Research Article

How Nutritive are the Pasture Browse Species of Nepali Middle Hills?

Ram Prasad Ghimire

National Pasture and Fodder Research Program, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal.

Abstract | Middle hill pasturelands of Nepal have an abundance of browse species which are the major sources of roughage feeds for grazing goats. A study was conducted in order to determine the fodder quality of some common pasture browse species among them. The study included the analysis of fodders in the laboratory for nutrient composition, the feeding experiment determining fodder intake and weight gain monitoring in the goats, and a subsequent *in-vivo* experiment determining the apparent digestibility of fodder nutrients of those browse species. Both of the experiments were conducted in Randomized Complete Block Design (RCBD) with six treatments and five replications on native hill goats of Nepal. The fodders of popular five browse species from the pasturelands of Nepali middle hills; Dhayero (*Woodfordia fruticosa* Kurz), Musure katus (*Castanopsis tribuloides* (Sm.) Lindl.)), Bamboo (*Bamboosa arundinacea* (Retz.) Willd.), Titepati (*Artemisia vulgaris* Willd.) and Sal ((*Shorea robusta* Roth.) and a mixed fodder were used as the treatments. The results of the study revealed that *W. fruticosa* was obtained best for nutrient composition (6.94±2.32% total ash and 10.625±2.67% crude protein contents), voluntary fodder dry matter intake (74.40±10.12 g day^{-1} per kg metabolic weight of goat), apparent dry matter digestibilities of dry matter (54.96±4.77%), crude protein (57.73±5.97%), neutral detergent fiber (52.48±6.0%) and acid detergent fiber (39.29±4.18%) and for the body weight gain of goats (5.35±0.51 kg goat^{-1} in 120 days) among the investigated five browse species. However, fodders of all the evaluated browse species were inferior in nutrient compositions with less digestible nutrients and contributed to the poorer body weight gain of male goats in comparison to the mixed fodder treatment. The study revealed that the browse species included in the study were substandard in fodder quality to goats. This indicates the goats reared in the middle hills of Nepal are undernourished without supplementation and require concentrate feed or good quality fodder to supplement their diet.

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***Correspondence** | Ram Prasad Ghimire, National Pasture and Fodder Research Program, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal; **Email:** ramghimire.narc@gmail.com
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Introduction

Goat farming has evolved from subsistence to commercial enterprises in recent years in Nepal. On the contrary, the researchers, development workers and entrepreneurs are not devoting ample efforts to the improvement of feeding management of the goats. Consequently, in the Western middle hills, most breeds of goats especially native hill goats (*Khari*) are raised by grazing during the daytime (Nepali *et*

al., 2007; NAMDP, 2018). These goats are grazed on pasturelands and uncultivated lands, in forest buffer zones and community forests, and on other marginal lands. The foraging habit of goats indicates that they graze predominantly on shrubs and bushes of browse species in their pasturelands (Sanon *et al*., 2007). In the rearing practices prevalent in Nepali middle hills, they are often not supplemented with concentrate feeds or quality fodders before or after grazing. Their only source of roughage feed is the fodders consumed in the pasturelands (Dhakal *et al*., 2019).

Many browse species of natural bushes and vines are grazed by the Native hill goats in the pasturelands of the middle hills of Nepal. Dhayero (*Woodfordia fruticosa* Kurz), Musure katus (*Castanopsis tribuloides* (Sm.) Lindl.), Bamboo (*Bamboosa arundinacea* (Retz.) Willd.), Titepati (*Artemisia vulgaris* Willd.) and Sal ((*Shorea robusta* Roth.) are some of the most widespread browse species in the pasturelands of Western middle hills of Nepal (Ghimire, 2013). Other species, such as *Saccharum spontaneum* L., *Rumex nepalensis* Spreng., *Fragaria nubicola* Undl. Ex Lacaita, *Drymaria cordata* (L.) Willd., *Potentilla microphylla* D. Don., *Gentiana capitata* Buch. Hamex D. Don, *Cotoneaster frigidus* Wallich. Ex Lindley., *Trigonella emodi* Benth., *Trifolium repens* L., *Ipomea purpurea* Linn., *Taraxacum officinalis* Webb., *Polygonum virginianum* L., *Anemone discolor* Royle, *Campanula aristata* Wall., *Lonicera lanceolate* Wall., *Rheum austral* D. Don etc. are also used by the goats in these areas (Thapa *et al*., 2016). Moreover, *Buddleja asiatica*, *Cajanus cajan*, other Bamboo species, *Vitex negundo*, *Thysanolaena maxima* are some other species used by goats for browsing in the western middle hills of Nepal (Pandey *et al*., 2009).

Although the hill goats rely on these browse species for their roughage requirements, limited information about the fodder values of these browse species is available. As well as that, there is little or no information available regarding the nutritional qualities of these browse species, especially at the interface between fodders and goats. In turn, this has created a serious challenge for emerging goat farming industries in the middle hill areas of Nepal (Upreti and Shrestha, 2006; Ghimire, 2013; Pariyar *et al*., 2013). In this context, evaluation of different shrubs and browse species based on ruminant performance can help to reduce the severity of undernourishment and to keep ruminants productive (Khanal and Upreti, 2008). It has been urging the determination of the fodder quality of these browse species and understanding the need for supplementation of quality fodders or nutrients are the felt needs of those goat-raising systems. Therefore, this study was undertaken to assess the quality of these browse species through laboratory works and *in-vivo* experiments on goats.

Materials and Methods

The experiment was conducted at the National Goat Research Program, Bandipur Tanahun, located in the middle hill ecology of Nepal. The geographical coordinates of the experimental site were 27°57'00" N and 84°23'39" E at an elevation of 854 m asl.

Voluntary feed intake and body weight monitoring

A total of 30 *Khari* (native hill goats) male goats of five- to six-month age and of average initial body weight of 10.26 kg were used in the experiment. The experiment was executed in the Randomized Complete Block Design (RCBD) with six treatments and five replications for 120 observation days during the lean season of fodders from October to February. The fodders of five browse species from the grazing lands of Western middle hills were compared with the mixed fodder (used as a control treatment) in the study. The browse species evaluated in the experiment were; Dhayero (*Woodfordia fruticosa* Kurz), Musure katus (*Castanopsis tribuloides* (Sm.) Lindl.)), Bamboo (*Bamboosa arundinacea* (Retz.) Willd.), Titepati (*Artemisia vulgaris* Willd.) and Sal ((*Shorea robusta* Roth.). The control group consisted of a mixture of the several fodders being commonly fed to ruminants in tethering or confinement systems. The mixture consisted of; *Pennisetum purpureum* Scumach., *Brachiaria decumbens* Stapf., *Pogantherum* sp., *Desmodium intortum* (Mill.) Urb., *Hypoxis aurea* Lour., *Cynodon dactylon* (L.) Pers., *Stylosanthes* spp., *Themeda triandra* Forsk., *Setaria pallidesesca*, *Pittosporum nepaulense*, *Echinochloea frumentacea*. In the experiment, a male goat was used as an experimental unit and was kept individually in the experimental pen. The light was provisioned in the experimental pens during nighttime. The experimental animals were provided *ad-libitum* drinking water and concentrate feed (with 16.66% crude protein and 12.71 % total ash content) @ 1% of their body weight for 24 hours duration. They were offered the leaves together with twigs and petioles of the browse species in *ad-libitum* two times daily at

09:00 and 17:00 hours. The bunch of the allocated fodders were offered by hanging over the head of the experimental animal. Each experimental animal was offered 15% more fodders than the previous day's intake. The experimental goats were kept in an adaptation period of 14-day in their allocated diets at the beginning of the experiment. The experimental goats were drenched with Albendazole @ 10 mg kg^{-1} body weight before 15 days of the experiment.

Daily feed offered and refused were recorded. The body weights of the goats were monitored at 15-day intervals during the experimental period.

Nutrient digestibility determination

Following the experiment on voluntary feed intake and body weight gain monitoring, the successive experiment on *in-vivo* nutrient digestibility for the fodder of those browse species was continued. In this experiment, the same animal assigned to the specific fodder in the previous experiment was repeated for the particular treatment. The experiment was conducted in a similar design as in the previous one, RCBD with six fodder treatments and five replications. In the digestibility experiment, an adaptation period of seven days was maintained offering them *ad-libitum* water and allocated fodder without concentrate feed. During the course of the digestibility experiment, only the allocated fodder was given to a goat without concentrate feed. The experimental goats were offered the assigned fodders two times a day, at 09:00 hours and 17:00 hours. Fodder refusals and voided feces were collected twice daily in the evening and in the next morning before the new ration offer. The weight of fodder offered, refused and fecal samples were recorded daily.

The apparent digestibility (AD) coefficients were calculated by using the data on nutrients offered in fodders, nutrients refused in fodders, and nutrients voided in the feces.

Laboratory analysis

Dry matter of the fodder and fecal samples were calculated in the laboratory of the National Goat Research Program, Bandipur by using constant heat in the hot air oven at 72°C for 24 hours. The proximate parameters were analyzed in the laboratory of the National Animal Nutrition Research Center, Khumaltar, Lalitpur according to the Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC, 1990, 2019). Nitrogen content was determined by following the Micro Kjheldal method and crude protein content was calculated on the basis of nitrogen. Total ash content was determined by ashing the samples at 550°C in a Muffle Furnace for 16 hours. The fiber fractions of the samples were analyzed by using Fodder Fiber Analysis Methods (Goering and Van Soest, 1970; Van Soest *et al.*, 1991).

Statistical analysis

The data on nutrient composition, voluntary fodder intake, body weight parameters of goats, and digestibility of nutrients were analyzed by using one-way ANOVA. The statistical software R-Package (R Core Team, 2020) was used for the analysis of data.

Results and Discussion

Nutrient contents of the fodders of browse species

The total ash (TA), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), hemicellulose (HC) and cellulose (C) contents were significantly different ($p<0.05$) for the fodders of investigated browse species (Table 1). The *W. fruticosa* was obtained superior among the experimented browse species in terms of fodder nutrient contents, except for total ash. Similarly, the fodders of *B. arundinacea*, *A. vulgaris* and Mixed fodder treatment were better ($p<0.01$) for TA contents, whereas *W. fruticosa, C. tribuloides* and *S. robusta* had shown reasonably lower ($p<0.01$) contents of the total ash. Likewise, *C. tribuloides* and *A. vulgaris* were superior ($p<0.01$) in terms of CP content. The mixed results were obtained for the fiber fractions of the different fodders, then again all the investigated browse species had shown lower fodder quality in terms of NDF, ADF, HC and Cellulose. Comparatively lower proportions ($p<0.01$) of ADL were found in the fodder of *W. fruticosa*, control treatment, and *A. vulgaris* than in other browse species. The greater variability in the data of nutrient content of control treatment indicated by higher standard deviation values might be associated with the mixing of several fodders.

As described by Upreti and Shrestha (2006), based on the proportions of CP, NDF and ADF contents, all the pasture browse species investigated in the study were considered of lower quality. Tree fodders and shrubs containing ≥18% CP are considered good in quality, 10.01 to 17.99% are moderate in quality, and

≤10% are low in quality. Similarly, the fodders with ≤40% NDF, 40.01 to 60% NDF and ≥60% NDF are considered as good, medium, and low-quality, respectively. Likewise, the fodders with a ≤ 31% ADF are considered to be of good quality, those with a 41.01 to 45% are moderate in quality, and those with a ≥45% ADF are considered to be of low quality (Upreti and Shrestha, 2006). Further, lignin, which is considered a common anti-nutritional factor in fodders, was found to be higher in all investigated browse species with more than 15% on the DM basis.

Fodder intake

Significantly different (p<0.01) voluntary fodder intake (VFI) and fodder dry matter intake (fodder DMI) per kg metabolic weight were obtained for the fodders of different browse species (Table 2). The *W. fruticosa* had the best (p<0.01) VFI and fodder DMI per kg metabolic weight among the pasture browse species, however, none of the browse species had an equal or better intake of fodder than the control treatment. Murney *et al.* (2019) had obtained similar results of obtaining better fodder intake to goats in case of botanically more diverse fodder species. Some fodders used in mixed-fodder treatment could have rapidly degradable species in the rumen as in the experiment of Burke *et al.* (2000). In case of mixed-fodder treatment, there might be rapid emptying of rumen facilitated by mixed fodder species that could be responsible for higher DMI. Soft and smaller-leaved fodders increase the mastication per bite, result smaller herbage particle size swallowed and reduce ruminative chewing and results (Gregorini *et al.*, 2013). *Castanopsis tribuloides* and *B. arundinacea* were similar (p>0.05) in VFI and fodder DMI, which were higher (p<001) than *A. vulgaris*. The fodder of *A. vulgaris* had shown remarkably low (p<0.01) VFI and fodder DMI per kg metabolic weight in the experiment. According to Pandey *et al.* (2017), the leaves of *A. vulgaris* contain higher proportions of alkaloids, flavonoids, saponin, quinone, sterols, tannin, terpenoids, and reducing sugars; and these phytochemicals are listed to have a variety of biological effects in animals. Thus, these compounds could have suppressed the goats VFI and fodder DMI in this study.

Table 1: *Nutrient content of the fodders of popular browse species in the Nepali middle hills.*

Fodders	TA	CP	NDF	ADF	ADL	HC	C
Woodfordia fruticosa	6.94±2.32^{b}	10.625±2.67^{b}	66.39±10.32^{a}	46.99±6.66^{bc}	15.00±3.23^{c}	19.40±5.12^{a}	31.99±6.67^{a}
Castanopsis tribuloides	4.25±2.74^{c}	13.96±2.25^{a}	59.58±17.63^{b}	44.11±3.21^{c}	27.49±4.36^{a}	15.47±4.84^{b}	26.10±7.23^{b}
Bamboosa arundinacea	10.41±2.33^{a}	9.32±3.33^{c}	58.44±8.99^{b}	47.81±11.23^{bc}	29.68±5.91^{a}	10.63±3.13^{c}	18.13±5.68^{c}
Artemisia vulgaris	10.96±2.0^{a}	13.36±1.25^{a}	67.40±8.25^{a}	52.94±7.76^{ab}	18.01±2.89^{bc}	14.46±2.14^{b}	26.55±6.15^{b}
Shorea robusta	6.395±1.6^{b}	10.07±3.59^{bc}	59.45±12.6^{b}	54.64±8.32^{a}	21.24±4.22^{b}	4.81±1.33^{d}	33.40±9.10^{a}
Mixed fodder	11.81±3.6^{a}	10.8±4.11^{b}	59.99±17.3^{b}	47.90±10.88^{bc}	17.12±5.30^{c}	12.09±3.67^{bc}	30.78±6.69^{ab}
Significance	<0.01	<0.05	<0.05	<0.05	<0.01	<0.01	<0.01

TA= Total ash, CP= Crude Protein, NDF= Neutral detergent fiber, ADF= Acid detergent fiber, ADL acid detergent lignin, HC= Hemicellulose, C= Cellulose

Table 2: *Voluntary fodder intake and total dry matter intake of the goats for fodders of different browse species of Nepali middle hills.*

Fodders	Voluntary fodder intake, g day^{-1} animal^{-1}	Total DMI	
		Feed DMI, g day^{-1} kg^{-1} metabolic weight	Fodder DMI, g day^{-1} kg^{-1} metabolic weight
Woodfordia fruticosa	543.39±37.88^{b}	14.28±1.58	74.40±10.12^{b}
Castanopsis tribuloides	447.25±22.77^{c}	14.25±0.69	62.29±7.36^{c}
Bamboosa arundinacea	421.46±46.65^{cd}	14.28±0.52	59.03±10.75^{cd}
Artemisia vulgaris	282.27±46.25^{e}	14.29±1.13	37.93±9.21^{e}
Shorea robusta	381.99±23.73^{cd}	14.30±0.12	49.84±5.71^{d}
Mixed fodder	612.67±38.42^{a}	15.68±0.08	84.81±8.66^{a}
Significance	<0.01	NS	<0.01

DMI= Dry matter intake, NS= Non-significant.

Table 3: *Apparent digestibility of fodder nutrients of different pasture browse species.*

Fodders	DM	CP	TA	NDF	ADF
Woodfordia fruticosa	54.96±4.77^{ab}	57.73±5.97^{b}	47.33±3.67^{bc}	52.48±6.0^{b}	39.29±4.18^{b}
Castanopsis tribuloides	41.33±3.28^{cd}	44.46±5.01^{c}	48.69±3.33^{b}	38.29±4.11^{c}	26.54±3.61^{c}
Bamboosa arundinacea	44.36±4.99^{c}	41.78±4.66^{c}	67.67±4.12^{a}	39.22±5.34^{bc}	33.19±3.39^{bc}
Artemisia vulgaris	32.22±3.73^{d}	38.40±2.33^{c}	35.46±2.35^{c}	31.56±3.72^{c}	29.61±2.48^{bc}
Shorea robusta	39.65±4.12^{cd}	43.12±4.31^{c}	41.59±3.97^{bc}	43.87±3.68^{bc}	31.88±3.47^{bc}
Mixed fodder	65.23±5.13^{a}	72.91±4.46^{a}	63.28±4.19^{a}	66.67±5.19^{a}	52.34±5.11^{a}
Significance	<0.01	<0.01	<0.01	<0.01	<0.01

Along with the poorer quality of the fodders of investigated browse species in terms of CP, NDF, ADF and lignin contents (Table 1), their VFI and DMI per kg metabolic weight were also obtained lower (Table 2). This result showed that the higher fiber fractions in these browse species, which are considered to reduce fodder quality (Upreti and Shrestha, 2006), might be contributing to the decline in VFIs and fodder DMIs per kg metabolic weight. The roughage intake of a ruminant is regulated by rumen capacity. The faster rumen emptying leads to a greater intake of fodders (Owensby *et al.*, 1996). When the diet contains a high proportion of cell wall components (complex structural polysaccharides), the ingesta is retained longer in the rumen to ensure protein extraction. The rate at which fiber and lignin pass through the gastrointestinal tract increases on diets low in fiber and lignin.

Apparent digestibility of nutrients

The apparent digestibilities of nutrients were obtained significantly higher (p<0.01) for the control treatment: Mixed fodder (Table 3). The DM digestibility was obtained low for all the browse species involved in the experiment. Medium to lower digestibilities of the nutrients were found for the fodders of all the investigated browse species. Among the investigated browse species, the *W. fruticosa* fodder which contains modest CP and better fodder DMI per kg metabolic weight, yet again had better DM and CP digestibilities. However, it had lower TA content with poorer digestibility. The NDF and ADF digestibilities for *W. fruticosa* were obtained best among the investigated pasture browse species, nevertheless, their digestibility coefficients were also substandard so far. The fodder of *W. fruticosa* contains higher proportions (14.6%) of tannin (Upreti and Shrestha, 2006), which might have affected negatively in the digestibilities of CP, minerals, and fibers in this experiment. A study on *W. fruticosa* leaves reported the presence of higher extents of alkaloids, glycosides, flavonoids, tannins, and phenolic compounds (Vanmala *et al.*, 2014), which could be the reason for the lower nutrient digestibilities of *W. fruticosa* fodder in comparison to Mixed fodder in this experiment.

Similarly, *B. arundinacea* fodder with higher TA content (Table 1) had relatively superior (p<0.01) TA digestibility (Table 3), but its CP content and digestibility were poorer. Even though the NDF and ADF contents in the fodder of *B. arundinacea* were modest (Table 1), their digestibilities were obtained lower in the experiment. This might be due to the higher ADL content (Table 1). Moreover, Akinmoladun (2022) reported that *B. arundinacea* leaves are rich in saponins (3.98%), phytate (42.03 mg per 100 g) and flavonoid (2.85%). The higher levels of these phytochemicals could have decreased the bioavailability of CP and negatively affected the nutrient digestions in the gastrointestinal tract of the goats, as described by Akinmoladun (2022).

Likely, smaller digestibility coefficients of TA, CP and fiber fractions for the fodders of *C. tribuloides* and *S. robusta* were obtained in the nutrient digestibility experiment. Higher levels of tannin (>6.0% and >10% in *C. tribuloides* and *S. robusta* fodders, respectively) are found in these fodders (Upreti and Shrestha, 2006). A higher level of tannin inhibits the protein and dry matter digestibilities (Wood *et al.*, 1995; Upreti and Shrestha, 2006), which might be the reason for the lower digestibility coefficients of nutrients for *C. tribuloides* and *S. robusta* fodders. The fodder of *A. vulgaris* also showed smaller digestibility coefficients of DM, CP, TA, NDF, and ADF in the experiment. The foliage of *A. vulgaris* contains higher levels of anti-nutrient factors (Pandey *et al.*, 2017), which could have reduced the digestibilities of the nutrients in this fodder.

The lower CP contents in the fodders of investigated browse species (Table 1) could have declined the overall digestibility of fodders, and thus reduced the rate of passage of ingesta through the rumen due to lower microbial activity. When CP content is low in the ration, the bacteria responsible for the digestion of feeds and fodders cannot sustain at an adequate level, which reduces the animals' intake and digestibility. Microbes require large amounts of protein to maintain fermentation (Owensby *et al*., 1996). Likewise, the fodders of all the investigated browse species contained high levels of ADF, which were even more in the fodders of *S. robusta* and *A. vulgaris*. The ADF, which includes cellulose and lignin, is the least digestible plant component of the fodders. The ADF is inversely proportional to the digestibility of the fodders and lowers the energy content of the fodders (Upreti and Shrestha, 2006). This could also be another reason responsible for the lower quality of experimented fodders.

The rate of passage in the ruminant's gastrointestinal (GI) tract is determined by the digestibility of fodders. The fodders low in the cell wall, fiber and lignin contents have a faster rate of passage and increased intake to animals. Ruminants cannot compensate for poor-quality diets by consuming more fodders because of their digestive system (Owensby *et al*., 1996). The results of this experiment had also supported this report.

Body weight gain

A significantly superior (p<0.01) body weight gain was obtained from the Mixed fodder treatment than all the investigated pasture browse species in the experiment (Table 4). The *W. fruticosa* fodder had attained the highest body weight gain of goats among the pasture browse species tested in the experiment. Superior nutrient contents, comparatively higher fodder DMI per kg metabolic weight and better digestibilities of nutrients (especially CP and NDF fractions) might be the reasons associated with the higher body weight gain for *W. woordifordia* fodders compared to other browse species. It is nevertheless not considered good quality fodder. Compared to Mixed fodder, *W. woordifordia* was significantly inferior (p<0.01) in nutrient compositions, fodder DMI, digestibilities of nutrients, and body weight gain of goats.

In the experiment, *B. arundinacea* was also obtained as a substandard fodder in terms of fodder nutrient composition, digestibility of nutrients, and body weight gain. In spite of its better TA content with superior digestibility, the lower CP content with lesser digestibility and lower fodder DMI could have resulted the smaller body weight gain. The higher ADL content in this fodder was supposed to be another factor responsible for the lower body weight gain of the goats. The ADL is inversely proportional to the fodder intake (Harper and McNeill, 2015), and that may be the reason associated with lower fodder DMI per kg metabolic weight, which ultimately could have resulted to lower body weight gain of goats in the experiment.

Likewise, *S. robusta* and *C. tribuloides* were also obtained as the fodders of substandard quality on the basis of nutrient composition (Table 1). The dropped DMI and accordingly declined productivity are the major consequences of the inferior fodder quality (Owensby *et al*., 1996). The lower digestibilities of CP and fiber fractions of these fodders could be responsible for attaining the poor body weight gain (Table 4). As ADL forms complexes with hemicellulose, which is otherwise digestible, higher ADL content reduces nutritional digestibility (Khanal and Upreti, 2008). High lignin and high ADF content in the fodders (Table 1) could have declined the nutrient digestibility of *S. robusta* and *C. tribuloides* in this experiment.

Table 4: *The body weight gains of the male goats fed with fodders of different pasture browse species during a 120-day experimental period.*

Fodders browse	Initial body weight, kg	Final body weight, kg	Body weight gain in 120 days, kg
Woodfordia fruticosa	10.37±1.09	15.60±2.09^{b}	5.35±0.51^{b}
Castanopsis tribuloides	10.25±0.53	11.62±1.19^{cd}	1.36±0.73^{cd}
Bamboosa arundinacea	10.20±0.74	11.13±2.70^{cd}	0.93±0.19^{d}
Artemisia vulgaris	10.63±1.14	9.65±1.28^{d}	-0.97±0.13^{e}
Shorea robusta	10.95±1.04	13.29±2.26^{bc}	2.34±0.46^{c}
Mixed fodder	10.32±1.26	19.86±2.39^{a}	9.47+1.51^{a}
Significance	NS	P<0.01	P<0.01

The *A. vulgaris* is seemed to be the most inferior fodder in terms of nutrient contents, fodder DMI per kg metabolic weight, nutrient digestibility especially CP and fiber fractions, and also the weight gain in a 120-day experimental duration. The experimental animals fed with the fodder of *A. vulgaris* had obtained negative body weight gain (Table 4). Notwithstanding the better TA and CP contents in *A. vulgaris* fodder, extremely low fodder intake (Table 2), quite higher ADF content (Table 1), lesser digestibilities of nutrients (Table 3) and the higher level of anti-nutrient factors (Pandey *et al*., 2017) could have contributed to the negative weight gain in goats during the 120-day experimental duration. Although *A. vulgaris* fodder had higher CP content, the presence of elevated levels of anti-nutritional factors could have interfered with the digestion of CP (Table 3). The tannin (condensed tannin, CT), one of the anti-nutritional factors presented in *A. vulgaris* fodder, contributes to the reduction of fodder intake, fodder quality and overall digestibility of fodder (Pandey *et al*., 2017). The CT is highly negatively correlated with NDF, ADF and ADL digestibility of the fodders (Mekonnen *et al*., 2009).

In the study, the fodder nutrient compositions of all the investigated pasture browse species were found at substandard levels. Most of them were lower in the CP and TA contents. When the nitrogen or CP concentration of the fodder is decreased and the concentration of fiber components is increased, the amount of fodders intake decreases (Owensby *et al*., 1996). Moreover, there were lower nutrient digestibilities of investigated pasture browse species than the average standard, which were not able to satisfy the reasonable body weight gain of goats. The digestibilities of NDF and ADF were obtained further lower which could have decreased the overall digestibilities of the fodder nutrients. The digestibility of NDF is determined to predict the total digestibility of fodders in recent times (Hoffman *et al*., 2022). From the perspectives of the nutrient compositions, fodder DMI per kg metabolic weight, body weight gain and digestibility of nutrients, the results of the experiments revealed that the fodders of all the investigated pasture browse species were inferior to the Mixed fodder treatment.

The findings of the study indicated that the native hill goats in the Nepali middle hills reared solely on grazing on browse species, without supplementations of concentrate feed or quality fodders, are severely undernourished.

Conclusions and Recommendations

The pasture browse species; *Woodfordia fruticosa* Kurz, *Castanopsis tribuloides* (Sm.) Lindl., *Bamboosa arundinacea* (Retz.) Willd., *Artemisia vulgaris* Willd. and *Shorea robusta* Roth. in the Nepali middle hills are substandard in quality in terms of nutrient compositions and nutrient digestibilities. These browse species are moderate in CP content, although, the digestibilities of their crude protein are poorer. The fiber qualities of these browse species are also inferior in terms of NDF and ADF contents and digestibility of fresh leaves. These browse species result lower fodder dry matter intake and accordingly poorer body weight gains of Nepali hill goats. The experiment concludes that these pastures browse species of Nepali middle hills are substandard to meet the nutrient requirement of Nepali hill goats for commercial goat production unless they are supplemented.

Therefore, if goats are fed or grazed on these pasture browse species that are prevalent in the Nepali hills, it is necessary to supplement them with high-quality fodders.

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Novelty Statement

The browse species of the middle hill of Nepal were not found sufficiently nutritive for the goats. It necessitates the nutrient supplements to goats that are reared in forest browsing systems and also opens the area for future research in these areas.

Conflict of interest

The authors have declared no conflict of interest.

References

Akinmoladun, O.F., 2022. Effect of processing methods on chemical and nutrient composition of Bamboo (*Bambusae arundinacea*) leaves. J. Anim. Pl. Sci., 32(2): 330-335.

AOAC, 1990. Official methods of analysis of the association of official analytical chemist. 15th ed. Association of Official Analytical Chemists, Washington DC

AOAC, 2019. Official methods of analysis of the association of official analytical chemist. Official methods of analysis of aoac international. 21st ed. Association of Official Analytical Chemists, Washington DC.

Burke, J.L., G.C. Waghorn, I.M. Brookes, G.T. Attwood and E.S. Kolver. 2000. Formulating total mixed ration from forages- defining the digestion kinetics of contrasting species. Proceedings of New Zealand Society of Animal Production, 60: 9-14.

Dhakal, B., S. Subedi, B. Khanal, B. and N.R. Devkota. 2019. Assessment of major feed resources and its utilization in Manaslu conservation area (MCA), Nepal. J. Agric. For. Univ., 3: 133-143.

Ghimire, R.P., 2013. Fodder management strategies and their challenges for commercial goat production in Nepal. In: Gurung, T.B., B.R. Joshi, U.M. Singh, B.S. Shrestha, K.P. Rijal, and D.R. Khanal, editors. The Proceedings of the National Research and Development Strategies for Goat Enterprises in Nepal. September 27-28, 2012; Kathmandu, Nepal, pp. 24–41.

Goering, H.K. and P.J. Van Soest. 1970. Fodder fiber analysis. USDA Agriculture Handbook No. 379. USDA_ARS, Washington DC.

Gregorini, P., E.M.K. Miniee, W. Griffiths and J.M. Lee. 2013. Dairy cows increase ingestive mastication and reduce ruminative chewing when grazing chicory and plantain. J. Dairy Sci., 96: 7798-7805. https://doi.org/10.3168/jds.2013-6953

Harper, K.J. and D.M. McNeill. 2015. The role of iNDF in the regulation of feed intake and the importance of its assessment in subtropical ruminant systems (the role of iNDF in the regulation of forage intake). Agriculture, 5: 778-790. https://doi.org/10.3390/agriculture5030778

Hoffman, P.C., R.D. Shaver, D.K. Combs, D.J. Undersander, L.M. Bauman and T.K. Seeger. 2022. Understanding NDF digestibility of forages. Team Forage, University of Wisconsin-Madison (https://ffyi.extension.wisc.edu/forage/understanding-ndf-digestibility-of-forages/). Retrieved on Nov 08, 2022.

Khanal, R.C. and C.R. Upreti. 2008. Evaluation of selected species of tree fodders cultivated for feeding ruminants in hills of Nepal. Pak. J. Anim. Nutr., 7(2): 297-302. https://doi.org/10.3923/pjn.2008.297.302

Mekonnen, K., G. Glatzel and M. Sieghardt. 2009. Indigenous and exotic woody plant species in the highlands of central Ethiopia. Mount. Res. Dev., 29(2): 135-142. https://doi.org/10.1659/mrd.1098

Murney, R., V. Burggraaf, N. Mapp, E. Ganche and W. King. 2019. The effect of cultivated mixed-species green fodder in intake, milk production and milk composition of housed dairy goats. Animal, 13(12): 2802-2810. https://doi.org/10.1017/S1751731119000867

NAMDP, 2018. Goat meat sector assessment and strategy. In: Nepal Agricultural Market Development Program. Government of Nepal, Embassy of Switzerland, CEAPRED and Swisscontact. 50p. https://beamexchange.org/uploads/filer_public/d5/49/d549a6be-6b07-4916-97b6-514c931dd80a/goat_sector_analysis_and_strategy_compressed.pdf.

Nepali, M.B., M.R. Tiwari, S. Sapkota, H.P. Poudel, B.R. Acharya and S. Gautam. 2007. Marketing constraints to goats in the Western hills of Nepal. Nepal Agric. Res. J., 8: 95-102. https://doi.org/10.3126/narj.v8i0.11601

Owensby, C.E., R.C. Cochran and L.M. Auen. 1996. Effect of elevated Carbon dioxide on forage quality for ruminants. Carbon Dioxide, Populations and Communities, pp. 363-371. https://doi.org/10.1016/B978-012420870-4/50056-6

Pandey, B.P., R. Thapa and A. Upreti. 2017. Chemical composition, antioxidant and antibacterial activities of essential oil and methanol extract of *Artemisia vulgaris* and *Gaultheria fragrantissima* collected from Nepal. Asia Pac. J. Trop. Med., 10(10): 952-959. https://doi.org/10.1016/j.apjtm.2017.09.005

Pandey, L.N., M. Kam, S.B. Pandey, C.R. Upreti, N.P. Osti and A.A. Degan. 2009. Indigenous knowledge of fodder tree selectivity by local goats in the mid-hills of Nepal. J. Enterp. Communities: People and Places in the Glob. Econ. 3: 241-255.

Pariyar, D., K. Shrestha and R. Poudyal. 2013. Package of practice for yearround fodder production for commercial goat farming for different agro-regions. In: Gurung, T.B., B.R. Joshi, U.M. Singh, B.S. Shrestha, K.P. Rijal and D.R. Khanal, editors). The Proceedings of the National Research and Development Strategies for Goat Enterprises in Nepal. September 27-28, 2012, Kathmandu, Nepal, pp. 42–55.

R-CoreTeam, 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Website: http://www.r-project.org/

Sanon, H.O., C. Kabore-Zoungrana and I. Ledin. 2007. Behaviour of goats, sheep and cattle and their selection of browse species on natural pastures in a Sahelian area. Small Rumin. Res., 67(1): 64-74. https://doi.org/10.1016/j.smallrumres.2005.09.025

Thapa, S., J. All and R.K.P. Yadav. 2016. Effect of livestock grazing pastures in the Manaslu Conservation Area, Nepalese Himalaya. Mt. Res. Dev., 36(3): 311-319. https://doi.org/10.1659/MRD-JOURNAL-D-13-00066.1

Upreti, C.R., and B. Shrestha. 2006. Feedstuffs and animal production in Nepal- Basic principles of nutrient contents in feeds and fodders and their utilization. Nutrient Contents of Feeds and Fodders in Nepal. Animal Nutrition Division, Nepal Agricultural Research Council, Kathmandu, Nepal.

Van Soest, P.J., J.B. Robertson and B.J. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74(10): 3583-3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Vanmala, V.B., A.G. Mhase, A.M. Gurav and S.N. Murthy. 2014. Preliminary pharmacognostic and phytochemical standarization of Dhataki (*Woodfordia fruticosa* (L.) Kurz.) leaves. AYU J., 35(3): 309-315. https://doi.org/10.4103/0974-8520.153752

Wood, C.D., B.N. Tiwari, V.E. Plumb, C.J. Powel, B.T. Roberts and M. Gill. 1995. Intraspecific differences in ash, crude protein contents and protein precipitation activity of extractable tannins from Nepalese fodder trees. Trop. Sci., 35: 376-385.