

ANALYSIS OF THE ESSENTIAL OIL COMPOSITION AND NUTRITIONAL VALUE OF
THE AERIAL PARTS OF *HELICHRYSUM SPLENDIDUM* (THUB.) LESS. FROM THE
MENZE GUASSA CONSERVATION AREA, ETHIOPIA

Sisay Wube¹, Abera Seyoum¹ and Asemahegn Mersha¹

¹Ethiopian Biodiversity Institute, Forest and Range Land Biodiversity Research Executive,

ABSTRACT:The main objective of this study was to investigate the essential oil composition and nutritional value of *H. splendidum* collected from the Menze Guassa community conservation area. Aerial parts of the target species were collected at the flowering stage through purposive sampling. Three plots, each measuring 10 meters by 10 meters, were randomly placed within dense populations at two different sites. Hydro distillation of the aerial parts yielded 0.6% essential oil, and gas chromatography-mass spectrometry (GC-MS) analysis identified 48 compounds. The GC-MS results indicate that τ -Muurolol (13.49%), β -Pinene (13.21%), naphthalene derivatives (12.95%), and τ -Cadinol (9.16%) are the most prominent compounds. This specific profile suggests a unique chemotype, likely influenced by high altitude and environmental stress. Furthermore, nutritional analysis revealed a crude protein (CP) content of 7.7

5%, and the in vitro organic matter digestibility (IVOMD) result was 51.26%. The concentration of neutral detergent fiber (NDF) was 61.30%, while the metabolizable energy (ME) value was 7.42 MJ/kg. The analysis also indicated a total ash value of 5.30%. The dominance of β -Pinene and τ -Cadinol highlights the significance of antimicrobial and anti-inflammatory potential, while the high level of τ -Muurolol suggests future applications in eco-friendly pest management. The current findings underscore the importance of *H. splendidum* for both pharmacological and ecological uses, serving as an optimal forage resource for ruminants and emphasizing the need to conserve the Menze Guassa community conservation area. Further research should be conducted on bioactive assays and genetic analysis to characterize chemotype variation and ensure the sustainable utilization of this valuable plant resource.

Key words: chemotype, crude protein, forage resource, gas chromatography-mass spectrometry, τ -Muurolol,

INTRODUCTION

The genus *Helichrysum* is a highly diversified member of the Asteraceae family, comprising more than 500 species distributed worldwide, including Europe, Africa, Australia, North America, and Madagascar (Cavalli et al., 2001; Mashigo et al., 2015). In Ethiopia, 23 distinct species have been identified and recorded in the Flora of Ethiopia (Hedberg, 1996). Among these, *Helichrysum splendidum* (Thunb.) Less. is a woody shrub of the Afro-alpine ecosystem, occurring at altitudes between 2,500 and 4,300 m above sea level. The shrub is characterized by silvery-gray foliage, fragrant yellow flowers, and a typical height ranging from 20 to 75 cm (Hedberg, 1996). Its competitive growth and nutrient uptake can challenge native grasses, underscoring its ecological significance (Wube et al., 2021).

Globally, *Helichrysum* species attract considerable scientific interest due to their chemical constituents and medicinal potential. Several studies have shown that the plant contains various bioactive compounds, including flavonoids, terpenoids, and essential oils, which contribute to its antioxidant, anti-inflammatory, and antimicrobial properties (Lourens et al., 2008). Research has demonstrated that the essential oil composition of *H. splendidum* can vary significantly with geographic location and climatic conditions (Komape et al., 2014; Lourens et al., 2004; Mashigo et al., 2015; Mathekga & Meyer, 1998).

Ethiopian scholars have also reported increasing research interest in the chemical composition of essential oils (Abebe et al., 2018; Assefa et al., 2023; Black Solis et al., 2020; Buta & Kinki, 2023; Kebede et al., 2021; Matebie et al., 2023; Shiferaw et al., 2019; Tesfay et al., 2022). However, comprehensive phytochemical and nutritional data on Ethiopian *H. splendidum* populations remain scarce. This knowledge gap limits understanding of the plant's potential applications in diet and health. The lack of information not only concerns essential oil composition but also extends to the plant's traditional uses and nutritional status. Characterizing the chemical constituents could promote the sustainable use of *H. splendidum* in natural health products, cosmetics, and eco-friendly pest control. Similarly, evaluating its nutritional content may create opportunities for its use as a dietary supplement

or food additive, providing essential nutrients, minerals, and antioxidants. Assessing the nutritional content of *H. splendidum* is particularly important in the Ethiopian context, as it may enhance its utilization as a dietary supplement. In addition, such evaluations help elucidate plant adaptations in Afro-alpine ecosystems and provide data to inform sustainable management practices under increasing environmental pressures.

Despite its abundance and wide distribution in Afro-alpine ecosystems, *H. splendidum* remains underexploited in Ethiopia, although it is locally used as a fuel source and for home fumigation (Chengere et al., 2022). The motivation for conducting this research on nutritional status and essential oil composition arose during direct field observations of sheep browsing on this species, suggesting its potential as a dietary component within the study area ecosystem.

This research therefore provides a comprehensive analysis, including the chemical profile of essential oil, macronutrients, and nutritional value of the study plant. Understanding the nutritional value of these populations is crucial for assessing their potential as dietary supplements and as forage resources in Afro-alpine ecosystems (Tessema, 2017). The specific focus was supported by standardized methods for evaluating forage quality for ruminants, particularly fiber-based metrics developed by Van Soest (Van Soest, 1994).

We hypothesize that *H. splendidum* from the Menze-Guassa area possesses a distinct and complex chemical profile, with essential oils containing a diverse range of volatile compounds, and that the plant material exhibits significant nutritional value through high concentrations of essential minerals.

The main objective of this study was to identify the chemical composition of *H.splendidum* essential oil using Gas Chromatography-Mass Spectrometry (GC-MS) and evaluate its nutritional properties.

Specifically, the study aimed to:

- a) Identify the major chemical compounds of *H.splendidum*.
- b) Determine the main constituents and assess the nutritional value of the plant.

MATERIALS AND METHODS

Sampling Site

H. splendidum was collected from the Guassa Community Conservation Area in the Menz Gera Midir district of the North Showa zone, Amhara Regional State, Ethiopia. The conservation area's coordinates are between 10°15'–10°27'N and 39°45'–39°49'E, covering an area of 111 km² at altitudes ranging from 2600 to 3560 meters above sea level (m.a.s.l.) (Chengere et al., 2022).

Sample Collection and Preparation

Sampling areas were selected following a reconnaissance survey to represent dense populations of *Helichrysum splendidum* within the study area. In April 2023, 1 kg of aerial plant material was collected at the flowering stage from three independent plots (10 m × 10 m each), labeled AAs-001, AAs-002, and AAs-003, to capture spatial heterogeneity and ensure representative sampling of the study site (Figs. 1–3). Equal amounts of plant material from each plot were pooled to form a single composite, homogenized sample. This composite sample was then subdivided into two portions: one portion (AAs-04) was used for essential-oil extraction and GC–MS analysis, while the second portion (AAs-05) was used for nutritional analysis.

Pooling was adopted to maximize the overall essential-oil yield and to obtain a representative chemical profile of *H. splendidum* across the sampling area. Accordingly, the essential-oil yield was calculated from the pooled composite sample, and plot-specific variation in yield could not be assessed. The objective of the study was to characterize the general chemical composition and major constituents of the species rather than evaluating intra-population chemical variability. Future studies would incorporate true biological replicates and replicate GC–MS analyses to enable quantitative assessment of chemical variability among sampling plots.

The chemical composition of *H. splendidum* essential oil is known to vary significantly in response to environmental factors (Marongiu et al., 2006). To minimize this variability and obtain a comprehensive representation of the plant's chemical profile, aerial parts comprising stems, leaves,

and flowers were collected and pooled. These plant parts were selected due to their known richness in essential oils and bioactive compounds. Immediately after collection, samples were packed in plastic bags to minimize the loss of volatile constituents and prepared for subsequent laboratory analyses.



Figure 1. *H. splendidum* with a large canopy due to a recent fire



Figure 2. Dense *H. splendidum* lining the walkway



Figure 3. Expansion of *H. splendidum* overtaking *Festuca macrophylla*

Essential Oil Extraction

To maintain the integrity of the essential oils, the designated sample (AAS-04) was dried in a shaded, well-ventilated area before being ground. The ground sample was then subjected to hydro-distillation for 3 hours in a Clevenger apparatus with 2 liters of water. The resulting essential oil was dried with anhydrous Na₂SO₄, transferred to sealed vials, and stored at 4°C until chemical analysis.

Chemical Composition Analysis

The chemical composition of the essential oil was analyzed by Gas Chromatography-Mass Spectrometry (GC-MS), following the protocol of Béguin et al. (2006), a common method for analyzing volatile compounds. The GC-MS analysis was carried out on a 7890B GC system connected to a DB-5MS capillary column at Jije Analytical Testing Service Laboratory (Tabel 1). The operating conditions were as follows: inlet temperature 260°C, helium flow 1 ml/min, and a temperature program: 40°C held for 3 min, ramped to 90°C at 4°C/min (held for 3 min), ramped to 170°C at 4°C/min (held for 3 min), ramped to 230°C at 6°C/min (held for 4 min), and finally to 270°C at 10°C/min (held for 1 min). Compound identification was achieved by comparing the mass spectra with the NIST 62 library (McLafferty and Stauffer, 1989)

Nutritional Analysis

Calibration was conducted to develop a spectrochemical prediction model by integrating NIRS spectral data with reference laboratory values to generate predictive equations, following the approach described by Stuth et al. (2003). Samples designated for nutritional analysis (AAS-05) were ground to pass through a 1-mm sieve and pre-dried overnight at 60 °C to standardize moisture content prior to scanning. Visible–near infrared (Vis–NIR) spectra were collected over the wavelength range of 1108–2492 nm at 8-nm intervals, and spectra were averaged for each sample. Because only two samples of *H.splendidum* were available for nutritional analysis, a mixed forage sample population was used for calibration and validation. Calibration equations were developed and validated using stepwise multiple linear regression. Key nutritional parameters, including dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and metabolizable

energy (ME), were predicted to provide a comprehensive assessment of forage nutritive value (Table 2). All analyses were performed using Near Infrared Reflectance Spectroscopy (NIRS) at the Animal Nutrition Laboratory of the International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia.

RESULT

Chemical composition and nutritional values of *H. splendidum* from the two sampling sites are presented in Tables 1 and Tabel 2, respectively. Essential oil extracted from the aerial parts of *H. splendidum* via hydro-distillation yielded a yellow, fragrant oil at 0.6% of dry weight. The GC-MS analysis detected 48 chemical components, accounting for 93.93 % of the oil composition. The main constituents identified were τ -Muurolol (13.49%), β -Pinene (13.21%), naphthalene derivatives (12.95%), τ -Cadinol (9.16%), β -Guaiene (6.25%), and α -Muurolene (5.19%).Near Infrared Reflectance Spectroscopy values for the prediction of DM, Ash, CP, NDF, ADF, ADL, ME and IVOMD (on DM bases) *H. splendidum* samples were presented in Tables,1,2 and 3.

Dry Matter (DM) in the present study indicated moderate predictive results for 1.58 standard deviation (SD) (1.58), standard error of calibration (SEC) (0.72%) and coefficient of determination (R^2) (0.80). while, the highest coefficient of determination for calibration (R^2) and coefficient of determination for cross-validation (1-VR) were 0.95 and 0.95 for Ash, 0.99 and 0.98 for CP, 0.98 and 0.97 for NDF and 0.98 and 0.98 for ADF that followed by 0.92 and 0.91 for ME, and 0.92 and 0.91 for IVOMD; and 0.91 and 0.90 for ADL.NDF, and 0.897 and 0.843 for ADL. The chemical composition of *H. splendidum* from the two sampling sites is presented in Table 1, while the nutritional values are shown in Tables 2 and 3. Near Infrared Reflectance Spectroscopy values for the prediction of DM, Ash, CP, NDF, ADF, ADL,ME and IVOMD (on DM bases) *H.splendidum* samples were presented in Table 2. The analysis of the nutritional profile of the plant showed (Tabel 3) a dry matter (DM) content of 93.88% .

Table 1. Chemical Composition Analysis Using Gas Chromatography-Mass Spectrometry (GC-MS)

S/N	Compound Name	Formula	RT	%Area
1	α -Thujene	C10H16	5.59	0.09
2	α -Pinene	C10H16	5.72	1.32
3	Camphene	C10H16	6.00	0.11
4	Sabinene	C10H16	6.36	1.81
5	β -Pinene	C10H16	6.46	13.21
6	α -Phellandrene	C10H16	6.90	0.37
7	Terpinolene	C10H16	7.07	0.14
8	o-Cymene	C10H14	7.20	0.78
9	β -Phellandrene	C10H16	7.31	3.37
10	cis-Sabinene hydrate	C10H18O	7.55	0.12
11	3-Carene	C10H16	7.73	0.29
12	Octanoic acid, methyl ester	C9H18O2	8.25	0.15
13	trans-Pinocarveol	C10H16O	9.11	0.24
14	Pinocarvone	C10H14O	9.43	0.12
15	endo-Borneol	C10H18O	9.59	0.07
16	Terpinen-4-ol	C10H18O	9.69	0.48
17	(-)-Myrtenol	C10H16O	9.93	0.63
18	α -Cubebene	C15H24	12.03	0.10
19	α -Muurolene	C15H24	12.37	0.22
20	α -Copaene	C15H24	12.45	0.78
21	(-)- β -Bourbonene	C15H24	12.58	0.40
22	Methyleugenol	C11H ₁₄ O ₂	12.77	0.16
23	Caryophyllene	C15H24	13.06	0.29
24	β -Cubebene	C15H24	13.18	0.12
	(1S,4S,4aS)-1-Isopropyl-4,7-			
	dimethyl-1,2,3,4,4a,5-	C15H24	13.43	0.22
25	hexahydronaphthalene			
26	Humulene	C15H24	13.53	0.16
	Naphthalene,			
27	1,2,3,4,4a,5,6,8a-octahydro-	C15H24	13.59	1.80

S/N	Compound Name	Formula	RT	%Area
	7-methyl-4-methylene-1-(1-methylethyl)-, (1.alpha.,4a.beta.,8a.alpha.)-			
28	γ -Muurolene	C15H24	13.73	1.17
29	Germacrene D	C15H24	13.85	0.31
30	γ -Cadinene	C15H24	14.23	3.31
	Naphthalene, 1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(1-methylethyl)-, (1S-cis)-	C15H24	14.27	12.95
31	α -Cadinene	C15H24	14.51	0.63
32	α -Calacorene	C15H20	14.58	0.21
33	Cubebol	C15H ₂₆ O	14.75	0.23
34	β -Guaiene	C15H24	15.04	6.25
35	Spirojatamol	C15H ₂₆ O	15.13	1.69
36	Viridiflorol	C15H ₂₆ O	15.28	4.93
37	Globulol	C15H ₂₆ O	15.41	0.69
	(1S,3aS,4S,5S,7aR,8R)-5-Isopropyl-1,7a-dimethyloctahydro-1H-1,4-methanoinden-8-ol	C15H ₂₆ O	15.45	4.50
39				
40	Di-epi-1,10-cubenol	C15H ₂₆ O	15.63	1.79
41	τ -Cadinol	C15H ₂₆ O	15.80	9.16
42	τ -Muurolol	C15H ₂₆ O	15.97	13.49
43	Jatamansone	C15H ₂₆ O	16.22	1.95
44	γ -Himachalene	C15H24	16.44	0.11
	(4aS,8S,8aR)-8-Isopropyl-5-methyl-3,4,4a,7,8,8a-hexahydronaphthalen-2-yl)	C15H24O	16.57	0.18
45	methanol			
	(3R,3aR,5R,6R,7aR)-3,6-Dimethyl-5-(prop-1-en-2-yl)-6-vinylhexahydrobenzofuran-	C15H ₂₂ O ₂	17.72	0.72
46	2(3H)-one			

S/N	Compound Name	Formula	RT	%Area
47	2-Naphthalenecarboxylic acid, 1,2,3,4-tetrahydro-3-hydroxy-8-methoxy-, ethyl ester	C ₁₄ H ₁₈ O ₄	19.33	1.87
48	Aminoglutethimide	C ₁₃ H ₁₆ N ₂ O ₂	19.91	0.24
				93.93

The analysis of the nutritional profile of the plant showed a dry matter (DM) content of 93.88% and a total ash content of 5.30%. Key nutritional components included a crude protein (CP) content of 7.75% and a metabolizable energy (ME) value of 7.42 MJ/kg DM. Fibre analysis showed neutral detergent fiber (NDF) of 61.30%, acid detergent fibre (ADF) of 52.53%, and acid detergent lignin (ADL) of 15.65%. Furthermore, the in vitro organic matter digestibility (IVOMD) was determined to be 51.26%.

Table 2. Results of the calibration and validation equation

Chemical components	Calibration		Validation		
	SD	SEC(%)	R ²	SEC(%)	1-VR
				SEC(%)	SEC(%)
DM(%)	1.58	0.72	0.80	0.72	0.79
Ash(%)	6.70	1.45	0.95	1.5	0.95
CP(%)	7.00	0.85	0.99	0.88	0.98
NDF(%)	16.80	2.63	0.98	2.75	0.97
ADF(%)	11.85	1.62	0.98	1.69	0.98
ADL(%)	2.345	0.72	0.91	0.75	0.90
ME(MJ/DM Kg)	1.355	0.39	0.92	0.40	0.91
IVOMD(%)	8.75	2.55	0.92	2.64	0.91

R² = coefficient of determination in calibration SEC = standard error of calibration, 1-VR = coefficient of determination of cross validation SECV = error of cross validation.

Table 3. Descriptive statistics of forage chemical composition of *H.splendidum* (Thunb.) Less

Sample no	DM (%)	Ash (%DM)	CP (%DM)	NDF (%DM)	ADF (%DM)	ADL (%DM)	ME MJ/kg DM	IVOMD (%DM)
1	94.61	4.14	5.26	66.87	61.36	16.97	7.87	53.29
2	93.16	6.45	10.23	55.73	43.69	14.32	6.97	49.22
Mean	93.88	5.30	7.75	61.30	52.53	15.65	7.42	51.26

DISCUSSION

Chemical Content and Chemotype

The essential oil extracted from the aerial parts of *Helichrysum splendidum* via hydro-distillation yielded 0.6% of the plant's dry weight. This value is consistent with results reported for other *Helichrysum* species (Ras, 2013). Gas Chromatography–Mass Spectrometry (GC–MS) analysis identified 48 chemical constituents, representing 93.93 % of the total oil composition. The major components were τ -Muurolol (13.49%), β -Pinene (13.21%), naphthalene derivatives (12.95%), and τ -Cadinol (9.16%). The dominance of β -Pinene, a monoterpene, in this analysis agrees with previous findings in other *Helichrysum* species (Lourens et al., 2008). Moreover, the high proportion of sesquiterpenes such as τ -Muurolol and τ -Cadinol is particularly noteworthy. These compounds are known for their antimicrobial, anti-inflammatory, and antioxidant properties (Lourens et al., 2008; Maroyi, 2019), supporting the traditional medicinal uses of *H. splendidum*.

The relatively high concentrations of τ -Muurolol and τ -Cadinol observed in the Menze Guassa population suggest a unique chemotype. Such chemical diversity is likely influenced by environmental conditions specific to the Afro-alpine ecosystem, including altitude, ultraviolet (UV) radiation, and climatic stress, which can affect essential oil composition (Melito et al., 2016; Shiferaw et al., 2019). Comparative studies from South African and Madagascan populations have reported considerably lower levels of these sesquiterpenes than those detected in this study (Cavalli et al., 2001; Marongiu et al., 2006; Mashigo et al., 2015). This variation may be attributed to marked intraspecific variability within the *Helichrysum* genus, where chemical composition depends on both environmental and genetic factors (Jafari et al., 2016). According to Melito et al. (2016), high-altitude conditions—characterized by strong UV radiation, temperature fluctuations, and low oxygen levels—can induce the synthesis of protective secondary metabolites, thereby influencing essential oil composition.

Nutritional analysis

The calibration and validation statistics demonstrated that the near-infrared reflectance spectroscopy (NIRS) equations used in this study were robust and exhibited high predictive accuracy for most chemical constituents. The performance of the NIRS calibration and validation models for *H.splendidum* was comparable to previously reported results for forage species (Nigam and Blümmel, 2010).

Dry matter (DM) in animal nutrition refers to the fraction of feed remaining after the complete removal of water or moisture. The determination of DM is fundamental for accurately quantifying other chemical constituents in forage, as moisture content in plant feedstuffs can vary widely. Typically, dried feeds contain less than 15% moisture or more than 80% DM (Musa et al., 2021). Consequently, DM determination is among the most routinely performed analyses in animal nutrition laboratories (Musa et al., 2021).

The DM content of *H. splendidum* observed in the present study was comparable to that reported for *Vachellia seyal* (Delile) P.J.H. Hurter (93.6%) and *Cordia africana* (93.9%) (Belete et al., 2024), as well as *Vachellia nilotica* (L.) (93.5%) (Deraro and Kitaw, 2018) and was higher than the DM content of most multipurpose fodder trees, shrubs, and indigenous browse species previously studied in Ethiopia (Tesfaye et al., 2020; Belete et al., 2024). Similarly, the DM content was comparable to that reported for the leaves of *Helichrysum odoratissimum* (93.9%) (Afuape et al., 2022), as well as the fruits and leaves of *Mussaenda arcuata* (94.11%), *Celosia trigyna* (94.48%), and *Pteridium aquilinum* (94.41%) (Daba et al., 2025).

The high DM content of *H. splendidum* indicates a low moisture level, which may be associated with a more fibrous plant structure. Such a characteristic is advantageous for storage, as it reduces the risk of microbial growth and spoilage (Afuape et al., 2022).

Ash content, which reflects the mineral composition of forage, was moderate in *H. splendidum*. The ash value recorded in this study was comparable to that of the stem fraction (5.27%) but lower than the leaf fraction (10.07%) of *H. odoratissimum* (Afuape et al., 2022), and slightly lower than that reported for *A. nilotica* (5.6%) (Belete et al., 2024).

The crude protein (CP) content of *H. splendidum* met the minimum requirements necessary to support rumen microbial activity and maintenance in ruminants (Van Soest et al., 1991). Its CP content was similar to that reported for the leaves of *H. odoratissimum* (7.75%) but higher than that of the stem fraction (Afuape et al., 2022). In contrast, the neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were higher than those reported for *H. odoratissimum* (45.56% and 32.31%, respectively) (Afuape et al., 2022) and comparable to the NDF (59.14%) and ADF (52.53%) values reported for *Cordia africana* (Debela et al., 2017).

Between the two analyzed samples, sample 2 exhibited higher CP and lower NDF contents than sample 1, which may be attributed to differences in morphological composition, particularly the leaf-to-stem ratio (Aydin et al., 2022; Belete et al., 2024). Overall, the mean CP content of *H. splendidum* was higher, while its NDF content was lower, than the average values reported for several grass species in Ethiopia (Keba et al., 2013).

Furthermore, the in vitro organic matter digestibility (IVOMD) and metabolizable energy (ME) values of *H. splendidum* were comparable to those of common indigenous browse species such as *Acacia tortilis* (53.8% IVOMD) and *Balanites aegyptiaca* (7.3 MJ/kg DM ME) (Belete et al., 2024).

Variations in chemical composition and forage quality among species and sites may be influenced by factors such as soil fertility, seasonal conditions, and stage of harvest. Overall, the laboratory results indicate that *H. splendidum* possesses a favorable nutritive profile for ruminant livestock, with ADF (52.53%) and acid detergent lignin (ADL; 15.65%) values within acceptable limits, and CP (7.75%), NDF (61.36%), ME (7.42 MJ/kg DM), and IVOMD (51.26%) values sufficient to meet maintenance requirements (Van Soest et al., 1991; Kenkel et al., 1989).

Implications for Potential Applications

The unique chemical profile of *H. splendidum* populations from the Menze Guassa conservation area has several practical implications. The dominance of β -Pinene and τ -Cadinol, known for their antimicrobial and anti-inflammatory activity (Lourens et al., 2008), indicates the essential oil's potential use in pharmaceuticals, therapeutics, and the cosmetics industry (Agidew, 2022).

Furthermore, the high concentration of the sesquiterpene τ -Muurolol suggests future applications in eco-friendly pest management, as it has been reported to possess insect-repellent effects (Black Solis et al., 2020). Additionally, it has been recognized that *H. splendidum* is a highly competitive species that challenges endemic grasses like *Festuca macrophylla* (Wube et al., 2021). The findings of this study, which characterize the shrub oil composition and nutritional content, support the sustainable utilization of this plant as it is an underutilized resource, offering a management approach that benefits both conservation efforts and local economic interests.

LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

This research has limitations. First, studying one population restricts our ability to generalize our findings. Comparative studies across different Ethiopian habitats should be conducted to verify the consistency of the chemotype and assess environmental effects on chemical variation. Second, while the GC-MS provided comprehensive chemical identification, it lacks concurrent bioactive tests, and the pharmacological potential currently remains hypothetical.

Future research must include bioactivity analysis of the major constituents, such as antimicrobial, anti-inflammatory, and antioxidant activity, to confirm traditional uses and explore new therapeutic promise (Kebede et al., 2021). Investigating synergistic interactions between compounds is also important, as the combined effect of multiple compounds may enhance overall bioactivity (Zheng et al., 2021). Finally, genetic studies across different altitudes and climatic regimes will help illuminate the role of environmental adaptation in driving chemotypic variation.

CONCLUSION

This research successfully characterized *H. splendidum* from the Menze Guassa area, which has dual significance as both a source of unique bioactive compounds and a critical livestock supplement. Essential oil analysis revealed a distinct chemotype likely influenced by the high altitude, with major constituents including τ -Muurolol (13.49%), β -Pinene (13.21%), and τ -Cadinol (9.16%). The latter two indicate potential for antimicrobial and anti-inflammatory applications. Nutritional analysis of

H.splendidum falls within the optimum threshold values for use in ruminant diets, particularly regarding its ADF (52.53%) and Acid Detergent Lignin (ADL 15.65%) values. This finding confirms the direct field observations of sheep browsing on the plant and validates its role as a critical and viable dietary component within the study area. The detected variation in nutrients between sampling sites, with higher CP and lower NDF, results from factors such as soil fertility or harvest stage, which influence the final nutritional quality and warrant further investigation.

RECOMMENDATION

The findings of this study reveal that *H.splendidum* (Thunb.) Less. essential oil from the Menze Guassa Conservation Area possesses unique chemical constituents and significant nutritional potential, highlighting its ecological and economic importance. It is therefore recommended that further detailed studies be conducted to evaluate its pharmacological and therapeutic properties, as well as to assess variations in chemical composition across different ecological zones and seasons.

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