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NUTRITIONAL EVALUATION OF *Pentas schimperiana* AS LIVESTOCK FEED AND POTENTIAL PROTEIN SUPPLEMENT

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ABSTRACT: *Pentas schimperiana* is locally available and dominantly used as a dairy cattle feed in the Dawuro zone's Maraka district, Ethiopia. There is some information about its utilization practice, however, data on its nutritional benefit is limited. This research aimed to examine the chemical content and digestibility of *P. schimperiana* for use as cattle feed during the dry season. For this study, a 2×2 factorial design with two agro-ecologies (midland and highland) and two seasons (wet and dry) was used for this study. *P. schimperiana* leaves, twigs and stems were gathered and processed for laboratory analysis from two agro-ecologies and two seasons. The chemical composition, in vitro digestibility, and in sacco degradability of the samples were determined after incubation at 0, 6, 12, 24, 48, 72, and 96 hours. Effective degradability (ED) and Potential degradation (PD) were computed. The collected data were subjected to an Analysis of Variance and the means that had significant deference, the mean separation was performed by Tukey with alpha level of 0.05. In vitro dry matter digestibility (IVDMD) (87.41%) and crude protein (CP) (17.39%) were significantly higher in highland. Digestible crude protein (DCP) was significantly larger in dry than in the wet season with the content of neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) decreased. During the wet season, potential degradability (PD) and effective degradability (ED) of DM were highest in the highland with a decrease in leg time, which was related to the low content of ADF, ADL, NDF, tannin, and high CP in vegetative stages of *P. schimperiana.* The result indicates that *P. schimperiana* might be used as supplementary feeds to enhance utilization of low-quality feed resources and improve the performance of ruminants during the dry season when feed is scarce.

Keywords: Chemical composition, Degradability, Digestibility, *Pentas schimperiana,* Tannin.

INTRODUCTION

Ethiopia is well-known for its abundant and diverse livestock resources with 70.29 million cattle, 42.91 million sheep, 52.46 million goats (CSA, 2021). However, because livestock contributes more to rural households' livelihoods, the benefit we derive from the resource is negligible and not compromised by the livestock's potential (Asfaw et al., 2011; Kebebe, 2019). The major ruminant livestock feed supplies in Ethiopia are green fodder from natural pasture (grazing) and crop residue with low nutritional value (Alemayehu et al., 2017; CSA, 2020). Feed scarcity, particularly during the dry season, severely limits animal production in most of Ethiopia. In many parts of the country, available feed resources are insufficient to meet the nutritional needs of animals throughout the year, either due to a lack of supply or due to poor feed quality (Alemayehu et al., 2017). Under Ethiopian conditions, the use of indigenous forages as a feed resource is appealing in order to increase livestock production and productivity (Shapiro et al., 2015). Indigenous fodder trees could be considered as reliable feed resource to develop sustainable livestock feeding system due to their ability of remaining green for a longer period (Aganga and Tshwenyane 2003). Using locally available indigenous fodder species, on the other hand, increases livestock production and productivity while also increasing the livestock producer's income.

Indigenous fodder species in the study area are potentially cheap feed resources for livestock and are highly valued by farmers, especially during the dry season of the year when feed quantity and quality are limited. *Pentas schimperiana*, named after Georg Heinrich Wilhelm Schimper, who collected primarily in Ethiopia and is known locally as *Dawuro-daama*, is one of the locally available livestock feeds in the Maraka districts of the Dawuro zone. It is a woody herb up to 2.5 m tall, with mostly oblong twinkle broad leaf. It stayed green throughout the year. *Pentas schimperiana* is locally known indigenous fodder, which provides valuable benefits such as a source of traditional medicine, and as livestock feeds especially during the dry season (Woretaw et al., 2022). Local people provide the leaf and stem chopped and mixed with salt and water and given to drink mainly for milking cows and fattening cattle. The leaves and twigs of *P. schimperiana* were preferred by the various cattle groups in terms of palatability, according to Woretaw et al. (2022). According to the same authors, *P. schimperiana* was applied to cows during milking to boost milk yield and both the quality and amount of butter. As a result, it was given the name "milk feed," which improved the milk's quality and flavor. The leaf and stem were chopped, ground, and mixed with salt and water to make a drink primarily for milking cows and fattening cattle (Andualem et al., 2015).

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However, limited researches on the nutritional benefits of this locally accessible cattle feed has been undertaken. Therefore, the purpose of this study was to determine the chemical composition, degradability and digestibility of *P. schimperiana.*

MATERIAL AND METHODS

The study area

The study was carried out in Maraka districts of Dawuro zone, Southern Nation Nationalities and People Region (SNNPR), Ethiopia. The area is located 544 kilometers southwest of Addis Ababa and 17 kilometers from the zonal city of Tarcha. It is located between 6°56'00" to 7°04'00"N and 37°02'00" to 37°16'00"E, at an elevation of 1000-2400 m above sea level. The predominant macroclimatic conditions included temperatures ranging from 15.10°C to 27.50°C and rainfall ranging from 1314 to 1516 mm. It is classified into three agro-ecological zones based on the agro-ecological categorization criteria: highland (>2300 m.a.s.l), midland (1500 – 2300 m.a.s.l), and lowland (500-1500 m.a.s.l), with total coverage of 41.77, 50 and 8.23 percent, respectively (MoA, 2000). Since *P. schimperiana* is growing in high- and midland altitudes the lowland was not considered in this study (Woretaw et al., 2022).

Ethical consideration

The experimental animals were treated or managed according to an animal experimental protocol approved by the Ethics Commission of the Wolaita Sodo University reference number WSU/41/14/1023.

Sample collection and preparation

Pentas schimperiana samples were collected, labeled, and dried in each of the two major seasons, wet (May to September) and dry season (November to March) from two (midland and highland) agroecological zones of the study area. The samples were partly dried at 60°C for 72 hours and ground by Thomas Willy mill (model 4) to pass through 1 mm sieve for chemical analysis and in vitro digestibility and 2 mm sieve size for in sacco degradability study. Ground samples were kept in sealed plastic containers for further chemical and digestibility testing.

Chemical analysis

To estimate dry matter (DM), ash, and crude protein (CP), the AOAC (1990) proximate analytical methodologies were employed. Using the Kjeldahl method, the nitrogen (N) levels were measured, and the CP value was computed by multiplying the N concentration in the feed by 6.25. The AOAC (2000) technique was used to determine ether extract (EE). The neutral detergent fiber (NDF) contents were determined using Van Soest et al. (1991), while the acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed by Van Soest and Robertson (1985).

In vitro dry matter digestibility

To determine the in vitro dry matter digestibility (IVDMD), the Tilley and Terry (1963) technique, as modified by Van Soest et al. (1991), was employed. A 0.5 g of feed was incubated at 39°C in 125 ml flasks containing rumen fluid-medium, which was collected from rumen-fistulated sheep. The sheep were fed Rhodes grass hay at *ad libitum* and 400 g concentrate mix daily in two equal parts.

In sacco degradability

About 2.5 g of feed sample was put in nylon bags and incubated in the rumens of three rumen-fistulated sheep to investigate the in sacco DM degradability characteristics. The sheep were fed as indicated above. The feed samples were incubated for 0, 6, 12, 24, 48, 72, and 96 hours in three ruminal fistulated steers fed a maintenance diet. Following the incubation period, the nylon bags were removed, rinsed with running tap water, and oven-dried for 72 hours at 60°C. The protocols for zero-hour incubation losses were obtained by washing and drying duplicate bags with samples which were not incubated in the rumen. The following formula was used to calculate the percentage disappearance of DM and CP:

$$\text{Dry matter degradability (DMD)} = \frac{(\text{DM in sample} - \text{DM in residues})}{\text{DM in sample}} * 100$$

$$\text{Crude Protein degradability (CPD)} = \frac{\text{CP in sample} - \text{CP in residues}}{\text{CP in sample}} * 100$$

Effective degradability (ED) of DM was calculated following the method of Ørskov and McDonald (1979). Estimation of protein degradability in the rumen based on incubation measurements weighted by passage rates. $Y = a+b\ (1-e^{-ct})$, where: P = the potential disappearance of DM at time t, a = rapidly degradable fraction, b = the potentially, but a slowly degradable fraction, c = the rate of degradation of b, e = the natural logarithm, t = time. Effective degradability (ED) of DM was computed in accordance with Ørskov et al (1988) using the formula ED = A+ [Bc/(c+k)] at rumen outflow rates (k) of 0.04/h. Potential degradation (PD) was calculated as (A+B).

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Tannin determination

The condensed tannin was determined by using 70% aqueous acetone and Butanol-HCl procedures and expressed as leucocyanidin equivalent (% of DM) (Makkar et al., 2007). Absorbance was measured spectrophotometrically at 550 nm. The concentrations of condensed tannins were calculated from tannic standard curve by the formula:

$$\frac{\text{Absorbance at 550 nm} \times 78.26 \times \text{Dilution factor}}{\%\ \text{DM}}$$

The dilution factor was equal to 1 if no 70% acetone was added or 0.5 ml per volume of the extract was taken (Porter et al., 1986). Digestible crude protein was estimated from crude protein (Church, 1982): DCP = 0.929*CP (g) - 3.48.

Statistical analysis

All chemical composition, degradability and digestibility data were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure of SAS version 9.4 (2013) in a 2×2 factorial design with two agro-ecologies (midland and highland) and two seasons (wet and dry season). For the means had a significant difference, mean separation was performed by Tukey with an alpha level of 0.05.

The statistical model used was:

$Y_{ijk} = \mu + S_i + A_j + SA_{(ij)} + e_{ijk}$

Where: Y_{ijk} = the response of the parameter under investigation, DM, OM, Ash, CP, CF, EE, NDF, ADF and ADL, IVDMD, DCP, DE and tannin

μ = Overall mean

S_i = the effect of i^{th} agro-ecology (I = Midland, Highland)

A_j = the effect of j^{th} study season (j = Wet, Dry)

SA_{ij} = the interaction effect of agroecology and season.

e_{ijk} = random error

RESULTS AND DISCUSSIONS

Chemical composition

Table 1 shows the influence of season and agroecology on the chemical compositions of *P. schimperiana*. The dry season had a greater (P<0.05) DM content. The findings of Gaiballa (2012) who studied on 43 tree and shrub species which useful browse source for livestock were comparable to our result. However, Babayemi and Bamikole (2006) reported that advancing in age or higher temperatures in the dry season resulted in nutrient depletion in the soil due to weather and continual usage by season. The ash content was lower (P<0.05) during the dry season, which might be attributed to the poor translocation of the root system and the lignification process during the dry season. The ash concentration (1.29-5.79%) was lower than that of previously reported on fodder browse species (6-20.5%) and (4.62% and 16.22%) by Abdullah et al. (2014) and Geng et al. (2020), respectively.

Table 1 - Chemical composition (as DM basis) of *P. schimperiana*

Items	Season	Midland	Highland	SEM	Agro.	Season.	Agro.*Season.
DM	Dry	51.01[a]	42.44[b]	2.56			
	Wet	47.36[a]	40.27[b]	2.05	0.001	0.026	0.43
OM	Dry	98.71[a]	94.27[b]	1.28			
	Wet	97.33[a]	94.27[b]	0.96	0.0001	0.002	0.003
Ash	Dry	1.29[b]	5.73[a]	1.28			
	Wet	2.47[b]	5.79[a]	0.96	0.0001	0.002	0.003
CP	Dry	11.56[b]	15.40[a]	1.11			
	Wet	12.4[b]	17.39[a]	1.44	0.001	0.0001	0.006
EE	Dry	3.08	3.12	0.06			
	Wet	3.34	3.19	0.58	0.574	0.132	0.329
ADF	Dry	16.60[a]	9.14[b]	2.16			
	Wet	13.89[a]	8.20[b]	11.64	0.0001	0.005	0.52
ADL	Dry	11.56[a]	7.35[b]	1.22			
	Wet	10.06[a]	6.10[b]	1.14	0.0001	0.003	0.607
NDF	Dry	25.35[a]	17.06[b]	2.44			
	Wet	22.23[a]	14.94[b]	2.13	0.0001	0.011	0.479

[a, b,] rows means with different superscripts are significantly different (P<0.05); DM=Dry matter; OM=Organic matter; CP=Crude protein; NDF is neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent lignin; SEM=Standard error of the mean; Agro. = Agroecology effect (P<0.05), Season. = Season effect (P<0.05); Agro.×season. = Agroecology×Season effect (P<0.05).

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Significant interaction (P<0.05) was recorded in CP values between agroecology and seasons. The observed CP values of *P. schimperina* were ranging from 11.56% to 17.39% in midland-dry season and highland-wet season, respectively. The values were within the range reported by Shenkute et al. (2012) for browse species, which ranged from 8.9 to 20.9 percent. Similarly, Liman et al. (2016) reported in the range of 6.57% and 28.13% for *Boswellia dalzelia* and *Newbouldia laevis,* respectively in Ardo-Kola, Jalingo and Lau local government of Taraba State, Nigeria. The crude protein content (CP) of the browse species was higher in the wet season except *Acacia seyal* which had higher value in the dry season (210 g/kg DM). The lower CP content of browse species harvested during the dry season as compared to the wet season may be caused by the plant's advancing age, which is associated with leaf maturity, the soil's lower moisture content and availability of less nitrogen, and the higher proportion of the fiber fraction (Belachew et al 2013). The present value varied from 11.6 percent to 17.4 percent, which was higher than the ruminant's maintenance protein requirement as the minimum average CP for a rumen microbe's requirement is 7% (NRC, 2001). The high CP in *P. schimperiana* implies its potential for a dry season protein supplement to ruminants fed on low-quality hay and crop residues.

In the current study NDF concentrations were consistent with Singh and Oosting (1992) finding who stated that roughage diets with less than 45 percent NDF content were classified as high-quality feed. During the dry season, the midland had considerably (P<0.05) greater NDF levels than the highland. The moderate temperatures and high precipitation tend to decrease the cell wall fraction of the plants (Boufennara et al., 2012). The midland (16.60 percent) had a greater (P<0.05) ADF content during the dry season than the highland (8.20 percent) during the rainy season. ADF values were lower than those reported by Liman et al. (2013) for browse species which had a range of (19.25-28.98%). ADF content plays a significant role in voluntary feed intake and digestibility. ADL contents in the current study were comparable with the results of Mtui et al. (2009) for browse species, which ranged from 3.3 to 11.0%. However, Babayemi and Bamikole (2006) reported that advancing in age or higher temperatures in the dry season resulted in nutrient depletion in the soil due to weather and continual usage by season. The observed disparities in fiber fractions of NDF, ADF, and ADL in dry and wet seasons might be due to increased solar radiation intensity and less rainfall during the dry season, resulting in quicker maturation and higher cell wall contents (Evitayani et al., 2004). The influence of genotype on nutrient intake, soil qualities that give nutrients to plants, growth stage, plant maturity, and the proportion of different browsed components in harvested samples (Upreti and Shrestha, 2006).

In vitro dry matter and crude protein digestibility

During the wet season, the in vitro dry matter digestibility (IVDMD) value was greater (P<0.05; Table 2). The low ADF, ADL, NDF, and high CP might explain the high IVDMD values during the wet season. The current variations of IVDMD may be related to the effect of growth stage, plant maturity, and the fraction of tree components chosen for chemical composition analysis (Mtengeti and Mhelela, 2006). Significant (P<0.05) interaction effect was recorded in DCP and IVDMD values between agroecology and seasons. In the wet season, the DCP values ranged from 8.0 to 12.64%, which was significantly higher (P<0.05) in highland with the highest value in wet season. The values in the current study were slightly lower than those reported by Ahamefule et al. (2006) among browse plants; the highest DCP value recorded in *Napoleona vogelii* was 13.65%. Ahamefule et al. (2006) reported feedstuffs containing greater than 7% CP to have good digestibility. Therefore, *P. schimperiana* has better digestibility, as DCP ranged from 3.24 to 14.98% reported by Liman et al. (2016) for 20 browse fodder species. DCP was significantly (P<0.05) higher in the highland-wet season as compared to the midland-dry season as the ADF, ADL, and NDF contents decreased. The moderate temperatures and high precipitation in the study area tend to decrease cell wall fraction (Boufennara et al., 2012). The significant (P<0.05) interaction result of IVDMD was observed between agroecology and season. The value was ranged from 65.31 to 87.41% in midland-dry season and highland-wet season, respectively. The observed results are consistent with those reported by Nasrullah et al. (2003) and Evitayani et al. (2004) and lower than the results reported by Aster et al. (2012), the IVDMD values among the 10 browse species in Borana rangeland, Ethiopia varied from 96.57 to 71.89% and 97.47 to 67.63% in the dry and rainy seasons, respectively. The differences in IVDMD might be attributed to the seasonal variation during harvesting and selection of plant parts that improved the nutrient contents and its rumen degradability (Kassahun et al., 2016). Lignification interferes with the digestion of cell-wall polysaccharides by acting as a physical barrier to microbial enzymes (Moore and Jung, 2001).

Digestible energy and tannin

In the wet season, DE ranged from 1.41 to 3.14 MCal/kg. A higher DE (P<0.05) was recorded in midland (Table 2). DE was significantly (P<0.05) lower in the wet season and this might contribute to the decrement of the energy source of fiber content (Gaiballa, 2012). Lignification controls the amount of fiber that can be digested and, hence has a direct and frequently significant influence on the forage's digestible energy (DE) value of the forage (Jung and Allen 1995; Moore and Jubg, 2001). Worknesh and Getachew (2018) showed that feeds containing DM more than 2.87 and DE less than 2.15 MCal/kg are categorized as high and low energy feeds, respectively.

The condensed tannin (CT) value in the current study (0.14 – 0.17%) was in the lower range of the value reported by Aster et al. (2012) ranged from 0.12 to 33.2% DM in *Balanites aegyptiaca* and *Acacia tortilis*, respectively in Borana rangeland, Ethiopia. However, the results indicated that the tannin contents (0.14 - 0.17%) were lower than the level of tannin that adversely affects digestibility in ruminants (2 and 5%) (Gidado et al., 2013). However, the combined effect of both agroecology and season didn't bring a significant difference (P<0.05) in tannin content.

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Table 2 - In vitro dry matter and crude protein digestibility, digestible energy and condensed tannin

Items	Season	Midland	Highland	SEM	Agro.	Season.	Agro.*Season.
IVDMD (%)	Dry	65.31[b]	83.34[a]	5.78			
	Wet	68.21[b]	87.41[a]	5.54	0.01	0.0001	0.015
DCP (%)	Dry	7.22[b]	10.79[a]	1.03			
	Wet	8.0[b]	12.64[a]	1.33	0.01	0.0001	0.006
CT (%)	Dry	0.17[a]	0.15[b]	0.01			
	Wet	0.17[a]	0.14[b]	0.01	0.01	0.008	0.73
DE (MCal/kg)	Dry	3.14[a]	1.71[b]	0.49			
	Wet	3.03[a]	1.41[b]	0.47	0.03	0.028	0.71

[a, b,] rows means with different superscripts are significantly different (P<0.05); IVDMD= in vitro dry matter digestibility; DCP=Digestible crude protein; ME=Metabolic energy; CT=condensed tannin; SEM=Standard error of the mean; Agro.=Agroecology effect (P<0.05); Season.=Season effect (P<0.05); Agro.×season.= Agroecology×Season effect (P<0.05).

In sacco dry matter degradability of *P. schimperiana*

The dry matter degradability was higher (P<0.05) in highland than in midland during all incubation hours (Table 3). There were significant differences (P<0.05) at 6, 12, 24, and 48 hours incubation periods during both the dry and wet seasons in midland and highland agroecology. The differences in dry matter degradability between dry and wet seasons suggested that the high intensity of solar radiation and lower amount of rainfall during the dry season caused faster maturation, resulting in higher cell wall contents and lower cell contents than those of the rainy season, which was consistent with the findings of Evitayani et al. (2004) on the nutritive value of tropical forages. The degradability percentage of *P. schimperiana* was above 40% at 24 h of incubation implying its potential utilization for feeding ruminants based on the recommendations of FAO (1986) which suggested a minimum of 40 to 50% degradation at 48 hours in the rumen Malgwi and Mohammed (2015). The DMD values of browse species were higher in wet season than in the dry seasons and increased with increasing incubation periods in all browse species in the semi-arid Rift Valley areas of Ethiopia (Ahmed et al., 2017). Njidda (2011) reported that dry matter disappearance of browse plants increased with increased incubation time.

The DM disappearance rate of *P. schimperiana* was higher (P<0.05) during the wet season might be attributed to the lower in fiber content that the dry season. Aster et al. (2012) reported that the DM disappearance rates of browse species were higher in the wet season due to seasonal differences in accumulation of structural component differences in the stage of maturity and possibly wider climate and edaphic differences. Dry matter degradability is influenced by the nutrient contents of the plant in turn nutrient contents are influenced by the harvesting season, soil fertility, the amount of rainfall, and temperature (Kassahun et al., 2016). Aster et al. (2012) found that the DM disappearance rates of browsing species were greater during the rainy season due to seasonal changes in structural component accumulation, differences in the maturity stage, and perhaps larger climatic and edaphic differences. The nutrient content of the plant influences dry matter degradability, and nutrient content is determined by the harvesting season, soil fertility, quantity of rainfall, and temperature (Kassahun et al., 2016).

A rapidly degradable fraction of *P. schimperiana* was recorded in the highland (24.75%) compared to that of the midland (20.27%) during the wet and dry seasons, respectively (Table 4). A rapidly degradable fraction in highland is related to the low level of lignification in browse species (Liman et al., 2016). The slow degradable fraction in the midland might be the higher content of cell wall components of *P. schimperiana* than in the highland. Significantly lower (P<0.05) rates of degradation were observed in highland (0.03 fraction/h) and higher (P<0.05) in midland (0.044 fraction/h) in the wet and dry seasons, respectively. This study indicated that *P. schimperiana* had higher in sacco dry matter degradability across all the degradability parameters which made it a good nutritional contribution to supplement poor quality roughages. The result is in agreement with the study of Kassahun et al. (2016) on *Ficus thonningii* and *Terminalia schimperiana* in Chilega District, North Gondar. The recorded lag time indicated that degradation did not occur similarly in the rumen. The effective degradation in the rumen is determined by the length of time the feed remains in the rumen, which is also determined by the quality of the feed supplied to the animals (Liman et al., 2016). During the dry and wet seasons, effective degradability (ED) of *P. schimperina* was in line with Liman et al. (2016) on browse species (40.90-66.10%) which were conveniently used in the formulation of high-quality ruminant feed for fattening and maintenance feeding. The potential degradability (PD) varied significantly (P<0.05) from 66.52 to 76.5% and 68.08 to 77.60% in the dry and wet seasons of midland and highland respectively. The PD value from the current study was higher than reported values of browse species ranged from 61.6 – 67.8 % in wet season and from 55.2 – 65.2% during the dry season in our study (Ahmed et al., 2017). Previous research revealed that variations in the degrading parameters of browse species might be attributed to chemical composition (Kamalak, 2006; Belachew et al., 2013; Gusha et al., 2013), differences in the stage of maturity and possibly climate and edaphic differences (Ahmed et al., 2017). These variations in PD in the rumen have been reported as a result of variations in fibre content and tannins levels (Gusha et al., 2013). These values were in the range obtained by Liman et al. (2016) who reported a potential degradability ranging from 40.40 to 93.40% in browse species.

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Table 3 - Percentage Dry matter degradability of *Pentas schimperina* (%)

Time	Season	Midland	Highland	SEM	Agro.	Season	Agro.×Season
0	Dry	21.52[b]	24.42[a]	0.85			
	Wet	24.33[b]	27.62[a]	0.95	0.0001	0.0001	0.29
6	Dry	27.76[b]	31.38[a]	1.09			
	Wet	30.79[b]	31.70[a]	0.27	0.004	0.013	0.03
12	Dry	35.65[b]	37.79[a]	0.63			
	Wet	41.64[a]	41.61[b]	0.045	0.001	0.0001	0.001
24	Dry	48.72[b]	50.34[a]	0.48			
	Wet	53.36[b]	58.44[a]	1.47	0.0001	0.0001	0.0001
48	Dry	61.52[b]	66.36[a]	1.40			
	Wet	52.83[b]	68.71[a]	1.69	0.0001	0.0001	0.03
72	Dry	61.63[b]	70.63[a]	2.31			
	Wet	65.56[b]	73.45[a]	2.28	0.0001	0.0001	0.74
96	Dry	64.63[b]	72.64[a]	2.32			
	Wet	67.48[b]	75.08[a]	2.19	0.0001	0.0001	0.16

[a,b,]rows means with different superscripts are significantly different (P<0.05); SEM is Standard error of the mean, Agro.= Agroecology effect (P<0.05), Season.= Season effect (P<0.05); Agro.×season.= Agroecology × Season effect (P<0.05).

Table 4 - Dry matter degradability parameters (%)

Parameters	Season	Midland	Highland	SEM	Agro.	Season	Agro.×Season
a	Dry	20.27[b]	23.06[a]	0.81			
	Wet	23.01[b]	24.75[a]	0.5	0.001	0.001	0.001
b	Dry	46.25[b]	53.47[a]	2.09			
	Wet	45.06[b]	52.65[a]	2.19	0.001	0.001	0.073
c	Dry	0.04[a]	0.03[b]	0.003			
	Wet	0.044[a]	0.04[b]	0.11	0.001	0.001	0.002
PD	Dry	66.52[b]	76.53[a]	2.89			
	Wet	68.08[b]	77.40[a]	2.68	0.006	0.045	0.509
ED	Dry	62.43[b]	64.08[a]	0.52			
	Wet	63.40[b]	64.66[a]	0.37	0.001	0.001	0.001
Leg.T	Dry	0.64[a]	0.44[b]	0.57			
	Wet	0.48[a]	0.34[b]	0.40	0.001	0.001	0.001

[a, b,] rows means with different superscripts are significantly different (P<0.05SEM is Standard error of the mean, a=rapidly degradable fraction; b=slowly degradable fraction; c=rate of degradation; PD=potential degradability; ED=effective degradability (P<0.05), Agro.= Agroecology effect (P<0.05), Season = Season effect (P<0.05); Agro.×season = Agroecology × Season effect (P<0.05).

Crude protein degradability of *P. schimperiana*

The percentage of crude protein disappearance at 0, 12, 24, 48, 72, and 96 hours incubation time was significantly (P<0.05) affected by agroecology and season (Table 5). The significant difference (P<0.05) of CPD was related to lesser crude protein and higher fiber fractions (NDF, ADF, and ADL) in midland during both the dry and wet seasons for the macroclimatic factors variations in harmony with Lebopa et al. (2011) on crude protein degradation of woody plant species. The disappearance of CP increases with increased incubation time. The CP disappearance of *P. schimperiana* was greater in the highland (P<0.05) than in midland except at 48 and 72 hours incubation time in the dry season. CP disappearance at 96 h had values above 80%, which was in line with Njidda (2011) on the tree and shrub. Similarly, Larbi et al. (1998) stated that the crude protein disappearance of multi-purpose trees and shrubs was higher in the wet season. The recorded differences in midland and highland agro-ecology during the dry and wet seasons contributed to the effect of genotype on nutrient absorption, properties of soil to supply nutrients to plants, growth stage, and maturity of the plant (Njidda, 2011).

The CP degradability values (Table 6) revealed a high rate of CP degradation constant in high effective degradability, which was consistent with the findings of Njidda (2011) who experimented on multiple trees and shrub leaves which were served as a high-protein value feed source for ruminants. During the dry and wet seasons, *P. schimperiana* had a short lag time due to a high rapidly degradable fraction (a) and a low slowly degradable fraction (b). The short lag time in this study indicated that *P. schimperiana* had a higher amount of CP and low ADF, ADL, and NDF in the wet season and this result was in line with Liman et al. (2016) on browse species in Taraba, Nigeria.

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Table 5 - Crude protein degradability (%)

Time	Season	Midland	Highland	SEM	Agro.	Season	Agro.×Season
0	Dry	46.75[b]	48.56[a]	0.54			
	Wet	50.53[b]	52.67[a]	0.63	0.01	0.0001	0.46
6	Dry	55.43	59.53	1.19			
	Wet	59.51	56.31	0.93	0.068	0.07	0.0001
12	Dry	62.57[b]	63.53[a]	0.28			
	Wet	65.67	63.34	0.68	0.07	0.0001	0.0001
24	Dry	67.38[b]	67.58[a]	0.11			
	Wet	69.74[b]	70.41[a]	0.22	0.057	0.0001	0.22
48	Dry	72.42[a]	70.39[b]	0.59			
	Wet	74.55[b]	79.67[a]	1.48	0.0001	0.0001	0.0001
72	Dry	75.43[a]	75.33[b]	0.09			
	Wet	76.73[b]	85.48[a]	2.53	0.0001	0.0001	0.0001
96	Dry	80.28[b]	85.40[a]	1..49			
	Wet	82.55[b]	88.12[a]	1.61	0.0001	0.0001	0.37

[a, b,] rows means with different superscripts are significantly different (P<0.05); SEM is Standard error of the mean, Agro.= Agroecology effect (P<0.05), Season.= Season effect (P<0.05); Agro.×season.= Agroecology × Season effect (P<0.05).

Table 6 - Crude protein degradability (%)

Parameters	Season	Midland	Highland	SEM	Agro.	Season	Agro.×Season
a	Dry	47.36[b]	53.07[a]	1.64			
	Wet	52.14[a]	52.11[b]	0.05	0.0001	0.0001	0.0001
b	Dry	30.33[b]	34.28[a]	1.14			
	Wet	27.63[b]	39.27[a]	3.36	0.0001	0.0001	0.0001
c	Dry	0.05[a]	0.02[b]	0.009			
	Wet	0.051[a]	0.03[b]	0.006	0.001	0.31	0.22
ED	Dry	67.12[a]	67.09[b]	2.05			
	Wet	68.25[b]	69.54[a]	0.37	0.0001	0.0001	0.001
PD	Dry	77.69[b]	87.35[a]	2.80			
	Wet	77.77[b]	91.38[a]	3.81	0.0001	0.0001	0.001
Leg.T	Dry	0.15[b]	0.17[a]	0.52			
	Wet	0.11[b]	0.13[a]	0.51	0.0001	0.0001	0.94

[a, b,] rows means with different superscripts are significantly different (P<0.05SEM is Standard error of the mean, a=rapidly degradable fraction; b=slowly degradable fraction; c=rate of degradation; PD=potential degradability; ED=effective degradability (P<0.05), Agro.= Agroecology effect (P<0.05), Season = Season effect (P<0.05); Agro.×season = Agroecology × Season effect (P<0.05).

CONCLUSION

The findings of this study indicated that the chemical compositions of *P. schimperiana* in the study area were influenced by agroecology and season. This study showed that *P. schimperiana* has relatively high crude protein and lower fiber fraction which leads to a better digestibility. Therefore, it has the potential to use as a dry season protein supplement for ruminants fed on low-quality hay and crop residues and it can correct the nutrient deficiency that exists in low-quality feeds. However, it needs a biomass yield study and also to know its effect on animal performance, the researchers recommend supporting this result with animal experiments.

DECLARATIONS

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Authors' contribution

T. Woretaw performed conceptualization, data curation, formal analysis, investigation, methodology, software, validation, writing original draft; N. Beyero performed conceptualization, methodology, supervision, writing – original draft, writing, review & editing of the manuscript for important academic contents.

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Conflict of interests

The authors have not declared any conflict of interests.

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