipticum, F. vasta and G. ferruginea browse species fulfill the CP concentration of more than 150 g/kg DM which is required to support lactation and growth [22].

NDF was lowest in S. ellipticum while highest in C. africana. Similar work was reported by Muleta [16], who noted that C. africana contained high NDF. Similarly ADF content ranges from 253 g/kg DM in S. ellipticum to 486 g/kg DM in S. kanthianum. F. sycomorus had lowest 114 g/kg DM and S. kanthianum had highest 321 g/kg DM ADL content. As NDF is considered an indicator of forage bulkiness and is related to dry matter intake, higher NDF content in C. africana may reduce forage intake. In this study the NDF content was quiet variable between species grouped under moderate quality except C. africana as NDF content of roughage feeds with less than 450 g/kg DM was grouped as a high quality feed, while feed with NDF content of 450-650 was categorized as medium quality feed and above 650 g/kg DM to be categorized under low quality feed Singh and Oosting [23]. The present study indicated that ADF content of BTSs had medium to high quality which is related to digestibility of feed where all browse species had bellow 550 g/kg DM. According to Kazemi et al. [20], legumes with ADF values less than 310 g/kg DM are rated as superior quality whereas those with values greater than 550 g/kg DM are considered inferior.

Hemi-cellulose ranges from 148 g/kg DM to 331 g/kg DM in S. kanthianum and G. ferruginea, respectively. Moreover cellulose in V. amygdalina was lowest 41 g/kg DM while F. sycomorus had highest 297 g/kg DM. Indigestible fiber content was lower as plant maturity is not advanced in the wet season. As noted by Gezahegn et al.[24] structural polysaccharides composed primarily of cellulose and hemicelluloses are primary restrictive determinants of nutrient intake and digestibility. Muluken et al. [25] reported that though season has significant effect on the chemical composition parameters of the different species, the degree of its effect varies across the species. The chemical composition was consistent with Belete et al.[25], however the ranges of fiber contents of the browses in the current study were higher than the findings of (Solomon et al.; Aster et al.; Ahmed et al.) [15, 7, 17]. This might be due to difference in stage of maturity, browse species and location.

Chemical composition also varies during the dry season. F. thonningii had lowest (913 g/kg) while G. ferruginea had highest 955 g/kg dry matter content in the dry season. The ash content ranges from 62 g/kg DM in C. edulis to 204 g/kg DM in S. kanthianum which was consistent with Mergia [26]. The ash content of BTSs was higher than the finding of Aster et al. [7]. In both seasons C. edulis had low ash content. The ash content of BTSs was highest in the dry season. This result agreed with Ahmed et al. [17] who reported that ash content was higher in the dry season than in the wet season. As reported by Belete and Hassen [27] variation in ash content is attributed to the differences in stage of maturity, part of the plant included in the analysis, soil type, and climate factors such as temperature and rain fall. OM content was lowest in S. kanthianum and highest in C. edulis 796 g/kg DM and 938 g/kg DM, respectively.

In terms of CP content S. kanthianum has the lowest (96 g/kg DM) and V. amygdalina has the highest (163 g/kg DM). CP content was lower than reported by Mergia (26] in Afar and Borana rangelands and Solomon et al. [15] in northern Ethiopia might be due to type of browse and location. The CP content of BTSs during the dry season were slightly reduced which could be related to stage of maturity of browse species and climatic factors. In addition food reserves translocated from leaves to stems and roots during stress. Muluken et al. [28] attributed such CP variation to response to seasonal variation, root depth, degree of nutrient dilution and resistance to leaching. In this study BTSs except S. kanthianum and C. edulis had greater nutritive value and can be utilized as protein supplements too low to medium production levels to improve utilization of poor natural pastures and crop residues. On the other hand, S. ellipticum and V. amygdalina had CP concentration of more than 150 g/kg DM which is required to support lactation and growth in dry season [22].

NDF content ranges from 579 g/kg DM in F. vasta to 752 g/kg DM in C. africana. The NDF content was higher in the dry season than in the wet season. C. africana had highest NDF content in both seasons which may reduce feed intake. Mergia [26] reported that the variation in the NDF composition of the forages is an indication of variability in species, genotype, soil, climate and the growth phonology of the forages. The ADF content was highest in the dry season. It ranged from 358 g/kg DM in S. kanthianum to 487 g/kg DM in C. africana in the dry season under medium quality. C. africana had higher NDF and ADF content. As reported by Kasale [29] who explained that neutral detergent fiber (NDF) and acid detergent fiber (ADF) are more useful measures of feeding value, and should be used to evaluate forages and formulate rations. ADL content ranges from 167 g/kg DM in P. thonningii to 258 g/kg DM in F. vasta. The ADL content was highest in the dry season. In the dry season fiber fractions are higher may be due to advancement of browse maturity and environmental factors. Boufennara et al. [30] reported high level of fibre content in some of the browse species could explain the environmental conditions, as high temperature and low precipitations tend to increase the cell wall fraction and to decrease the soluble contents of the plants.

Hemi-cellulose was lowest 92 g/kg DM in F. vasta while highest 309 g/kg DM in G. ferruginea. The hemi-cellulose content was higher than reported by Ahmed et al. (17) which might be difference in fiber content. Similarly cellulose content ranges from 168 g/kg DM in G. ferruginea to 279 g/kg DM in P. thonningii. As reported by Okunade et al. (5) the range of cellulose concentration shows that the fodders have the potentials to support intestinal movement, proper rumen function and promote dietary efficiency and as hemicellulose content increase feed value become higher since, it plays a significant role in voluntary intake and digestibility. The chemical composition was in the range reported by Muleta (16) in Daro Labu District except the NDF content.

In vitro dry matter digestibility of browse species

The IVDMD varied between species as shown in Table 3. It showed a variation between 239 g/kg DM in C. edulis to 683 g/kg DM in S. ellipticum. IVDMD values were lower during the dry season but improved in the main rainy season the same trend seen in the Aster et al. [7]. The lower digestibility of browses during the dry season could be the result of advancement in maturity and thus accumulation of cell wall components. As reported by Fadel et al. (26) increase in fibrous fractions at the late period of the dry season reflected a decrease in IVDMD for leaves of fodder trees. As reported by Ahmed et al. [17] the effect of season on the chemical composition and IVDMD of browse species might be due to reduced uptake of essential nutrients from the soil and reduced photosynthetic activities of the plants induced by environmental stress during the dry season. As reported by Naseri [32] over 700, 600 to 700, 400 to 600 and lower than 400 g/kg DM digestibility is considered as good digestibility, moderate digestibility, low digestibility and very poor digestibility, respectively. According to this classification, C. africana, C. edulis and F. sycomorus grouped as very low while V. amygdalina and S. ellipticum have moderate digestibility.

Table 3. *In vitro dry matter digestibility (g/kg DM) of browse species in the wet and dry season*

Browse Species	IVDMD Wet season	IVDMD Dry season
C. africana	349^{h}	261^{i}
F. sycomorus	441^{g}	369^{h}
F. vasta	439^{g}	422^{f}
F. thonningii	499^{d}	412^{g}
V. amygdalina	653^{b}	619^{b}
S. ellipticum	694^{a}	683^{a}
S. kanthianum	469^{f}	441^{e}
G. ferruginea	610^{c}	560^{c}
P. thonningii	494^{e}	463^{d}
C. edulis	283^{i}	239^{j}
SEM	28.21	31.17
P- Value	<.0001	<.0001

IVDMD = in vitro DM digestibility, Means with different letters within column are different at P≤0.05, SEM = standard error of the means

The IVDMD ranged from 282 g/kg DM in C. edulis to 694 g/kg DM in S. ellipticum. In both seasons, the highest IVDMD was recorded in S. ellipticum, whereas the lowest was in C. edulis. Low digestibility might be due to high fiber and liginin while high digestibility due to high CP content in this browses species. The wide range in IVDMD in the browse species is partly a reflection of differences in their chemical composition (Solomon et al.) [15]. The result was lower than reported by (Solomon et al.; Aster et al.; Ahmed et al.) [15, 7,17] . This may be due to high lignifications of browse species and also anti-nutritional factors though not considered in the study. Browse species having low fiber and high in crude protein content has high in vitro digestibility like S. ellipticum and V. amygdalina in both seasons. In vitro dry matter digestibility values were more corresponds with twenty four hour of incubation.

In sacco dry matter degradability of browse species

The in sacco dry matter degradability (DMD) of BTSs were significant (P<0.05) both in the wet and dry season (Table 4). The disappearance of DM increased, with increasing time of incubation except for F. thonningii, S. kanthianum and P. thonningii. The lowest DMD were recorded at 0 hour washing loss and the highest was at 96 hour of incubation. Browse species difference in DMD across incubation hours might be differences in chemical composition of the plant parts used for rumen microbes as reported by Belachew et al.(33) At 0 hour G. ferruginea had lowest 51 g/kg DM while S. kanthianum had highest 290 g/kg DM. At 96 hour C. africana had the lowest (404 g/kg DM) and S. ellipticum had the highest (799 g/kg DM) in sacco dry matter degradability. At all incubation hour's C. africana had lowest DMD except at 0, 6 and 12 hours which might be due to low degradation rate of the insoluble fraction and prolonged lag phase as reported by Aster et al.[7]. S. ellipticum had the highest DMD at 6, 12, 72 and 96 while V. amygdalina at 24, 48 and S. kanthianum at 0 hour. The DMD values measured in this study was lower than Ahmed et al. (17) for browse species in mid Rift Valley of Ethiopia this could be due to low soluble fraction and rate of degradation of the insoluble fraction and high fiber content Aster et al.[7].

Table 4. *In sacco ruminal dry matter degradability (g/kg DM) of browse species during the wet and dry seasons at different rumen incubation hours*

Browse species	Incubation times (in hours)													
	Wet season							Dry season						
	0	6	12	24	48	72	96	0	6	12	24	48	72	96
C. africana	106^{e}	169^{cd}	244^{cd}	289^{d}	3222^{d}	386^{f}	404^{e}	89^{e}	155^{c}	197^{e}	337	313^{d}	389^{c}	482^{fg}
F. sycomorus	116^{e}	179^{cd}	264^{bcd}	404^{c}	528^{bc}	575^{cde}	654^{c}	106de	193^{bc}	253^{cde}	384	549^{b}	577^{ab}	635de
F. vasta	158^{cd}	246^{bc}	319^{bc}	400^{c}	534^{bc}	551de	563^{d}	198^{a}	193^{bc}	278^{bcd}	381	467^{c}	562^{ab}	672^{cd}
F. thonningii	149^{d}	202^{cd}	339^{b}	441^{bc}	645^{ab}	696^{ab}	689^{bc}	119^{cd}	191^{bc}	295^{bc}	432	542^{bc}	638^{a}	753^{b}
V. amygdalina	216^{b}	321^{ab}	454^{a}	668^{a}	704^{a}	722^{ab}	751^{ab}	102de	237^{a}	330^{ab}	469	526^{bc}	622^{a}	767^{ab}
S. ellipticum	288^{a}	374^{a}	470^{a}	629^{a}	693^{a}	731^{a}	799^{a}	198^{a}	267^{a}	377^{a}	555	630^{a}	631^{a}	808^{a}
S. kanthianum	290^{a}	317^{ab}	433^{a}	505^{b}	615^{ab}	585^{cde}	546^{d}	207^{a}	189^{bc}	255^{cde}	482	535^{bc}	566^{ab}	610^{e}
G. ferruginea	51^{f}	102^{d}	216^{d}	492^{b}	644^{ab}	677^{abc}	758^{a}	137^{c}	162^{c}	216de	497	693^{a}	657^{a}	718^{bc}
P. thonningii	184^{c}	209^{c}	278^{bcd}	600^{a}	675^{a}	622^{bcd}	444^{e}	165^{b}	226^{ab}	278^{bcd}	337	359^{d}	398^{c}	434^{g}
C. edulis	132de	255^{bc}	341^{b}	382^{c}	453^{c}	488^{ef}	648^{c}	165^{b}	230^{ab}	257^{cde}	357	386^{d}	458^{bc}	502^{f}
SEM	13.93	17.09	17.79	22.46	24.19	21.64	24.18	7.99	7.27	11.00	21.05	22.25	22.33	23.28
p-value	<.0001	0.0006	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0007	<.0001	*0.2302*	<.0001	0.0081	<.0001

In sacco DMD in the dry season was significant (P<0.05) at all incubation hours except at 24 hour. There was an increasing trend of DM disappearance across the incubation hours in browse species despite the fact that inconsistence were observed on F. vasta and S. kanthianum at 6 hour, C. africana at 48 and G. ferruginea at 72 hours. The highest DMD was recorded at 96 hour this was supported by Belachew et al. [33] who noted that greatest DM disappearance at terminal incubation hours across plant species. At all incubation hour's C. africana was lowest except at 96 hour, for P. thonningii. As reported by Belachew et al. [33]greater NDF and CT concentrations though not evaluated in the plant species might be attributed to lower DM disappearances. At all incubation hours S. ellipticum, had highest in sacco DMD except at 0 h in S. kanthianum, and at 48 and 72 in G. ferruginea. As reported by a possible reason of this effect might be differences in CP and fiber content of the plant used for rumen microbes. In both seasons C. africana had lowest degradability except at 0, 6 and 12 hours while S. kanthianum had the highest degradability at 0 hour, might be due to high soluble fraction content and S. ellipticum at 6, 12, and 96 hours. At 96 hour except for F. sycomorus, G. ferruginea, P. thonningii and C. edulis had higher in sacco DMD in the dry season than in the wet season. Rising temperatures increase lignifications of plant tissues and thus reduce the digestibility and the rates of degradation of plant species [29].

The high to medium dry matter degradability of browse species in the present study suggests that they have great value as livestock feed in the study area in the dry season. The dry matter disappearance was consistent with Belachew et al. [33], however lower than (Aster et al.; Ahmed et al.) [7, 17]. This difference might be associated with the differences in browse species, location and chemical composition. In sacco dry matter degradability indicated it increases as incubation hour increases so that it needs further time of incubation beyond 96 hour this might be due to its high fiber contents of browse species.

In sacco dry matter degradability characteristics

In both dry and wet season, there was significant difference in all in sacco dry matter degradable characteristics except for degradation rate among the browse species (P<0.05) as shown in Table 5. G. ferruginea had lowest soluble fraction (a) (66 g/kg DM) while S. ellipticum highest (278 g/kg DM) in the wet season. The soluble fraction difference might be due to proportion of soluble structural carbohydrates contained in the BTSs. Slowly degradable fraction (b) varied from 305 g/kg DM in C. africana to 774 g/kg DM in G. ferruginea. There was no significant difference between species on degradation rate. Degradation rate (c) ranged from 0.021 to 0.084 in C. edulis and S. kanthianum, respectively. C. africana had lowest (415 g/kg DM) while C. edulis highest 832 g/kg DM potential degradable fraction. Effective degradation ranged from 275 g/kg DM to 571 g/kg DM in C. africana and S. ellipticum, respectively. S. ellipticum had highest in slowly degradable fraction (b) and ED fraction while C. edulis in PD and G. ferruginea in slowly degradable fraction.

Table 4. *In sacco dry matter degradability characteristics (g/kg DM) of browse trees and shrubs during wet and dry seasons*

Browse Species	Degradability characteristics of browse species									
	Wet season					Dry season				
	a	b	c	PD	ED	a	b	c	PD	ED
C. africana	110^{c}	305^{c}	0.044	415^{c}	275^{f}	103^{cd}	486^{bcd}	0.025	589^{cd}	275^{f}
F. sycomorus	107^{c}	590^{ab}	0.028	696^{ab}	381de	99^{cd}	588^{abc}	0.030	686^{bcd}	379^{cd}
F. vasta	155^{bc}	431^{bc}	0.042	586^{bc}	396de	184^{a}	902^{a}	0.010	1085^{a}	378^{cd}
F. thonningii	126^{c}	616^{ab}	0.033	742^{ab}	448^{bc}	126^{bc}	727^{ab}	0.021	853^{abc}	411^{bc}
V. amygdalina	187^{b}	562^{ab}	0.065	749^{ab}	570^{a}	129^{bc}	817^{a}	0.029	946^{ab}	429^{b}
S. ellipticum	278^{a}	528^{bc}	0.043	806^{ab}	571^{a}	182^{a}	610^{abc}	0.039	792^{abc}	493^{a}
S. kanthianum	258^{a}	331^{c}	0.084	589^{bc}	478^{b}	159^{ab}	476^{bcd}	0.032	635^{bcd}	403^{bc}
G. ferruginea	66^{d}	774^{a}	0.034	780^{ab}	416^{cd}	75^{d}	703^{ab}	0.034	778^{abc}	436^{b}
P. thonningii	125^{c}	469^{bc}	0.063	593^{bc}	442^{bc}	171^{a}	248^{d}	0.042	419^{d}	315^{ef}
C. edulis	181^{b}	651^{ab}	0.021	832^{a}	377^{e}	173^{a}	362^{cd}	0.026	535^{cd}	332de
SEM	24.85	45.92	0.006	41.22	28.35	12.35	64.37	0.002	63.21	20.33
P-value	<.0001	0.0097	*0.1074*	0.0326	<.0001	<.0001	0.0079	*0.2636*	0.0180	<.0001

a = soluble fraction that rapidly washed out; b = insoluble but potential degradable by micro-organism; c = degradation rate; PD = potential degradability; ED = effective degradability; Means with different letters within column are different at P≤0.05, SEM= standard error of the means

In both seasons S. ellipticum had high effective degradability followed by V. amygdalina this might be attributed to their high CP and low fiber contents and may also lower levels of anti-nutritional factor. ED of browse species was ranged from low to high as reported by Belachew et al. [33] that ED values of MPTS could be assigned to great (> 450 g/kg DM), medium (400–450 g/kg DM), and low (<400 g/kg DM) quality groups. The degradable characteristics of BTSs were lower than (Solomon et al.; Aster et al.) [15, 7]. The results were also lower than Ahmed et al. [17]

in ED fraction and rate of DM degradation (c) while higher value in rapidly degradable (a), slowly degradable (b) and PD fractions. This might be difference in chemical composition primarily in cell wall content.

In the dry season G. ferruginea has lowest rapidly degradable fraction (a) 75 g/kg DM, P. thonningii lowest in slowly degradable fraction (b) 248 g/kg DM. The rate of degradation was lowest in F. vasta (0.010), lowest PD fraction in P. thonningii (419 g/kg DM) and C. africana in ED fraction (275 g/kg DM). F. vasta has highest (184 g/kg DM) in rapidly soluble fraction (a), in slowly degradable fraction (b) (902 g/kg DM) and in potential degradability (PD) (1085g/kg DM), S. ellipticum in ED (491 g/kg DM) and P. thonningii in degradation rate (0.042) in the dry season. S. ellipticum has high dry matter degradable characteristics which could be attributed to the high CP and low fiber content. On the other hand, C. africana has low in effective degradability due to its high fiber content. The same result was reported by Takele et al. [3] C. africana had low in effective degradability being relatively high in fiber and lignin content. The differences among browse species in degradable characteristics might be partly attributed to the variations in chemical composition (mainly cell wall content). Slowly degradable fraction and potential degradability were higher in the dry season which might be attributed to advancement of plant maturity. The dry matter degradable characteristics measured in this study were within the range reported by Belachew et al. [33] and Takele et al.[3]. It was lower than Solomon et al. [15] in Northern Ethiopia, Aster et al. [7] in Southern Ethiopia and also by Ahmed et al. [17] in mid Rift Valley of Ethiopia for other browse species.

Conclusions

For all studied browse trees/shrubs, potential biomass yield, in vitro digestibility and in sacco degradability values fluctuated with season, but the degree of fluctuation varied with species. Based on the whole evaluated parameters such as estimated biomass yield, chemical compositions, in vitro digestibility and in sacco degradability the evaluated browse trees and shrubs could be used as potential sources of livestock feed mainly during the dry season in Bahir Dar Zuria District, Ethiopia. From this study Carissa edulis had low IVDMD digestibility and Cordia africana low in sacco DMD degradability and high fiber content while Sapium ellipticum had high CP, IVDMD and in sacco DMD degradability and low fiber content. Cordia africana and Carisa edulis has a characteristic of having relatively higher NDF, ADF and lignin contents which may impair digestion and should be supplemented with feed containing lower fiber. With this conclusion, the following recommendation is forwarded. Conserving browses in-season in the form of hay and silage should be practiced for use when there is feed scarcity. Further study on anti-nutritional factors and individual mineral content of browse species is necessary. Feeding trial, especially top quality browse trees/shrubs is important for suggesting efficient utilization of browse species.

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Conflict of interest

The authors declare that they have no conflict of interest

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