Effects of Varieties of Indigenous Bamboos (*Oxytenanthera abyssinica* and *Yushania alpina)*, their Morphological Fractions and Season of Harvest on Chemical Composition, *In Vitro* and *In Sacco* Degradability in Ethiopia

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Abstract: Chemical composition and nutritive values of lowland bamboo (LB) (*Oxytenanthera abyssinica*), red highland bamboo (RHB) and black highland bamboo (BHB) (*Yushania alpina)* varieties (V) harvested during wet and dry seasons were determined in this study. Morphological fractions of the varieties such as leaves, twigs and foliage were evaluatedo for the purpose. The chemical compositions were determined according to the standard procedures. IVDMD was determine using two-stage rumen inoculum-pepsin method. *In sacco* N degradability were evaluated by the nylon bag technique using three ruminally fistulated Boran x Holstein Friesian steers. The result of the study revealed that leaves collected from RHB had significantly (P<0.001) higher CP content (209 g/kg DM) than twigs and foliage of other two verities of bamboo. Significantly (P<0.001) higher NDF and ADF contents were recorded for highland bamboo varieties in the dry season which can be implicated for lower ME in the variety. Among the MF, only twig consisted smallest CP content (62 g/kg DM). Leaf collected from LB had significantly (P<0.001) higher IVDMD (447 g/kg) than the leaf of HB varieties (338 and 344 g/kg). The LB leaves and foliages harvested in the wet season had significantly (P<0.001) higher N degradability (69.9-88.3 g/kg DM) than the HB varieties. Likewise, the rapidly soluble, slowly degradable and effective degradability fractions of N were higher in LB leaves and foliages harvested in the wet season than in the leaf of HB varieties. The results of this study suggested the existence of variation on chemical composition and degradability among bamboo verities, morphological fractions and harvesting seasons. It was recommended that these variations among the component of the plant need to be considered for appropriate utilization of bamboo plants as a feed resource for ruminant.

Keywords: *Chemical composition, Indigenous bamboos, Nutritive value, Northwest Ethiopia, Season*

Introduction

The livestock feed shortage in Ethiopia is becoming more critical over the years. One of the current strategies to cope up with the feed crisis in many parts of the world is the efficient use of local feed resources (Alonso-Díaz *et al*., 2010) and the application of feed treatments. In this regard, bamboo is among the indigenous plants that can be used as an alternative feed resource in bamboo growing parts of Ethiopia. The lowland bamboo (*Oxytenanthera abyssinica*) and highland bamboo (*Yushania alpina*) species are widely grown in northwestern Ethiopia as a natural forest or backyard crop, and serve multifarious functions including as a source of fodder for livestock (Denbeshu, 2010; Yeshambel *et al*., 2011).

Previous reports indicated that the area coverage of bamboo in Ethiopia and the number of people who got access to these resources increased over the years and is expected to further increase (Boissière *et al*., 2019). This is attributed to the increased demand for local use such as for construction, handicrafts and furniture as well as the emerging industrial use of bamboo for purposes such as bamboo-based board for flooring and modern furniture. More than 52, 017 tons of fodder biomass can be harvested from forest bamboo in Ethiopia (Boissière *et al*., 2019), which makes it a very promising source of feed for ruminants. Surveys made by Denbeshu (2010) in Sidama Zone, southern Ethiopia and Yeshambel *et al*. (2011) in northwestern Ethiopia confirmed that bamboo can be an important source of livestock feed, especially during the long dry season. Moreover, Teklu *et al*. (2010) reported that farmers in the Assosa Zone, southwestern Ethiopia, use lowland bamboo as the main browse fodder to supplement donkeys and oxen using a cut and carry feeding system. Similarly, bamboo leaves and twigs are favorite feeds for elephants and pandas (Joshi and Singh, 2008) in other parts of the world. However, the rational use of bamboo as fodder for farm animals requires knowledge of its nutritive value.

The nutritive value of any fodder depends on its nutrient content, intake and degradability (Julier *et al.,* 2001). Moreover, plant species and/or varieties, plant morphological fractions, the season of the year and

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stage of maturity of the plant affect fodder nutritive values (Papachristou and Papanastasis, 1994). Previous studies in other countries (Yayota *et al*., 2009; Sahoo *et al*., 2010) noted that chemical composition, *in vitro* dry matter digestibility and *in sacco* nutrients degradability were significantly influenced by bamboo variety and season of forage sampling. However, such information has not been documented in Ethiopia to the knowledge of author(s). Therefore, the present study was undertaken to evaluate the effect of bamboo varieties, morphological fractions and seasons of harvest on chemical composition, *in vitro* and *in sacco* degradability of indigenous bamboo varieties grown in northwestern Ethiopia.

Materials and Methods

Study Areas

Samples of highland and lowland bamboos were collected from Awi and Metekel Zones, respectively of northwestern Ethiopia. Awi Zone is a high rainfall area with a bimodal annual rainfall ranging 1200-2000 mm. The short and long rainy season falls in February to March and June to September, respectively, followed by an extended dry season from October to February. The monthly temperature ranges from 17 to 27°C. The Awi Zone is located within a latitude and longitude of 10.95°N and 36.5°E and lies at an altitude range of 1800-3100 meters above sea level (AZARDO, 2008). Metekel Zone is situated within altitude ranges of 550-2500 meters above sea level. The average monthly temperature ranges between 20 to25°C. Metekel Zone is located at a latitude of 11º 12' N and longitude of 36º 20' E. It has a unimodal rainfall pattern; with a long rainy season from June to September. The amount of annual rainfall ranges from 500 to 1800 mm (MZARDO, 2007).

Forage Sampling

The edible morphological fractions (MF; foliages, leaves and twigs) from 1-3 years old lowland bamboo (*Oxytenanthera abyssinica)*, two varieties of highland bamboos (*Yushania alpina*), i.e., black (BHB) and red (RHB) were harvested in wet (July 2009–August 2009), and dry (January 2010–February 2010) seasons (S). From each Zone, four forage sampling locations were selected purposively based on bamboo availability and accessibility. At each location, three bamboo culms per variety were taken purposively based on the required age (1-3 years). Samples of the three bamboo varieties (V) were collected from backyard plantations. The selected culms were labeled and used as a forage sampling unit. Thus, a total of 36 bamboo culms, 12 for each variety, were used as a sample unit. Forage samples for chemical composition and nutritive value analysis were taken from the bottom, top and middle parts of the bamboo culms using plant pruning scissors. The forage harvested from the three culms at each location were bulked, thoroughly mixed and divided into two equal parts. One part was fractionated into leaf and twig and the other one part represented the foliage (both leaf and twig together) fraction. Forage samples were sun-dried under shade to reduce the moisture content to avoid mold growth on the samples and finally, samples were transported to Haramaya University Animal Nutrition Laboratory. Forage samples were dried at 60ºC for 72 hours and divided into two. One portion was ground to pass through 1 mm sieve size for determination of chemical composition and *in vitro* dry matter (DM) digestibility (IVDMD). The other portion was ground to pass through 2 mm sieve size for determination of *in sacco* nitrogen (N) degradability. The ground samples were kept in a plastic bottle pending analysis.

Chemical Analysis

The determination of DM (index no. 934.01), organic matter (OM; index no. 942.05), ether extract (EE) and N contents were determined according to the standard procedure of AOAC (1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin were analyzed according to the procedure of Van Soest and Robertson (1985). Sulfite and amylase were not used as reagents in the determination of NDF. N was determined by Kjeldhal procedure and Crude protein (CP) was calculated as N*6.25. Hemicellulose (HC) and cellulose (C) contents were calculated as NDF minus ADF and ADF minus lignin, respectively. The metabolizable energy (ME) was estimated according to the formula recommended by MAFF (1975) as ME (MJ/kg DM) = 0.16DOMD (g/kg DM); and DOMD = 0.98DMD (g/kg) −4.8; where DOMD is the digestible organic matter in dry matter and DMD is the dry matter degradability (g/kg).

In Vitro Dry Matter Digestibility

The two-stage rumen inoculum-pepsin method of Tilley and Terry (1963) was used to determine IVDMD. Rumen liquor was collected from three ruminally fistulated Boran x Holstein Friesian steers and transported to the laboratory using thermos flasks that had been pre-warmed to 39ºC. Rumen liquor was taken in the morning before animals were offered feed. These animals were under maintenance level of feeding and they were given with native grass hay (6% CP) and 2 kg of concentrate mixture of wheat bran and noug (*Guzotia abyssinica*) seed cake. A duplicate sample of 0.5 g of each MF was incubated with 30 ml of rumen liquor in 100 ml test tube in a water bath at 39°C for a period of 48 h for microbial digestion followed by another 48 h for enzyme digestion with acid pepsin solution. Blank samples containing buffered rumen fluid only were also incubated in duplicates for adjustment. Drying of samples residues was done at 105°C overnight.

In Sacco N Degradability

The ruminal *in sacco* N degradability of samples was determined by incubating 3 g of dried forage samples in nylon bags (41 μm pore size and 6.5 x 14 cm dimension) in three rumen-fistulated Boran x Holstein-

Friesian steers for 6, 12, 24, 48, 72 and 96 hours. These steers were individually penned, kept under maintenance ration and had free access to water and common salt. Upon the removal of nylon bags at the end of each incubation hour, all bags were washed manually under running tap water until the water was clean, gently squeezed to remove excess water, and dried at 60°C for 48 h in a forced draft oven. To determine washing loss (0-h disappearance), two bags containing 3 g of each test feed were soaked in tap water for half an hour and underwent the same washing and drying procedures as the incubated bags. The N contents were determined in the original samples as well as in the residues according to standard procedure (AOAC, 1990). The degradability of N(ND) was determined for each incubation time using the following formula: ND (g/kg DM) = (N in forage sample-N in residue)/N in forage.

The ND data were fitted to the exponential equation $p= a+b\ (1\text{-}e^{-ct})$ as described by Ørskov and McDonald (1979), using the Neway Excel program (Chen, 1995), where p is ND (g/kg DM) at time t. The lag time was estimated according to McDonald (1981) by fitting the model $p= A$ for $t<t_0$; $p = a + b(1\text{-}e^{-ct})$ for $t > t_0$ and the degradation characteristics of the bamboo fractions were defined as Aas washing loss (readily soluble fraction); $B = (a + b)\text{-}A$, representing the insoluble but fermentable material; c = the rate of degradation of B (/h) and the lag phase (L) = $(1/c)\ \log_e\ [b/(a+b\text{-}A)]$ (Ørskov and Ryle, 1990). Potential degradability (PD)was estimated as$(A + B)$, while effective degradability (ED) of N (EDN) was calculated using the formula $ED = A + [(B*c) / (c+k)]$ where A, B and C are as described above and k is rumen outflow rate which is assumed to be 0.03/h for roughage feeds(Ørskov and McDonald, 1979).

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS) software, version 9.1.3 (SAS, 2002) with the model consisting of V, MF, S and their interactions. The least significant difference test was employed for pair-wise comparison of means when the P-value of main effects and their interaction were significant ($P < 0.05$).

The statistical model used was:

$$Y_{ijk} = \mu + V_i + MF_j + S_k + (V*MF)_{ij} + (V*S)_{ik} + (MF*S)_{jk} + (V*MF*S)_{ijk} + \varepsilon_{ijk}$$

where: Y_{ijk} is the observation, μ is the overall mean, V_i is bamboo variety (i =1–3), MF_j is the effect of morphological fraction (j =1–3), S_k is the season effect (k=1-2) and $(V*MF*S)_{ijk}$ is the interaction between bamboo variety, morphological fractions and season and ε_{ijk} is the residual error.

Results

Chemical Composition

A Significant ($P<0.001$) three factors interaction of variety, morphological fraction and the season was noted only for OM content of bamboo (Table1). The BHB foliage and RHB twig harvested in the dry season had significantly ($P<0.001$) higher OM than most of the other combinations. The V*MF interaction was significant ($P<0.001$) for DM and CP. The DM content of MF varies for the two highland varieties and was in the order of twig > foliage > leaf but DM values for MF were similar for LB. The CP content of MF was in the order of leaf > foliage > twig for all bamboo varieties. However, the CP content of the leaf was highest for RHB, followed by BHB and was lowest for LB. The V*S interaction was significant ($P < 0.05$) for DM, NDF, ADF and ME and showed that the DM, NDF and ADF contents for all the varieties were greater in the dry than the wet season, while ME was in the reverse.

Generally, the NDF and ADF contents were greater and that of ME was lower for the highland varieties than the LB. Significant MF*S interaction ($P<0.001$) was noted for all chemical composition parameters, except for DM. In general, the CP and ME contents were greater and that of NDF and ADF contents were lower in the wet than the dry seasons for all the MF. The ME contents of the MF were also in the order of leaf > foliage > twig. On average, twig consisted of a CP value of 62 g/kg DM.

In Vitro Dry Matter Digestibility

Three-way (V*MF*S) and two-way (MF*S) interactions were not significant ($P> 0.05$) for IVDMD. However, significant V*MF ($P<0.01$) and V*S ($P<0.001$) interactions were observed (Table 1). For all the bamboo varieties, IVDMD was in the order of leaf > foliage > twig, and for each MF values for LB were greater than the two highland bamboo varieties. Similarly, for all the three bamboo varieties, samples of the wet season had greater ($P<0.001$) IVDMD than that of the dry season.

In Sacco Nitrogen Degradability

The ruminal ND and its degradability characteristics of bamboo varieties are presented in Table 2. Three-factor interaction (V*MF*S) was observed for NDat 6, 12, 24 and 48 hours of incubation. Generally, the leaf and foliage fraction of LB had greater ruminal ND than the other two highland varieties. Moreover, the twig had lower ND than the other two MF and the wet season samples were superior in ND than the dry season ones at 6, 12, 24 and 48 incubation hours. Two-way interactions for V*MF and V*S were significant ($P < 0.01$) for 72 and 96 incubation hours of ND. Both highland bamboo varieties had a lower leaf and foliage ND than LB at both 72 and 96 hours incubation time, while twig ND appeared to be similar among the three varieties. In general, twigs had lower ND than other MF, while leaf and foliage had similar ND at 72 and 96 hours of incubation. The wet season samples were superior in 72 and 96 incubation hours ND than the dry season samples.

Table 1. Effects of variety, morphological fractions, season and their interaction on chemical composition and IVDMD of bamboo

Factors			DM	OM	CP	NDF	ADF	Lignin	C	HC	ME	IVDMD
V*MF												
	LB	Foliage	376^{cd}	826^{e}	131^{d}	638	416	76	340	222	5.8	387^{b}
		Leaf	379^{c}	821^{e}	149^{c}	606	377	59	318	229	6.7	447^{a}
		Twig	369^{cd}	884^{bc}	46^{f}	698	516	112	404	182	3.7	287de
	BHB	Foliage	421^{b}	893^{ab}	146^{c}	620	408	99	309	212	4.1	309^{d}
		Leaf	362^{d}	879^{c}	178^{b}	608	378	77	301	230	4.6	338^{c}
		Twig	494^{a}	897^{a}	67^{e}	693	489	129	360	204	2.2	151^{f}
	RHB	Foliage	414^{b}	887^{abc}	152^{c}	626	405	89	316	221	4.0	269^{e}
		Leaf	383^{c}	868^{d}	209^{a}	589	369	76	293	220	4.8	344^{c}
		Twig	481^{a}	897^{a}	73^{e}	658	479	131	348	179	2.5	153^{f}
	SEM		5.9	0.37	0.38	1.04	0.76	0.36	0.78	1.00	0.17	0.80
	Significance		***	***	***	NS	NS	NS	NS	NS	NS	**
V*S												
	LB	Wet	378^{d}	864^{c}	133	549^{c}	359^{c}	65	294^{b}	190	6.5^{a}	413^{a}
		Dry	372^{d}	823^{d}	84	746^{b}	513^{b}	99	414^{a}	233	4.3^{b}	334^{b}
	BHB	Wet	420^{bc}	891^{a}	149	486^{d}	302^{d}	82	220^{c}	184	4.5^{b}	295^{c}
		Dry	432^{ab}	889^{a}	111	795^{a}	549^{a}	122	427^{a}	246	2.7^{c}	237^{e}
	RHB	Wet	417^{c}	889^{a}	166	467^{d}	301^{d}	79	222^{c}	166	4.5^{b}	257^{d}
		Dry	435^{a}	878^{b}	124	782^{a}	534^{a}	119	415^{a}	248	3.1^{c}	253de
	SEM		4.8	0.30	0.32	0.85	0.62	0.29	0.63	0.82	0.14	0.65
	Significance		*	***	NS	***	***	NS	***	NS	*	***
MF*S												
	Foliage	Wet	402	878^{b}	167^{b}	487^{e}	316^{e}	70^{d}	246de	171^{c}	5.6^{b}	337
		Dry	405	859^{c}	119^{d}	768^{b}	504^{b}	106^{b}	398^{b}	264^{a}	3.7^{d}	306
	Leaf	Wet	370	877^{b}	213^{a}	479^{d}	293^{e}	57^{e}	236^{e}	186^{bc}	6.6^{a}	404
		Dry	379	835^{d}	145^{c}	723^{c}	457^{c}	85^{c}	372^{c}	266^{a}	4.2^{c}	349
	Twig	Wet	442	889^{a}	68^{e}	535^{d}	355^{d}	99^{b}	256^{d}	180^{bc}	3.4^{d}	225
		Dry	454	896^{a}	56^{f}	831^{a}	635^{a}	149^{a}	486^{a}	196^{b}	2.2^{e}	169
	SEM		4.8	0.30	0.32	0.85	0.62	0.29	0.63	0.82	0.14	0.65
	Significance		NS	***	***	*	***	***	***	***	**	NS

Table 1 continued

Factors	DM	OM	CP	NDF	ADF	Lignin	C	HC	ME	IVDMD
V										
LB	374[b]	843[b]	108[c]	647[a]	436[a]	82[b]	354[a]	211	5.4 [a]	374[a]
BHB	425[a]	890[a]	130[b]	640[ab]	425[ab]	102[a]	323[b]	215	3.6[b]	266[b]
RHB	426[a]	884[a]	145[a]	624[b]	418[b]	99[a]	319[b]	206	3.8[b]	255[b]
SEM	3.4	0.21	0.22	0.60	0.44	0.20	0.45	0.58	0.10	0.46
Significance	***	***	***	*	*	***	***	NS	***	***
MF										
Foliage	403[b]	869[b]	143[b]	628[b]	409[b]	88[b]	321[b]	219[a]	4.7[b]	322[b]
Leaf	374[c]	856[c]	178[a]	601[c]	374[c]	71[c]	303[c]	227[a]	5.4[a]	376[a]
Twig	448[a]	893[a]	62[c]	683[a]	495[a]	124[a]	371[a]	188[b]	2.8[c]	197[c]
SEM	3.4	0.21	0.22	0.60	0.44	0.20	0.45	0.58	0.10	0.46
Significance	***	***	***	***	***	***	***	***	***	***
S										
Wet	404[b]	881[a]	149[a]	501[b]	321[b]	75[b]	246[b]	180[b]	5.2[a]	322[a]
Dry	412[a]	863[b]	106[b]	774[a]	532[a]	114[a]	418[a]	242[a]	3.4[b]	275[b]
SEM	2.8	0.17	0.18	0.49	0.36	0.17	0.37	0.47	0.08	0.38
Significance	*	***	***	***	***	***	***	***	***	***
Three factors interaction effect										
V*MF*S	NS	***	NS	NS	NS	NS	NS	NS	NS	NS

*[a-f]Mean values with different superscripts in a column are significantly different; ***= P<0.001; **= P<0.01; *= P<0.05; NS= Not significant; LB= Lowland bamboo; BHB= Black highland bamboo; RHB= Red highland bamboo; V= Variety; MF= Morphological fraction; S= Season; DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral detergent fiber; ADF= Acid detergent fiber; C= Cellulose; HC= Hemicelluloses; ME= Metabolisable energy; IVDMD= In vitro DM digestibility; SEM= Standard error of the mean.*

Table 2. Effects of variety, morphological fractions, season and their interaction on *in sacco* nitrogen degradability (g/kg DM) of bamboo

Factors			6	12	24	48	72	96	*A*	*B*	PD	*c*/h	*L* (h)	ED
V*MF														
	LB	Foliage	56.2^{a}	58.6^{a}	64.9^{a}	76.8^{a}	75.4^{a}	74.1^{a}	48.8^{a}	28.3	77.1^{a}	0.062	1.90	65.1^{a}
		Leaf	57.3^{a}	57.8^{a}	64.3^{a}	80.2^{a}	75.7^{a}	71.5^{ab}	50.7^{a}	26.7	77.4^{a}	0.052	1.60	65.3^{a}
		Twig	31.5^{f}	35.5^{d}	40.0^{e}	50.9^{d}	46.1^{e}	39.5^{g}	26.2^{e}	19.0	45.2^{f}	0.170	3.38	38.9^{e}
	BHB	Foliage	41.0^{d}	46.7^{b}	54.7^{b}	66.9^{b}	62.1^{bc}	57.1^{de}	36.1^{c}	26.1	62.2^{cd}	0.080	3.78	52.5^{c}
		Leaf	45.6^{b}	49.9^{b}	54.2^{bc}	67.7^{b}	62.1^{bc}	58.2^{de}	39.5^{b}	22.9	62.4^{c}	0.067	1.88	54.2^{bc}
		Twig	36.3^{e}	42.4^{c}	49.4^{cd}	56.5^{c}	53.4^{de}	49.0^{f}	30.7^{d}	22.2	52.9^{e}	0.110	3.86	45.9^{d}
	RHB	Foliage	42.6^{cd}	48.5^{b}	57.8^{b}	69.4^{b}	64.2^{b}	61.8^{cd}	35.8^{c}	30.4	66.2^{bc}	0.067	3.43	54.4^{bc}
		Leaf	43.5^{c}	50.1^{b}	58.6^{b}	69.0^{b}	69.4^{ab}	65.8^{bc}	35.8^{c}	34.9	70.7^{b}	0.06	1.52	56.6^{b}
		Twig	34.7^{e}	41.9^{c}	46.7^{d}	57.3^{c}	55.7^{cd}	53.1^{ef}	29.3^{de}	26.7	56.0^{de}	0.095	3.63	45.9^{d}
	SEM		0.45	0.82	1.10	1.00	1.63	1.53	0.69	1.36	1.36	0.03	0.53	0.58
	Significance		***	***	***	***	**	***	***	NS	***	NS	NS	***
V*S														
	LB	Wet	57.1^{a}	59.4^{a}	69.3^{a}	79.4^{a}	78.2^{a}	73.4^{a}	48.8^{a}	29.3	78.1^{a}	0.072	1.82	66.9^{a}
		Dry	39.7^{c}	41.8^{c}	43.5^{d}	59.4^{c}	53.1^{d}	49.9^{e}	34.9^{bc}	20.0	54.9^{d}	0.117	2.77	46.1^{d}
	BHB	Wet	44.2^{b}	49.9^{b}	56.6^{b}	67.4^{b}	61.8^{c}	58.6^{c}	37.4^{b}	25.1	62.5^{c}	0.094	2.71	54.2^{c}
		Dry	37.8^{d}	42.7^{c}	49.0^{c}	60.0^{c}	56.6^{cd}	51.0^{de}	33.3^{c}	22.6	55.9^{d}	0.074	3.64	47.5^{d}
	RHB	Wet	44.6^{b}	51.7^{b}	59.0^{b}	69.3^{b}	68.0^{b}	64.6^{b}	37.1^{b}	31.5	68.6^{b}	0.082	2.05	56.6^{b}
		Dry	36.0^{e}	42.1^{c}	49.4^{c}	61.1^{c}	58.2^{cd}	55.8^{cd}	30.2^{d}	29.8	60.0^{cd}	0.065	3.00	47.8^{d}
	SEM		0.37	0.67	0.86	0.82	1.33	1.25	0.56	1.11	1.11	0.02	0.43	0.47
	Significance		***	***	***	***	***	**	***	NS	***	NS	NS	***
MF x S														
	Foliage	Wet	53.3^{a}	57.4	68.2	76.0	72.5	72.0	45.8^{a}	28.6	74.4	0.075	2.15	63.8
		Dry	39.8^{c}	45.0	50.2	66.2	62.1	56.6	34.6^{c}	27.8	62.4	0.063	3.25	50.9
	Leaf	Wet	53.9^{a}	57.4	64.6	78.2	76.6	73.0	46.4^{a}	31.2	77.6	0.052	1.22	64.6
		Dry	43.8^{b}	47.7	53.4	66.1	61.4	57.4	37.6^{b}	25.3	62.9	0.067	2.11	52.8
	Twig	Wet	38.7^{c}	45.9	52.3	61.8	58.9	51.7	31.0^{d}	26.1	57.1	0.121	3.21	49.3
		Dry	29.8^{d}	33.9	38.6	48.0	44.6	42.7	26.4^{e}	19.4	45.8	0.127	4.04	37.9
	SEM		0.37	0.67	0.86	0.82	1.33	1.25	0.56	1.11	1.11	0.02	0.43	0.47
	Significance		**	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS

Table 2 continued

Factors	6	12	24	48	72	96	*A*	*B*	PD	*c*/h	*L* (h)	ED
V												
LB	48.5^{a}	50.6^{a}	56.5^{a}	69.3^{a}	65.8^{a}	61.8^{a}	41.9^{a}	24.8^{b}	66.7^{a}	0.094	2.3	56.5^{a}
BHB	41.0^{b}	46.2^{b}	52.8^{b}	63.7^{b}	59.2^{b}	54.9^{b}	35.5^{b}	23.7^{b}	59.2^{b}	0.084	3.2	50.9^{b}
RHB	40.3^{b}	46.9^{b}	54.2^{ab}	65.3^{b}	63.2^{ab}	60.2^{a}	33.8^{b}	30.7^{a}	64.5^{a}	0.074	2.5	52.3^{b}
SEM	0.26	0.47	0.61	0.58	0.94	0.88	0.39	0.78	0.78	0.02	0.30	0.33
Significance	***	**	*	**	*	**	***	***	***	NS	NS	***
MF												
Foliage	46.6^{b}	51.4^{a}	59.0^{a}	71.0^{a}	67.4^{a}	64.3^{a}	40.3^{a}	28.3^{a}	68.6^{a}	0.070^{b}	2.7^{b}	57.3^{a}
Leaf	48.8^{a}	52.5^{a}	59.0^{a}	72.3^{a}	69.1^{a}	65.1^{a}	42.1^{a}	28.2^{a}	70.3^{a}	0.059^{b}	1.7^{c}	58.7^{b}
Twig	34.2^{c}	39.8^{b}	45.4^{b}	54.9^{b}	51.8^{b}	47.2^{b}	28.6^{b}	22.7^{b}	51.3^{b}	0.123^{a}	3.6^{a}	43.5^{c}
SEM	0.26	0.47	0.61	0.58	0.94	0.88	0.39	0.78	0.78	0.02	0.30	0.33
Significance	***	***	***	***	***	***	***	**	***	*	***	***
S												
Wet	48.6^{a}	53.6^{a}	61.8^{a}	72.2^{a}	69.3^{a}	65.4^{a}	41.1^{a}	28.6^{a}	69.7^{a}	0.082	2.2^{b}	59.4^{a}
Dry	37.8^{b}	42.2^{b}	47.4^{b}	60.2^{b}	56.2^{b}	52.3^{b}	32.8^{b}	24.2^{b}	57.0^{b}	0.086	3.1^{a}	47.2^{b}
SEM	0.21	0.39	0.49	0.47	0.77	0.72	0.32	0.64	0.64	0.010	0.25	0.27
Significance	***	***	***	***	***	***	***	**	***	NS	*	***
Three factors interaction effect												
V*MF*S	***	***	***	***	NS	NS	*	NS	NS	*	NS	***

*$^{a-g}$Mean values with different superscripts in a column are significantly different; ***= P<0.001; **= P<0.01; *= P<0.05; NS= Not significant; LB= Lowland bamboo; BHB= Black highland bamboo; RHB= Red highland bamboo; V= Variety; MF= Morphological fraction; S= Season; SEM= Standard error of the mean; A= Rapidly soluble fraction; B = Slowly degradable fraction; PD= Potential degradability; c = Degradation rate; L= Lag time, ED= Effective degradability.*

Three-factor (V*MF*S) interaction ($P < 0.05$) was noted for ND parameters of *A*, *c* and ED (Table 2). The rapidly soluble (*A*) and effective degradable (ED) fractions were higher for LB leaf and foliage than the two highland varieties and were similar among varieties for the twig. The *A* and ED were lower for the twig fraction and were similar for the other two morphological fractions. Generally, the wet season samples had a greater *A* and ED than the dry season samples. The dry season twig samples had the highest *c* while other means were similar among each other. A two-way interaction of V*MF and V*S was apparent ($P < 0.001$) for PD. The PD of leaf and foliage fractions was greater and that of the twig was lower for LB than the highland bamboo varieties. For each variety leaf and foliage had greater PD than the twig fraction. Moreover, for each variety, PD values for the wet season were greater than the ones for the dry season. The *B* values for ND were affected by the main effects of variety and MF being in the order of RHB > BHB = LB for variety and twig < foliage = leaf for MF. The value for *L* was highest for twig, intermediate for foliage and lowest for leaf.

Discussion

The mean DM content recorded for bamboo species in the present study was consistent with that reported in a previous study (Denbeshu, 2010). The higher DM contents recorded during the dry season could be attributed to the reduced photosynthetic activity due to the lower moisture levels in the dry season relative to wet season. The lower CP content of LB as compared to HB varieties in the present study is not consistent with previous works (Denbeshu, 2010; Eyob, 2010; Teklu *et al.,* 2010) who reported lower CP content for HB (130 g/kg DM) than LB (170 to 205 g/kg DM). The discrepancy between the studies might be related to the differences in elements of the environment, stage of maturity at harvest, the variety of HB, leaf sampling style from the culm, the season of sampling and growing conditions. Denbeshu (2010) noted decreased CP and ME contents of HB grown in southern Ethiopia with decreasing altitude, indicating that the altitude at which the bamboo is grown affects its chemical composition. The CP content of LB leaf and foliage fractions harvested in the wet season and RHB and BHB leaf and foliage fractions harvested in the dry and wet season are above the 150 g/kg DM CP level required for lactation and growing cattle (Norton, 1994), indicating the potential of the indigenous bamboos as a feed resource to mitigate critical protein shortage during the dry season. However, the CP content of bamboo twig (46-73g/kg DM) is below the maintenance requirement for ruminants, which is below the critical protein requirement level (8%) for ruminants indicating that animals cannot be maintained only on twigs, but comparable with 50 g/kg DM reported for cactus pear (*Opuntia ficus-indica*) (Firew *et al*., 2006). In general, dry season CP content of the bamboo varieties was higher than that recorded for natural pasture grass hay and cereal crop residues (Lamrot *et al*., 2018; Degitu *et al*., 2019). The high CP content (> 8%) of bamboo varieties leaf and foliage in the dry season could be an indication of good nutritive value of the plant materials in the season when there is a critical shortage of feeds and when the major feed resources in the tropics are insufficient to satisfy the protein requirement of ruminants and other herbivores.

Xi *et al.* (2007) noted the presence of significant differences in chemical compositions among bamboo MF (stems, twigs and leaf) which is consistent with the present study. The higher CP and lower fiber (NDF, ADF and lignin) contents recorded in leaf compared to other morphological fractions of bamboo in the present study is consistent with previous studies on other plant species, such as *Sesbania sesban*, enset (*Ensete ventricosum*) and maize (*Zea mays*) (Adugna and Sundstøl, 1999; Ajebu *et al*., 2008; Etana *et al*., 2011).

Among bamboo varieties, LB had higher ME than the HB varieties. The estimated ME values of leaf and foliage of LB harvested in the wet season is above the maintenance requirement range of 3.7-4.1 MJ/day estimated for a 20 kg lamb (ARC, 1980) and would support adequate growth, while all MF of LB harvested in the dry season and leaf and foliage of HB harvested in both seasons are also within the recommended range to meet the maintenance requirement. However, estimated ME values of BHB and RHB twigs harvested in the dry season are below that required for maintenance.

In the present study, wet season harvested forage had high CP and ME. In agreement with the present study, seasonal variations in chemical compositions among bamboo varieties were observed in previous studies (Negi *et al*., 1980; Embaye *et al*., 2005; Yayota *et al*., 2009; Denbeshu, 2010; Halvorson *et al*., 2011). Similarly, Yayneshet *et al.* (2009) reported higher CP and ME for browse and grass species harvested in the wet than the dry season. On the other hand, Greenway *et al.* (1999) failed to detect a pronounced seasonal change in chemical composition among three temperate bamboo species. The lower CP contents during the dry season might have been largely due to moisture stress experienced by the bamboo plants during this period and the build-up of lignocellulosic structures and the dilution of nitrogen.

The NDF and ADF contents of LB leaf reported by Teklu *et al.* (2010) were lower than the fiber contents of LB leaf recorded in the current study. This could be attributed to differences in sampling location, stage of maturity at harvest and harvesting season. The fiber contents of the three bamboo varieties were comparable to the fiber contents of the major feed resources such as natural pasture hay and crop residues used for livestock production in the country (Fentie and Solomon, 2008; Solomon *et al*., 2008). It was noted that the threshold level of NDF in tropical grass beyond which DM intake of ruminants be affected is 600 g/kg DM (Meissner *et al.,* 1991). In the present study, MF harvested in the wet season from the three

bamboo varieties consisted of almost comparable NDF value to the threshold level, which also demands feed treatment technologies. However, this feed resource could not allow high intake and might be insufficient for finishing ruminants since the fiber content was above the range (150-200 g/kg DM) required for fattening (Buxton, 1996). The fiber content recorded in the dry season in bamboo MF were higher than values reported for natural pasture hay and crop residues (Andualem *et al*., 2015), but comparable to that from pseudostem and corm morphological fractions of *Ensete ventricosum* (Ajebu *et al.,* 2008) and different morphological fractions of maize stover (Adugna and Sundstøl, 1999).

The present study revealed that lowland bamboo recorded higher IVDMD than the highland bamboo varieties, which is in agreement with the previous studies (Denbeshu, 2010; Teklu *et al*., 2010). Similarly, Datt *et al*. (2006) and Sahoo *et al*. (2010) noted differences in IVDMD between different bamboo varieties/cultivars. Farmers in Ethiopia who used bamboo foliage as animal feed have the perception that the lowland bamboo was more digestible than highland bamboos (Yeshambel *et al*., 2011), which is consistent with the laboratory result of the current and previous findings (Denbeshu, 2010; Teklu *et al*., 2010).

Among MF of bamboo, the leaf had the highest, twig the lowest and foliage was intermediate in IVDMD. This finding is consistent with the report by Xi *et al*. (2007) in other parts of the world. The highest IVDMD value observed in the present study is relatively lower than IVDMD values of bamboo leaf reported in other literature (Wood *et al*., 2001; Denbeshu, 2010; Teklu *et al*., 2010), but higher than the 390 g/kg and 417 g/kg reported by Datt *et al*. (2006) and Negi *et al*. (1980), respectively. This might be because of the age of bamboo from which the forage sample was harvested, varietal differences and environmental conditions. The IVDMD of LB leaf was comparable with the IVDMD values of barley, *tef*, wheat straws and natural pasture grass hay (Solomon *et al.,* 2003; Ameha, 2006; Solomon *et al*., 2008), whereas the IVDMD of highland bamboo varieties morphological fractions were comparable to IVDMD of wheat and barley stubbles (Solomon *et al*., 2008).

The present study revealed that the bamboo forage harvested in the wet season had superior IVDMD than the dry season harvested foliages. In agreement with the current result, Denbeshu (2010) noted that the IVOMD of the highland bamboo leaf was influenced by season and the wet season harvested leaf had superior IVOMD than the dry season ones. However, Ando *et al*. (2005) reported that the *in vitro* digestibility of *Sasa nipponica* bamboo species did not change with the season. Although wet season harvesting increased IVDMD of bamboo foliage, the highest IVDMD value obtained in this study was below the critical value of 550 g/kg, which is known to affect feed intake and digestibility as describe by Standing Committee on Agriculture (SCA, 1990). The low IVDMD in all bamboo varieties studied could be attributed to its higher indigestible fiber components, although its NDF value in the wet season sample was within the acceptable range. It is reported that tree foliages with low NDF content (200-350 g/kg DM) are usually of high digestibility (Norton, 1994). Generally, foliage samples collected in the wet season showed significantly higher nutritive value than the dry season because bamboo foliages were in their growing stage and nutrient absorbability increases in the wet season.

The DM and N degradability of the three bamboo morphological fractions harvested in the dry season were lower compared to fractions harvested in the wet season. Yayota *et al*. (2009) also noted seasonal variation in ruminal DM and CP degradability of dwarf bamboo (*Pleioblastus argenteostriatus* f. *glaber)* in the rumen of fistulated Suffolk ewes in Japan. Denbeshu (2010) also noted the existence of seasonal variation *in vitro* organic matter digestibility of highland bamboo. Similarly, Solomon *et al*. (2010) reported seasonal variation in *in sacco* DM and N degradability of different browses species grown in the Tigray Regional State of Ethiopia.

The solubility of basal feed sources, the slowly degradable fraction and degradation rate are important factors that affect the intake of poor quality forages (Ørskov, 1994). The value of the rapidly soluble (*A*), slowly, but a potentially degradable fraction (*B*) and the rate of degradation (*c*) are considered to be precise predictors of feed intake, digestibility and growth rate (Shem *et al*., 1995). The *A, B* and PD for ruminal DM and N degradability of bamboo varieties in the present study were influenced by variety, morphological fractions and season. The highest rapidly soluble fraction of DM recorded for lowland bamboo leaf harvested in the wet season in the current study was relatively lower than that reported for *Bambusa arundinacea* (Keir *et al*., 1997), but higher than the value recorded for *Podocarpus nerifolia* foliage (Huque *et al*., 2001). These differences are attributable to differences in the chemical composition of the bamboo varieties. The BHB and RHB varieties contained relatively higher lignin, and hence had low degradability indicators.

The lowland bamboo had greater effective degradability (ED) of N than the highland bamboo varieties. A degradation rate of 3.1% reported for natural pasture hay (Ameha, 2006) was consistent with that obtained for bamboo leaf. To our knowledge, there was no reported information regarding the effective degradability of any bamboo species in the country and elsewhere in the world. The ED of DM for *tef* straw (Solomon *et al*., 2003) was similar to that noted for lowland bamboo leaf harvested in the wet season in the current study but lower than that recorded for Napier grass (Tessema and Baars, 2004). The ED of nitrogen in the lowland bamboo leaf and foliage harvested in the wet season of the current study, however, is higher than the value reported for *tef* straw by Solomon *et al*. (2003), indicating that low land bamboo is better in supplying rumen degradable N

than *tef* straw. The lag time fraction of DM and N for the three bamboo varieties in the present study was almost similar to the values of dwarf bamboo (Yayota *et al*., 2009) and Napier grass (Tessema and Baars, 2004).

The wide variation in the value of *A* fraction among bamboo varieties indicates that the level of soluble components was higher in leaf and foliage and lower in twig. This was also reflected in the ME content of these bamboo fractions. Accordingly, higher and lower ME content was recorded for leaf and twig, respectively. In agreement with this study, differences in morphological fractions on degradability characteristics were observed in *Ensete ventricosum* (Ajebu *et al.,* 2008) and maize stover (Adugna and Sundstøl, 1999). In line with the present study, the degradation rate (*c*) of DM and N were not influenced by season for dwarf bamboo (Yayota *et al.,* 2009). Unlike dwarf bamboo (Yayota *et al*., 2009), the *L* of DM and N of indigenous bamboo varieties was influenced by season. This indicates that the season of forage harvest has an impact on the nutritive value of bamboo foliages.

Conclusion

The overall result of this study suggested that lowland bamboo was superior in terms of chemical composition, *in vitro* dry matter digestibility and *in sacco* nitrogen degradability. It is concluded that lowland bamboo has a high potential as ruminant feed in northwest Ethiopia because of its moderate level of CP and nutritive values in the leaf harvested in the wet season. The large differences in chemical composition and nutritive values observed among bamboo varieties, morphological fractions and between seasons of harvest entail consideration of these factors for appropriate utilization of bamboo plants as a feed resource for ruminant and other herbivore animals. Hence, bamboo fodder can be used as conserved forage and mitigate the critical nutrient shortage in the dry season.

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Conflict of Interests

The authors declare that they have no competing interests.

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