

Chemical Composition and Condensed Tannin Content of Major Livestock Feeds from Borana Rangeland, Southern Ethiopia

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Abstract:

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Studies on available feed resources and their nutritional values are important. This study aimed to investigate chemical composition and Condensed Tannin (CT) content of major feed resources in Moyale district of Borana rangeland, southern Ethiopia. Samples were collected from major feed resources: five browse species (*Acacia brevispica*, *Acacia mellifera*, *Commiphora africana*, *Dichrostachys cinerea* and *Grewia tembensis*), five grasses (*Cenchrus ciliaris*, *Chrysopogon aucheri*, *Digitaria milanjiana*, *Eragrostis capitulifera* and *Panicum maximum*), mixed natural pasture, two crop residues (maize stover and haricot bean straw), wheat bran and two herbaceous legumes (*Indigofera volkensii* and *Commelina africana*). Samples were analyzed for ash, Dry Matter (DM), Crude Protein (CP), Neutral-Detergent Fiber (NDF), Acid-Detergent Fiber (ADF) and CT. There were variations in chemical composition and CT of the investigated feeds. For the browse species, CP (15.50 -19.08%), NDF (55.38-65.96%) and CT (1.32-24.71%) were found. For the grasses, CP (7.34-8.78%), NDF (67.20-76.41%) and CT (0.86-2.07%); and for mixed natural pasture, CP (11.28%), NDF (71.50%), and CT (1.01%) contents were recorded. For the crop residues, maize stover CP (3.13%) and NDF (73.55%), and haricot bean straw CP (4.74%) and NDF (70.03%) were found. The CP and NDF contents of wheat bran were 18.06% and 45.45%, respectively. For the legume forage species, CP (17.06%), NDF (57.30%) and CT (2.04%) for *Indigofera volkensii*, and CP (11.32%), NDF (73.03%) and CT (0.60%) for *Commelina africana* were recorded. In conclusion, the relatively high CP content of the browse species can be used as protein supplement to low-quality feeds during the dry season. Furthermore, the CT content of the browses (except *Dichrostachys cinerea*) and legume forages was in the level that promotes positive rumen effects. However, further studies entailing more browse species, detailed nutrient analysis, and involving animal feeding trials should be carried out for better screening of potential feeds in the study area.

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Keywords: Browse species; Chemical composition; Crop residues; Legume forages; Moyale district

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1. Introduction

Ethiopia has huge livestock population, estimated at 70 million cattle, 42 million sheep, 52 million goats, 8 million camels and 56 million chickens ([Agency,](#)

[2021](#)). The livestock sector contributes significantly to the livelihood of households and the country's macro and micro economies. As to [GebreMariam et al. \(GebreMariam et al., 2013\)](#), the livestock sector contributed 37-87% of household incomes, 35-40% of agricultural

Gross Domestic Product (GDP) and 15-17% of national GDP. In Ethiopia, the pastoral and agro-pastoral livestock production systems account for 61% of the country's total land mass (Tofu et al., 2023) supporting more than 10 million people and account to 8%, 100%, 70% and 50% of the national cattle, camels, goats and sheep population, respectively, in 2019, and the system is a multi-billion-dollar economy contributing significantly to the national economy of the country (for Pastoral Areas & Development), 2020).

Despite the huge livestock number and its significant contributions, the livestock sector in Ethiopia is characterized by its low productivity attributed to different factors including low production potential of the indigenous breeds, poor quality and varying seasonal availability of feeds, high disease incidence and parasite challenges, and low accessibility to services and inputs (Entropy, 2021) of which poor nutrition is the major one (Zereu & Lijalem, 2016). Mengistu et al. (Mengistu et al., 2017) reported that feed in terms of both quantity and quality is the bottleneck to livestock production in Ethiopia.

Feed is the most important input in livestock production and its adequate supply throughout the year is an essential prerequisite for substantial and sustained expansion in livestock production (Legesse et al., 2010; Samuel et al., 2008). In the Ethiopian rangelands, livestock feeds are primarily obtained from natural grasses, browses and bushes; however, there are large seasonal fluctuations in feed availability and quality (Mengistu et al., 2018). Good-quality browse species can be used to supplement low-quality natural pastures during the dry season (Hassen et al., 2017). On the other hand, most browse species are known to contain various compounds called anti-nutritional factors that limit their potential use as feed resources (Aster, 2010). Anti-nutritional factors are plant secondary metabolites that lower nutrient content and reduce intake by livestock (Abu Hafsa et al., 2022). Tannins are plant secondary metabolites produced as defense mechanism to abiotic and biotic stressors (Iqbal & Poór, 2025). Although there are diverse types of tannins in nature, the most abundant are grouped as CT and hydrolysable (HT) based on their chemical structure (Naumann et al., 2017). CT is found dominantly in nutritionally important and commonly consumed forages, trees, shrubs and legumes (Pandey et al., 2022). Depending on their type and chemical nature, the amount ingested by the animal, the composition of the diet especially crude protein content, CT can have beneficial or detrimental effects (Mueller-Harvey, 2006). Low to medium concentration (<50 g/kg DM) is generally considered to have beneficial effects (Pandey et al., 2022). Recently, there is a growing interest of using tannin containing plant feeds and plant extracts in ruminant diets to improve the quality of animal products (Tong et al., 2022). In ruminant nutrition, CT have been used as feed additives (Min et al., 2021), have antioxidant effects on animals and in their products (Soldado et al., 2021), found to improve body weight gain, change

ruminal bacterial community structure and reduce CH₄ emissions (Min et al., 2021).

For the improvements in animal production and productivity, an assessment should be done on the types and sources of livestock feeds (Endale, 2015). Further studies that aim to integrate feeds that have better nutritive values into the feeding system are required to evaluate feed intake, digestibility, and level of inclusion of supplementary feeds, animal's responses and anti-nutritional factors for more efficient utilization of indigenous and adapted feed resources for sustainable animal production (Deribe, 2015).

Lack of information on the nutritional quality of feeds could bring poor productivity and susceptibility to disease in livestock (Bayissa et al., 2022). Knowing the chemical composition of a feed is the primary step to evaluate its nutritive value. According to Gebremariam and Belay (Gebremariam & Belay, 2021) and Bayissa et al. (Bayissa et al., 2022), information on nutritional profiles of available feed resources in a given locality is needed for better understanding and efficient utilization, and hence, the improvement of livestock productivity. In the present study area—Moyale district, natural pasture, crop residues and agro-industrial by-products are the major feed resources (Hassan et al., 2020). However, information on chemical composition and CT content of the major feed resources in the study area is scanty. Hence, this study aimed to investigate the chemical composition and CT content of major feed resources available in Moyale district of Borana zone, southern Ethiopia.

2. Materials and methods

2.1 Description of the study area

This study was carried out in Moyale district Figure 1 of Borana zone, Oromia regional state, Ethiopia. The district is located at 775 km south of Addis Ababa, the capital of city of Ethiopia, and has an area of 14,810 km². The altitude of the district ranges from 1150 to 1350 m above sea level. The study area is located at 03°24'04" N latitude and 37°01'04" E longitude (Abiy, 2007). Moyale Town is split between Ethiopia and Kenya and straddles two of Ethiopia's regions (Oromia and Ethio-Somalia). The larger part is in Ethiopia's Oromia and Ethio-Somalia regions, and the smaller part is in Kenya (Security et al., 2010). The area is characterized by semi-arid lowlands and is predominantly occupied by pastoral and agro-pastoral populations whose livelihood is mainly dependent on range-based livestock production. The population is mainly composed of the Borana, and Gabra Oromo in Moyale district of Borana zone (Tolera & Abebe, 2007).

2.2 Sample collection and preparation

Representative samples from six feed types: five browse species (*Acacia brevispica*, *Acacia mellifera*, *Commiphora africana*, *Dichrostachys cinerea* and *Grewia tembensis*), five grass species (*Cenchrus ciliaris*, *Chrysopogon aucheri*, *Digitaria milaniana*, *Eragrostis*

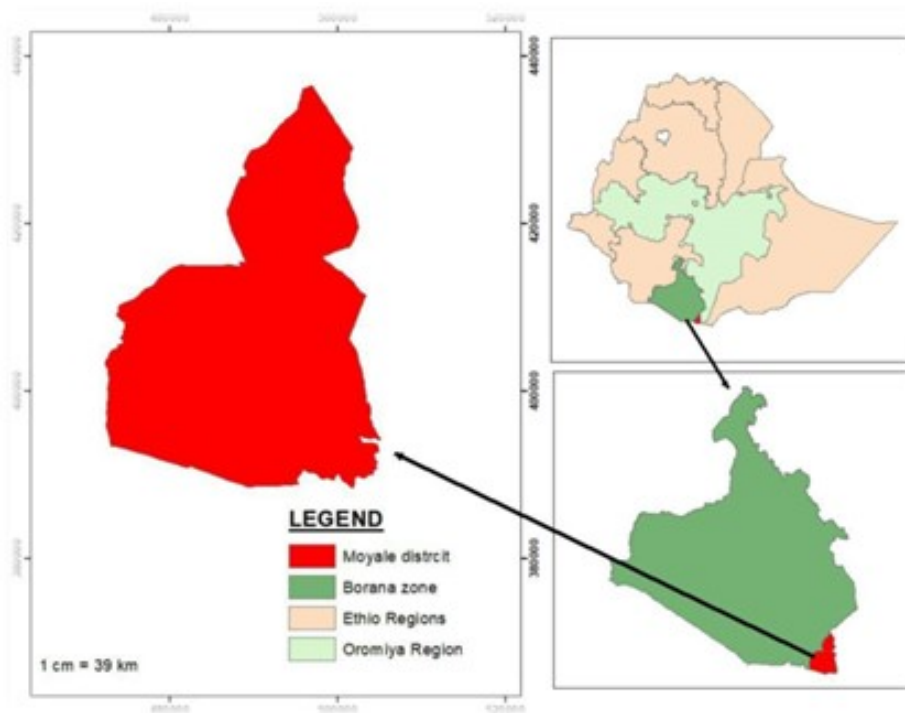


Figure 1. The location of the study area, Moyale district, Southern Ethiopia

capitulifera and *Panicum maximum*), one mixed natural pasture, two crop residues (maize stover and haricot bean straw), wheat bran and two herbaceous legumes (*Indigofera volkensii* and *Commelina africana*) most commonly used feed resources identified and ranked by farmers during feed resource assessment part of this research (Hassan et al., 2020) were used. Grasses, browse species, and herbaceous legumes were sampled at the end of the rainy season of the study area. The species of plants in the collected samples were identified and listed by their vernacular names and their scientific names were obtained from previous research reports from the current study area.

For the browse species, samples were harvested from at least 10 plants per species selected at random from each of the five selected kebeles (kebele is the smallest administrative unit of the Ethiopian Federal Government). Leaf samples were taken at three heights (top, middle and bottom of the trees). Other edible parts like pods, twigs and seeds were included and mixed thoroughly and sub-sampled for analysis. Samples for the herbaceous legume species were obtained from the grazing areas in each kebele mixed thoroughly and sub-sampled for analysis. Five grass species and one mixture of natural pasture, dominant, highly ranked and accepted by farmers were collected from each of the selected kebele (Hassan et al., 2020) mixed carefully per species and representative samples were taken for analysis.

Two top-ranked crop residues (maize stover and haricot bean straw) and wheat bran were collected from farmers, mixed thoroughly and subsampled. Careful labeling of feed samples was done during collection and

preparation. Three sub-samples for each feed type were taken for analysis. The samples were dried partially at 60°C for 48 h. The partially dried samples were ground using Thomas Willy mill (Model 4) to pass through a 1mm sieve for chemical composition analysis and a 0.5mm sieve for CT analysis. The ground samples were placed in air-tight plastic pockets and stored properly until analysis. The analysis was done at Hawassa University, Animal Nutrition Laboratory

2.3 Chemical analysis of feed samples

The DM content of all samples was determined by drying in air-forced oven at 105°C for 12 hrs (of Official Analytical Chemists, 2000). The total Nitrogen (N) content of all samples was determined by the Kjeldahl method (of Official Analytical Chemists, 2000) and then, CP content was calculated as $N \times 6.25$. The ash content of the samples was determined by complete burning in a muffle furnace at 600°C for 6 hours (of Official Analytical Chemists, 2000). Ether extract (EE) was extracted using the Soxhlet method. The NDF, ADF and acid detergent lignin (ADL) were analyzed according to the procedures of Van Soest et al. (Van Soest et al., 1991).

2.4 CT determination of feed samples

The CT was determined using 70% aqueous acetone and Butanol-HCl procedures and expressed as leucocyanidin equivalent (% of DM) (Makkar et al., 2007). Absorbance was measured spectrophotometrically at 550nm. The concentrations of condensed tannins were

calculated from tannic standard curve by the formula:

$$\text{Condensed tannins Conc.} = \frac{\text{Absorbance at 550 nm} \times 78.26 \times \text{Dilution factor}}{\%DM}$$

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).

2.5 Statistical analysis

The data on chemical composition and CT of the major feed samples were subjected to analysis of variance using General Linear Model procedures of SPSS version 20. Mean separation was performed by Tukey method at 5% level of significance. The results were organized and summarized in Tables.

3. Results

3.1 Chemical composition and CT content of browse and grass forage species

Browse species. The chemical composition and CT content of leaves and fine stems (twigs) of selected browse species is presented in Table 1. There were significant variations ($P < 0.05$) in chemical composition of the browse species, except for EE. DM content ranged from 84.12% in *Commiphora africana* to 95.24% in *Acacia mellifera* species. The lowest ash content (5.47%) was observed in *Dichrostachys cinerea*, while the highest value (11.45%) was found in *Commiphora africana*. The highest (19.08%) and the lowest (15.55%) CP content was observed in *Acacia mellifera* and *Grewia tembensis*, respectively. The NDF content ranged from 55.38% in *Acacia brevispica* to 65.96% in *Dichrostachys cinerea*; ADF content ranged from 28.19% in *Acacia mellifera* to 44.02% in *Dichrostachys cinerea*; the highest (17.46%) and the lowest (3.64%) ADL content was found in *Dichrostachys cinerea* and *Acacia mellifera*, respectively, in the present study (Table 1).

The results for CT content of the browse species showed wide variations ranged from 1.32% for *Commiphora africana* to 24.71% for *Dichrostachys cinerea* (Table 1).

Grass species. The chemical composition and CT content of selected grass species in the study district are presented in Table 2. There were significant variations ($P < 0.05$) in chemical composition, except EE, ADL and CT. Ash (16.56%) and CP (11.28%) contents were higher for *Digitaria milanjiana* and the mixture of natural pasture. *Eragrostis capitulifera* and *Panicum maximum* had the lowest ash (9.23%) and CP (7.34%) contents, respectively. The highest NDF (76.41%) content for *Eragrostis capitulifera* and the lowest NDF (67.20%) for *Cenchrus ciliaris* were observed. *Eragrostis capitulifera* had the highest ADF (49.70%) while *Digitaria milanjiana* had the lowest ADF (40.96%) contents. Regarding the ADL content, the highest (9.21%) was for *Digitaria milanjiana* and the lowest (5.17%) for *Cenchrus ciliaris* (Table 2).

3.2 Chemical composition and CT content of crop residues and legume forages

Crop residues and wheat bran. The chemical composition and CT content of crop residues (maize stover and haricot bean straw), wheat bran and legume forages (*Indigofera volkensii* and *Commelina africana*) are presented in Table 3. There were significant variations ($P < 0.05$) in chemical composition among the crop residues except DM and EE. CP content in the present study was (3.13%) for maize stover and (4.74%) for haricot bean straw. The NDF content was significantly higher ($P < 0.05$) in maize stover than haricot bean straw, while ADF and ADL were significantly higher ($P < 0.05$) in haricot bean straw than maize stover.

Herbaceous legume forages. The chemical composition of herbaceous legume forage species (*Indigofera volkensii* and *Commelina africana*) showed significant variations ($P < 0.05$), except EE (Table 3). DM content was 80.53% and 79.44% for *Indigofera volkensii* and *Commelina africana*, respectively. Higher CP content for *Indigofera volkensii* than CP content (11.32%) for *Commelina africana* was observed. Higher NDF (73.03%), ADF (53.91%) and ADL (11.87%) contents were also observed for *Commelina africana* than the NDF (57.30%), ADF (29.12%), and ADL (3.72%) contents for *Indigofera volkensii*. Regarding the CT content, a higher value (2.04%) for *Indigofera volkensii* than the value (0.60%) for *Commelina africana* (Table 3).

4. Discussion

4.1 Chemical composition and CT content of browse and grass forage species

Browse species. According to Turgut and Yanar (Turgut & Yanar, 2004), variations in nutrient composition of forages could be attributed to variety, stage of maturity during harvesting, soil type, weather conditions and management practices such as level of fertilization. The results of the present study (Table 1) revealed that there was variation in chemical composition, except EE and CT content of browse species. The ash content of browse species in the current study (5.47-11.07%) was slightly lower than the range (7.9-17.03%) reported by Fekade et al. (Fekade et al., 2020) from Central Gondar, Ethiopia. Higher ranges of ash content (8-18%) than the values of the present study were also reported by Njidda (Njidda, 2010) for semi-arid browses from North-Eastern Nigeria.

The highest CP content of browse species in the present study ranged from 15.55-19.08% was comparable to the values of 19.7% (Abebe et al., 2012) and 18.7% (Welay et al., 2018) reported from Borana and Mieso rangelands, Ethiopia. The CP content of browse species in the present study was in the range of 12.13 to 29.74%, reported by Fekade et al. (Fekade et al., 2020) from Central Gondar, Ethiopia and that of Ebrahim et al. (Ebrahim et al., 2023) who reported 9.96-22.23% for browse species from Northern Ethiopia. Variations in CP content between the browse species may result

Table 1. Chemical composition and CT content (%) of leaves and fine stems (twigs) of browse forage species in the study area.

Browse species	Chemical components							
	DM%	Ash%	CP%	EE%	NDF%	ADF%	ADL%	CT%
	%DM							
<i>Grewia tembensis</i>	94.83 ^a	9.96 ^b	15.55 ^d	8.45	64.73 ^{ab}	33.71 ^c	7.86 ^b	1.66 ^b
<i>Acacia brevispica</i>	95.22 ^a	5.89 ^d	16.99 ^c	7.45	55.38 ^c	32.15 ^c	10.29 ^b	3.39 ^b
<i>Dichrostachys cinerea</i>	91.60 ^b	5.47 ^d	18.34 ^b	6.72	65.96 ^a	44.02 ^a	19.26 ^a	24.71 ^a
<i>Commiphora africana</i>	84.12 ^c	11.45 ^a	17.04 ^c	8.78	62.02 ^{abc}	42.13 ^{ab}	17.46 ^a	1.32 ^b
<i>Acacia mellifera</i>	95.24 ^a	8.07 ^c	19.08 ^a	7.15	56.53 ^{bc}	28.19 ^d	9.03 ^b	3.64 ^b

Means with different superscript letters (a-d) in a column are significantly different ($P < 0.05$).

DM= dry matter, CP =crude protein, EE = Ether Extract, NDF= neutral detergent fiber,

ADF= acid detergent fiber, ADL= acid detergent lignin, CT= condensed tannins.

Table 2. Chemical composition and CT content (%) of selected grass species in the study area.

Grass Species	Chemical components							
	DM%	Ash%	CP%	EE%	NDF%	ADF%	ADL%	CT%
	%DM							
<i>Cenchrus ciliaris</i>	85.07 ^c	12.95 ^b	8.37 ^b	9.24	67.20 ^c	43.52 ^{bc}	5.17	1.16
<i>Digitaria milanijana</i>	91.21 ^b	16.56 ^a	8.78 ^b	9.02	72.32 ^b	40.96 ^c	9.21	2.07
<i>Panicum maximum</i>	92.06 ^b	12.33 ^b	7.34 ^c	6.93	76.28 ^a	47.71 ^{ab}	7.09	1.45
<i>Chrysopogon aucheri</i>	83.52 ^c	10.04 ^c	8.02 ^{bc}	8.35	75.08 ^{ab}	45.10 ^{abc}	6.81	0.86
<i>Eragrostis capitulifera</i>	96.02 ^a	9.23 ^d	7.85 ^c	6.46	76.41 ^a	49.70 ^a	8.78	1.49
Mixture of natural pasture	85.26 ^c	12.83 ^b	11.28 ^a	8.21	71.50 ^b	41.11 ^c	8.38	1.01

Means with different superscript letters (a-c) within a column are significantly different ($P < 0.05$).

DM= dry matter, CP =crude protein, EE = Ether Extract, NDF= neutral detergent fiber,

ADF= acid detergent fiber, ADL= acid detergent lignin, CT= condensed tannins.

from differences in protein accumulation during growth (Salem et al., 2006). All the browse species in the present study were found to contain CP concentration above the values 11% for maintenance and 13% for growth need of ruminant animals (Asaolu et al., 2011). The relatively high CP content of the browse species, in the present study, could make them suitable as protein supplements to poor-quality pasture and fibrous crop residues.

Slightly comparable values of NDF (40.8-65%) to the present study results (55.38-65.96%) were reported by Welay et al. (Welay et al., 2018), while lower values (20.93-47.51%) were reported by Fekade et al. (Fekade et al., 2020). Lower NDF value (31.8%) than the present result, for *Acacia brevispica* was reported by Abebe et al. (Abebe et al., 2012). Merga et al. (Merga et al., 2016) also reported lower NDF contents (25.4-43.2%) for browse species. Lower range of ADF (12.10-32.35%) than the present study was reported by Fekade et al. (Fekade et al., 2020). Compared to the ADF content (28.19%) of *Acacia mellifera* in the present study, lower value (25.3%) was reported by Welay et al. (Welay et al., 2018). For *Grewia tembensis*, a slightly higher ADL content (9.2%) than the present result was reported by Welay et al. (Welay et al., 2018) from Mieso rangeland, Ethiopia. Such variations could be attributed to species, season of harvest, plant part or fraction and age of the browse species.

Plant species, plant part, stage of growth and season can influence the concentration of CT (Li et al., 2014). Besides, several factors such as initial harvesting, drying and extraction method of the forage material are known to have significant effects on CT analysis. The variations in CT concentration within plant species can be more than 4 to 6-folds depending on plant provenance (Schofield et al., 2001). A review by Min et al. (Min et al., 2003) showed that high (> 5.5%) concentration of CT in forages reduces voluntary feed intake, digestibility, body and wool growth rates in grazing ruminants. According to Merga et al. (Merga et al., 2016), high tannin content (>10% DM) in browse species could limit their optimal utilization and depress their nutritive values. A review by Naumann et al. (Naumann et al., 2017) showed that CT in concentrations below 5% DM has beneficial effects on ruminant production by enhancing rumen bypass protein and carbohydrates, preventing bloat and helminthiasis and lowering the emissions of greenhouse gas. The CT contents of browse species in the present study, except *Dichrostachys cinerea* could have such beneficial effects when fed to ruminants. On the other hand, the high (24/71%) CT of *Dichrostachys cinerea* could have negative effects when consumed by ruminants.

Grass species. The CP content of grasses in the present study (ranged from 7.34-8.78%) was slightly lower than the CP (8.54-12.90%) values reported by

Bayissa et al. (Bayissa et al., 2022) from Haru District, Ethiopia. A comparable CP value (13.20%) to the present study was reported by Gebremariam and Belay (Gebremariam & Belay, 2021) for green grass. The CP (11.28%) content of mixture natural pasture found in the present study could be suitable as protein supplement to poor-quality pasture and fibrous crop residues. Such variations could be due to different factors, including maturity difference at harvesting, soil and climate factors, species, cultivar/variety difference, handling and management variation during harvesting and curing. Feeds containing less than 8% CP are unable to provide the minimum level of ammonia in the rumen that promotes optimum microbial activity (Norton, 1994). All the grass species in the present study had CP content of greater than 7% required for the maintenance requirement of ruminants (Bayissa et al., 2022). Furthermore, for optimum activity of micro-organisms in the rumen, about 6–8% rumen degradable CP is required (Coleman & Moore, 2003) the level which the grasses in the present study contained.

Comparable NDF (69.70%) but lower ADF (35.90%) and ADL (6.00%) to the present study were reported by Gebremariam and Belay (Gebremariam & Belay, 2021) for green grass. Compared to the present result, higher NDF (74.9%) and ADF (65.4%) contents for *Cenchrus ciliaris* are reported by Abebe et al. (Abebe et al., 2012) from Borana rangeland, southern Ethiopia. According to Singh and Oosting (Singh & Oosting, 1992), forages containing above 65% NDF are considered as poor quality feeds. Therefore, the results of the present study reveal that such feeds have to be supplemented with high-quality feeds and/or need treatment to improve their quality.

Consistent with the results of the present study, Mueller-Harvey (Mueller-Harvey, 2006) reported that typically, grasses don't contain tannins, but the concentration of tannins can vary widely between and within species. The growth stage, plant part and management conditions have an impact on tannin concentration. Furthermore, several factors are known to have significant effects on CT analysis. Such factors include initial harvesting, drying and extraction method of the forage materials (Schofield et al., 2001).

4.2 Chemical composition of crop residues, wheat bran and herbaceous legume

Crop residues. The ash content (9.22%) of maize stover in the present study was in the range of 6.89–9.35% reported by Bayissa et al. (Bayissa et al., 2022) from Haru District, Ethiopia, but higher than the value (4.38%) reported by Gebremariam and Belay (Gebremariam & Belay, 2021) from central Tigray, North Ethiopia.

The CP (3.13%) of maize stover in the present study was lower than the value (4.91%) reported by Gebremariam and Belay et al. (Gebremariam & Belay, 2021) from North Ethiopia. Comparable to the results to the present study, Belay et al. (2022)(Belay2022) reported

ash content (8.19%) and CP content (6.43%) for bean straw. The CP content of maize stover and haricot bean straw in the present study was below the critical level (7%) required for optimum rumen microbial function of ruminants (Van Soest, 1994). Feed resources with low CP contents need supplementation with other protein sources, especially during dry time when livestock depend mainly on standing hay and crop residues (Kassahun et al., 2016).

The NDF (73.55%), ADF (40.81%) and ADL (3.03%) contents of maize stover in the present study were lower than the NDF (76.15%), ADF (47.53%) and ADL 5.23% reported by Gebremariam and Belay (Gebremariam & Belay, 2021) and the NDF (78.19%), and ADF (55.37%) reported by Bayissa et al. (Bayissa et al., 2022). The ADF content of maize stover (40.81%) in this study was in the range of 19.2–48.3% reported by Kassahun et al. (Kassahun et al., 2016). The NDF (70.03%) and ADF (50.38%) contents for haricot bean straw in the present study were slightly lower than the values of NDF (72.60%) and ADF (53.77%) for bean straw reported by Bayissa et al. (Bayissa et al., 2022). The ADF of haricot bean straw in the present study was in the range (48.4–56.5%) reported by Tesfaye and Musimba (Tefaye & Musimba, 2003). According to Singh and Oosting (Singh & Oosting, 1992), fibrous feeds with NDF content of < 45%, 45–65% and > 65% were grouped as high, medium and low quality roughages, respectively. Accordingly, the maize stover and haricot bean straw analyzed in the present study are categorized as low-quality roughages and as a result, they may impose limitations on feed intake and lower performance unless supplemented and chemical and/or physical treatment is applied. Thus, supplementation and treatment of those crop residues are necessary to improve their feeding values.

Wheat bran. Wheat bran (WB) is a fraction of the outer pericarp layer left as by-product after milling (Aprich et al., 2014). The ash content (6.50%) of WB in the present study was comparable to the value (6.86%) reported by Gashaw and Defar (Gashaw & Defar, 2017), but higher than the values (5.32%) and (3.9%) reported by Eyob et al. (Eyob et al., 2017) and Mengistu et al. (Mengistu et al., 2016), respectively.

The CP content (18.06%) of WB in the present study falls in the range of 18.16–19.47% reported by Mengistu et al. (Mengistu et al., 2016). Lower CP values of 11.05% (Eyob et al., 2017), 14.43% (Gashaw & Defar, 2017), and 16.50% (Solomon et al., 2004) than the present study were reported. Higher CP (23.08%) value than the present study was reported by Bishaw and Melaku (Bishaw & Melaku, 2008).

The NDF content (45.15%) of WB in this study was comparable to different reports (Mulat, 2006; Simret, 2005), but lower than the reported NDF values of 53.78% (Mengistu et al., 2016), 61.95% (Eyob et al., 2017) and 61.2% (Tekele & Getachew, 2011). The ADF content of WB (17.02%) in the present study was comparable to the report (16.42%) by Mengistu et

Table 3. Chemical composition of maize stover, haricot bean straw, wheat bran and herbaceous legume forage species in the study area.

Feed types		Chemical components							
		DM%	Ash%	CP%	EE%	NDF%	ADF%	ADL%	CT%
		%DM							
Crop residues	Maize stover	95.00	9.22 ^b	3.13 ^b	0.56	73.55 ^a	0.81 ^b	3.03 ^b	0.50 ^a
	Haricot bean straw	94.99	10.42 ^a	4.74 ^a	0.99	70.03 ^b	50.38 ^a	8.43 ^a	0.16 ^b
AIBP	Wheat bran	95.47	6.50	18.06	3.53	45.15	17.02	5.76	0.40
HLFS	Indigofera volkensii	80.53 ^a	15.48 ^a	17.06 ^a	10.21	57.30 ^b	29.12 ^b	3.72 ^b	2.04 ^a
	ommelina africana	79.44 ^b	12.89 ^b	11.32 ^b	8.99	73.03 ^a	53.91 ^a	11.87 ^a	0.60 ^b

Means with different superscript letters (a-b) in a column within each feed type are significantly different ($P < 0.05$).

DM= dry matter, CP =crude protein, EE=Ether Extract, NDF= neutral detergent fiber, ADF= acid detergent fiber, ADL= acid detergent lignin, CT= condensed tannins; AIBP= Agro-industrial by-product; HLFS=Herbaceous Legume Forage Species

al. (Mengistu et al., 2016). Lower values (19.73 and 33.24%), than the present values were reported by Eyob et al. (Eyob et al., 2017) and Gashaw and Defar (Gashaw & Defar, 2017), respectively. The ADL (5.76%) content of WB in the present study was comparable with the value (5.85%) by Mengistu et al. (Mengistu et al., 2016) and lower than the value (9.4%) by Tekele and Getachew (Tekele & Getachew, 2011) and 6.26% by Gashaw and Defar (Gashaw & Defar, 2017), but higher than the value (3.96%) reported by Eyob et al. (Eyob et al., 2017). The discrepancies among the reports might be due to the variations in the raw material, methods of milling, and the extended storage of WB after milling.

Wheat bran contains various compounds that have potential nutraceutical functions (Chalamacharla et al., 2018). CT content (0.4%) of WB in the present study was higher than the value (0.22%) reported by Kara (Kara, 2016). CT has both positive (at low level: <3%) and negative (at high level: >5%) effects on feed digestibility and animal performance, depending on both the quantity and biological activity of the CT (Kara et al., 2015; Min et al., 2006). Based on this, the CT content of WB in present study would not have negative effects.

Herbaceous legume forages. The chemical composition of herbaceous legume forages (Table 3) shows significant variations ($P < 0.05$) except EE. The ash contents (15.48%) for *Indigofera volkensii* and (12.89%) for *Commelina africana* in the present study were lower than the value (20.12%) reported by Habtamu et al. (Habtamu et al., 2013) in semi-arid areas of Borana, Ethiopia. Herbaceous plants with CP contents in the range of 6-8% are adequate for ruminants (Ganskopp & Bohnert, 2001). On the contrary, Minson (Minson, 1990) argued that the critical level of CP content for tropical herbaceous species should be greater than 10.6%. The CP content of *Indigofera volkensii* (17.06%) and *Commelina africana* (11.32%) in the present study (Table 3) was above the critical threshold level (Ganskopp & Bohnert, 2001). Similar to the results of the present study, Habtamu et al. (Habtamu et al., 2013) reported 11.51% CP for *Commelina africana*. The EE content of

Indigofera volkensii (10.21%) was slightly higher than *Commelina africana* (8.99%). The variation in the nutritive value of herbaceous species might also be attributed to site potential in terms of differences in edaphic factors and temperature condition. The NDF (73.03%), ADF (53.91%) and ADL (11.87%) content of *Commelina africana* species were higher than *Indigofera volkensii*, with NDF (57.30%), ADF (29.12%) and ADL (3.72%) values. Lower values of structural component NDF (60.82%), ADF (47.97%) and ADL (10.53%) than the present study for *Commelina africana* were reported by Habtamu et al. (Habtamu et al., 2013) from the Semi-arid areas of Borana, Ethiopia. The degree of plant cell wall lignification may reach 12% with forage aging (Gidenne, 2015). CT is higher for *Indigofera volkensii* (2.04%) than *Commelina africana* (0.60%). Da Silva et al. (Da Silva et al., 2011) have reported that the nutritive value of rangeland forages could be affected by season and variation in temperature across a wider landscape of arid regions.

5. Conclusions

The chemical composition values from the present study indicated that the browse species had CP contents that would make them potentially as protein supplements to poor quality feeds, especially during the dry season. On the other hand, the crop residues (maize Stover and haricot bean straw) had low CP and high cell wall contents and consequently, demanded supplementation with protein supplement feeds. The CT content of the browse (except *Dichrostachys cinerea*) and legume forages was in the level below 5% that promotes positive rumen effects. However, the present results should be supported by further studies that entail more browse species, detailed nutrient analysis, and feeding trials.

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Authors contributions

All the authors have participated sufficiently in the intellectual content, conception and design of this work or the analysis and interpretation of the data (when applicable), as well as the writing of the manuscript.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The authors declare that they have no conflicts of interest.

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