Original Research Article||

Evaluation of Nutritive Values of Cactus (Oputinia ficus-indica L.) Cultivars and other Browse Species in Eastern Tigray, Ethiopia

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Abstract

Seasonal feed shortage is one of the major constraints for livestock production in Ethiopia. This study evaluated the nutritive value of five cactus cultivars (Dekik, Korem, Lematse, Tsaeda, and Keyh) and other browse species (Acacia saligna, Eculea schimperi, Olea europea, Carisa edulis and Dodonaea viscosa) in Eastern Tigray, Ethiopia for their potential to address the constraint. These plants were chosen for their abundance and utilization as animal feed by local community. The plants were characterized in terms of chemical composition and nutritive values and compared by seasons. The cactus cultivars and browse species differed significantly in chemical composition and nutritive values. Among the browse species, D. viscosa had the highest crude protein (CP) content (17.73%) during the wet season and O. europea and C. edulis had the lowest. Eculea schimperi had the lowest in vitro dry matter digestibility (IVDMD) (44.23%) during the wet season and D. viscosa had the highest value with 70.47%. This plant also showed higher dry matter digestibility (DMD) (80.97%) and relative feed value (309.27) compared to the other browse species. Among cactus cultivars, the lowest CP content was recorded in Korem and Dekik in the dry season (7.8%), while the highest was recorded for Lematse in wet season (11.17%). The highest IVDMD was recorded in Keyh during the wet season (70.59%) while the lowest was in Tsaeda and Dekik in dry season (61%). In this study plant samples harvested in wet season showed higher CP, IVDMD, relative feed value and energy content than those samples harvested during the dry season. Plants harvested in the dry season showed higher fiber contents. The finding signaled that the cactus cultivars Lematse and Keyh and the browse species A. saligna and D. viscosa can be promoted as valuable feed resources for ruminants in the stud area. However, feeding trials are needed to affirm the results of this study further.

Key words: Acacia saligna, Crude Protein, Dodonaea viscosa, Lematse, nutritive value

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INTRODUCTION

Mixed crop-livestock production system in which livestock play a key role in the national economy and rural livelihoods predominate in Ethiopian rain-fed agriculture (FAO, 2018; Mekuria and Mekonnen, 2018). Livestock production in Ethiopia is however, constrained by inadequate supply of quality animal feeds (Balehegn et al., 2020). The problem is even more severe in areas, where erratic and unreliable rainfall results in seasonal fluctuations in feed supply.

Multipurpose browse species, either native or introduced, or both offer considerable potential for use in mixed crop-livestock systems in dry areas to alleviate and complement the low quality forages from communal grazing lands and crop residues in Ethiopia (Bezabih et al., 2014; Sisay et al., 2017). For a large part of the dry season the browse species could maintain higher CP levels that could partly help solve the shortage of energy and protein during the dry season and supplement low quality forages grazed by ruminant livestock (Sisay et al., 2017; Feyisa et al., 2022). Browse species are useful sources of animal feeds, as these plants remain green during the dry season and also provide vegetation with better nutritive value than other annual grasses and herbaceous species that declined in abundance (Aregawi et al., 2008; Mangara, 2018; Belachew et al., 2020). Multipurpose browse species can also complement crop production by maintaining soil fertility by fixing nitrogen or by using it as mulch (Murmu, 2018). Hence, the use of these forage plants can be potentially efficient way to improve sustainable feeding in smallholder farming systems. It would thus be justifiable to look for locally available alternative feed resources that are easily accessible to smallholder farming communities.

The cactus plant is grown abundantly in many dry land areas of northern Ethiopia and can be used to address livestock feed shortages. It can maintain its greenness and nutritive value through the dry season. This plant can grow in areas receiving as little as 200 mm of rainfall (Georgis et al., 2010). Its importance increases as it has been introduced in the marginal lands of Ethiopia to combat feed and food insecurity, support household income, and prevent land degradation (Tegegne, 2007; Georgis et al., 2010 ; Belay et al., 2011; Ziadat & Bayu, 2015; Meaza et al., 2024). Cactus is widely grown in dry land areas because it can tolerate water-limited conditions, high temperatures, and poor soils (Sipango et al., 2022). In Tigray region alone, wild cactus covered about 32,000 ha of land (Belay et al., 2011). It is also increasingly cultivated by smallholder farmers. and is reported to be important livestock feeds, especially in moisture deficient or drought prone areas like in Tigray in Ethiopia (Tegegne, 2007; Georgis et al., 2010; Gebretsadik et al., 2013;; Lijalem and Kebede, 2024). Cactus remains green throughout the year, rich in water and water soluble carbohydrates and therefore it is suitable as a supplement to crop residue when other feeds are scarce. However, it is low to moderate in CP content (Tegegne, 2007; Nipane et al., 2021) suggesting the need to search for alternative fodder plants that can be combined with this species.

There are several indigenous browse species that are untapped and can help to ease some of the problems associated with low feed quality and partly address the major problems of long-term sustainability of crop-livestock systems in Ethiopia. These feed resources in Tigray region, for instance, are widely used by the farmers in conjunction with cactus and crop residues (Georgis et al., 2010; Tegegne, 2007). Although a number of works—on the nutritional values (e.g., in terms of their digestibility and chemical composition) of browse species including cactus are available in different parts of Ethiopia (e.g. Fentahun et al., 2020; Gebreegziabher & Tsegay, 2015; Hassen et al., 2017; Bazie et al., 2019; Teklu et al., 2023), such studies are still scarce in Tigray region, northern Ethiopia. Such studies are essential to identify—from a pool of observed species—a few promising species (that is those that are consistently better performing in at least two seasons in the same year) in the area where they are identified (in the present study case, the eastern Tigray region). These studies are also vital for predicting the production performance of the grazing/browsing animals in the study area, identifying limiting nutrients for target production, and for prioritizing individual species or pasturelands for management or development (Bezabih et al., 2014). Hence, the present study was conducted to evaluate (and compare over seasons) the nutritive value of five cactus cultivars (Lematse, Tsaeda, Dekik, Korem, and Keyh) and selected tree/shrub species (Eculea schimperi, Dodoneae viscosa, Olea europea, Acacia saligna, and Carisa edulis) identified from the eastern Tigray zone, northern Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

This study was carried out in the Eastern zone of Tigray region located in northern Ethiopia. It is located between 13°33′ to 14°40′ N and 39°11′ to 39°59′ E. The total area of the zone is 561,000 ha, which is divided in to seven districts: Erob, Hawzen, Wukro, Atsbi-Womberta, Ganta-Afeshum, Gulo-Mekeda, and Saesie-Tsaeda-Emba. The altitude ranges from 1500 to 3280 m above sea level. The study zone has three traditional agro-ecological zones: (i) highland, with areas over 2,300 m above sea level; (ii) midland, between 1,500 and 2,300 m above sea level; and (iii) lowland, with areas less than 1,500 m above sea level (Meles et al., 1997). Most of the districts are categorized as Highland or Dry Dega, followed by Midland or Dry Weinadega. The area has a semi-arid climate and receives bimodal rainfall: the main rainy season (June–September), locally known as Kiremt and a small rainy season (February–May), locally known as Belg The rainfall is highly variable due to the complex influences of topography (Meles et al. 1997). The mean annual rainfall ranges from 520 to 680 mm, and the mean annual temperature varies between 16 and 20 °C (Kahsay et al., 2019).

Sample Collection

Samples were collected from Ganta-Afeshum, Saesie-Tsaeda Emba and Atsbi-Womberta districts of the study zone. These districts were selected purposively based on the abundance and utilization of the below-mentioned browse species and cactus plants. These districts are relatively homogenous in terms of agroecology, farming systems and natural vegetation though the former two districts are relatively rich in cactus plants. Five commonly grown, multipurpose cactus cultivars namely Dekik, Keyh, Korem, Lematse, and Tsaeda and five tree/shrub species (*A. saligna, C. edulis, O.europea, E.schimperi, and D.viscosa/angustifolia*) were selected based on the abundance of the species and their broader utilization by the farmers in the study area (Gebretsadik et al., 2013 ; Mengistu, 2017; Atsbha & Wayu, 2020). Species selection was also based on extension agents' opinion and farmers' knowledge of the tree forages preferred by animals. Samples of cactus cultivars were collected from two randomly selected (one each from Ganta-Afeshum (i.e. Kokob Tsibah) and Saesie-Tsaeda Emba (i.e. Emba-Esmena) kebeles, while samples of the tree/shrub species were collected from a randomly selected kebele of Kelisha from the Atsbi-Womberta district where the above-listed trees/shrubs are dominantly found. For trees/shrubs, sampling was conducted in an enclosed land. Samples were harvested from cladodes or young leaves of cactus and the leaf part of the tree/shrub species during the wet season (August/September) and in the dry season (January/ February). The samples of tree/shrub were collected at the same time during the early growth stage (before flowering) from 5 to 10 plants in three replicates per species. The samples from cactus cultivars were harvested before they started to produce fruits from 2 to 5 plants in three replicates per cultivar. The samples were oven-dried for 72 hours at 65 ºC and reweighed to determine the DM content. The dried samples were ground separately and passed through a 1-mm sieve. The nutritive quality of plants collected from the study area during the wet and dry seasons was evaluated on the basis of chemical composition, IVDMD, dry matter intake, dry matter digestibility, and relative feed value. Samples were analyzed at the Animal Science Laboratory of Mekelle University and Holleta Agricultural Research Center, Ethiopia.

Chemical Analysis and *in vitro* Dry Matter Digestibility

The ground samples were analyzed for chemical composition on a dry matter basis. The nitrogen (N) concentration was determined based on AOAChemists (1990). Crude protein (CP) content was calculated as 6.25 x N concentration. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were determined according to Van Soest (1994). The in vitro dry matter digestibility was determined using the two-stage (Tilley & Terry, 1963) method. Rumen liquor was collected and transported to the laboratory using thermos flasks and pre-warmed to 39 ºC before the daily meal of the three cannulated Boran-Friesian steers. The steers were 40 months old, weighed 490 kg and were fed natural pasture hay (6% CP on a DM basis) ad libitum supplemented with a 22 kg concentrate mixture (20% CP on a DM basis) per day per head. The sample (0.5 g) was incubated in a test tube at 39 ºC for 48 h with 10 ml of rumen fluid and 50 ml of buffer solution. After microbial digestion, enzymatic digestion with an acid pepsin solution (i.e., 5 ml per tube) was continued for another 48 h.

Determination of Relative Feed Value (RFV) Index

Dry matter intake (DMI), digestible dry matter (DDM), and relative feed value (RFV) were estimated using the following equations:

DDM (%) = 88.9 - (0.779 * % ADF); DMI (% of BW) = 120 / % NDF (Mertens, 2002) and

RFV = (% DDM × % DMI) /1.29 (Jeranyama & Garcia, 2004)
Metabolizable energy (ME) was computed following the formula recommended in Australian Agricultural Council (1990) as:

$$\text{ME}(\text{MJ kg-1 DM}) = (0.17 * \%\ \text{IVDMD}) - 2.0$$

Where, DDM is the dry matter digestibility; ADF is the acid detergent fiber (% of DM); DMI is the dry matter intake (% of BW) and RFV is the relative feed value. The forage quality grading standard assigned by the Hay Marketing Task Force of the American Forage and Grassland Council, the RFV, was assessed as roughages based on prime (>151), premium (151–125), good (124–103), fair (102–87), poor (86–75), and reject (<75) (Rohweder et al., 1978).

Data Analysis

The data on chemical compositions, IVDMD and DMI, DDM, and RFV were analyzed using factorial analysis of variance (ANOVA) using the general linear model procedure of SPSS (version 16.0). In addition, Pearson's correlation coefficient (r) was used to decide whether there was a linear relationship between IVDMD, CP, ash, NDF, ADL and ADF. The statistical model included the effects of plant species, season and their interactions. Tukey's significance difference (HSD) was used to compare means ($P < 0.05$). The significance level was set at 5%.

The following model was used for data analysis:
$Y_{ijk} = \mu + A_i + B_j + (AB)_{ijk} + e_{ijkl}$,

Where Y_{ij} = response variable, μ = overall mean, A_i = effect of plant species/cultivars, B_j = effect of season, $(AB)_{ijk}$= interaction effect of season with species/cultivar, and e_{ijkl} = random error.

RESULTS AND DISCUSSION

Chemical Composition and *in vitro* Dry Matter Digestibility of Tree/Shrub Species

The chemical composition and *in vitro* dry matter digestibility of the tree/shrub species are shown in Table 1. Among the tree/shrub species, the highest DM content was recorded in *O.europaea* in the dry (93.60%) and the wet (92.81%) seasons; followed by *C. edulis* and *D.viscosa*. in the dry and wet seasons. The lowest DM content was recorded in *E. schimperi* in the wet season (85.22%). The total ash content of the tree/shrub species ranged from 2.62% in *A. saligna* in the wet season to 9.48% in *C. edulis* in the dry season. Factors such as soil, climate, stage of maturity and season contribute to variations in the nutritive values of forages. The DM, for example, increases as the plant matures and as the dry season advances (Mueller-Harvey, 2006) in line with what we observed in the current study. The ash value of *A. saligna* was lower than the ash value 7.9%-14.1% reported by Gebremeskel et al. (2019). The ash value of *C.edulis* and *O.europea* was similar to the value 8.39% and 7.09% reported by Girma et al. (2015). But, the ash value of *C.edulis* was higher than the value 6.2% reported by Fentahun et al. (2020).The ash content of tree/shrub species reported in this study were higher than the reported data by Ali et al. (2020).

Overall, the CP ranged from 8.2 to 17.73%. *Dodonaea viscosa* had the highest CP content (17.73%) followed by *A.saligna* (15.92%) in the wet season. In dry season *A. saligna* (14.25%) followed by *D. viscosa* (12.43%) had the highest CP content and *O. europea* had the lowest CP content. As expected a wide variation in CP content was recorded in this study between the species in both seasons; the amount of CP increased from dry to wet season. The CP values reported in this study were comparable to the results of other studies (Yayneshet et al., 2009; (Girma et al., 2015; Hassen et al., 2017; Flores et al., 2020) reported values (10.3%–24.4% for wet season and 7.6%–20.2% for dry season). The CP value reported for *D.viscosa* in this study was lower than the value of 14% reported by Yisehak & Janssens (2013) but similar to the value (17.43%) reported by Ali et al. (2020). Similarly, the CP value reported for *C. edulis* and *O.europea* in this study was similar to the value reported by Ali et al.(2020). The CP value reported for *C. edulis* (8.12%) in the dry season and 10.32% in the wet season was similar to the CP values 10.8% and 8.15% reported by Girma et al. (2015). However, it was lower than the CP value 13.6% reported by Yisehak & Janssens (2013).The CP value reported for *O. europea* 12.2% in the wet season and 11.6% in the dry season was lower than the value reported by Girma et al. (2015). The lower CP content of tree/shrub species during the dry season compared to the wet season may be attributed to a higher percentage of fiber fractions (NDF,ADF, ADL), lower soil moisture content, a higher age of the plant linked to leaf maturity, and less nitrogen availability (Anele et al., 2008; Anele et al., 2009; Belachew et al., 2013; Yayneshet et al., 2009;Yu et al., 2022) and translocation of nutrients especially nitrogen from leaf to stem (Hagen-Thorn et al., 2006).

The CP content is a very important criteria for nutritional quality assessments in animal feed resources. In our study, the tree/shrub species tended to have higher CP content (range: 8–18%) which is above the recommended crude protein levels of 7% which supply the microbial requirements of nitrogenous compounds; below which ruminal fermentation of forages (digestibility) may be limited and NDF is not used adequately and feed intake decreases (Van Soest, 1994). Crude protein content of three of tree species was adequate for recommended minimum CP requirements (11-12%) for moderate level of production (ARC, 1980) and CP content of *A. saligna* and *D.viscosa* was above the recommended minimum requirement for early finishing lambs (14.5%CP) (NRC, 1985). The results showed the CP content of the tree/shrub species was adequate to sufficiently high to warrant consideration of their use as protein supplement to low quality diets except for *C. edulis* and *O.europaea* in the dry season; which showed less promising potential than the other tree/shrub species.

The fiber content of tree/shrub species in this study increases from the wet to dry season. This might be due to the low moisture content of soil, advanced maturity of plants, and low rainfall, harvesting season (Hassen et al., 2007; Camacho et al., 2010; Arigbede et al., 2012). The NDF content was lowest in *D. viscosa* in both seasons and while highest in *O. europaea* in *E. schimperi* in the dry season. The NDF content of tree/shrub species in this study ranged from 24.40% to 57.80%. The studied tree/shrub species had NDF content below 45% on dry matter basis with the exception of *E. schimperi* and can be classified as high-quality forages (Singh & Oosting, 1992). Their NDF content was below the threshold level of 60% (Meissner et al., 1991), beyond which the DM intake by the animal is negatively affected.

The ADF content was lowest in *D. viscosa* in both seasons and highest in *O. europaea* in the wet season. The ADF comprises of proteins, cellulose, and lignin, which prevents the cell wall's carbohydrates from breaking down at the rumen stage (Harper & McNeill, 2015). It is used to indicate the forage species' potential for consumption, energy availability, and diet digestibility i.e. thus, the lower the ADF content of the forage, the higher its nutritional quality and energy levels (Tambara et al., 2017). All the tree/shrub species in this study had ADF content below 40% and can thus be classified as high-quality forages (Kellems & Church, 2002).

The ADL content was lowest in *D. viscosa* in both seasons and highest in *C. edulis* in the wet season and *E.schimperi* in the wet and dry seasons. Despite wide variations between seasons, with the exception of *E. schimperi*, in both seasons in this study, tree/shrub species had lignin contents below the maximum threshold of 10%, which is expected to restrict the amount of DM consumed (Reed[1] et al., 1988). Consequently, none of the tree/shrub species in this study were likely to have an effect on the animals' DM consumption. The higher fiber (NDF, ADF and ADL) content of tree/shrub species in the dry season was due to advanced stage of maturity and lignification (Hussain & Durrani, 2009) and higher temperature which promotes the development of structural fibers in plants (Bismarck et al., 2005 ; Goudenhooft et al., 2019).

Dodonaea viscosa in the wet season had the highest *in vitro* dry matter digestibility (70.47%) compared to the other tree/shrub species. The lowest IVDMD was recorded in *E.schimperi* in dry season (44.24%). *In vitro* dry matter digestibility did not vary due to the interaction effect of season and species. However, it varied among species and between seasons. It was higher in the wet season than in the dry season and its value ranges from 44.24% to 70.47%. This coincides with the values of previous studies (Hassen et al., 2017; Fentahun et al., 2020; Ravhuhali et al., 2022) which reported (62.3%–67.8%, 64.78%, and 49.61% for the wet season) and (50.8–65.8%, 57.35%, and 44.69% for the dry season), respectively. Due to the negative correlation between feed digestibility and ADF content, tree/shrub species with high ADF content may have low digestibility (McDonald et al., 2002). There is a physical restriction on eating when IVDMD is less than 550 g/kg. Additionally, the rate of digestion and transit through the gastrointestinal system implies that intake is limited; therefore weight loss is inevitable (Dynes & Schlink, 2002).

Table 1. Chemical composition and *in vitro* dry matter digestibility (in %DM) of tree/shrub species

Season	Chemical composition						
	DM%	Ash	CP	NDF	ADF	ADL	IVDMD
Wet	89.18^{b}	6.55^{b}	13.53^{a}	39.61^{b}	18.00^{b}	9.30	58.00^{a}
Dry	90.00^{a}	7.42^{a}	10.75^{b}	41.59^{a}	19.15^{a}	8.88	53.62^{b}
SEM	0.206	0.084	0.23	0.33	0.28	0.203	0.55
P-value	0.011	<0.0001	<0.0001	<0.0001	0.009	0.304	<0.0001
Species *Season							
Wet Season							
A.saligna	88.93^{bc}	2.62^{e}	15.92^{ab}	34.38^{f}	16.92^{cd}	8.86^{c}	59.50^{bc}
C. edulis	89.76^{bc}	8.36^{b}	10.32^{e}	39.83^{de}	17.24^{d}	11.29^{b}	51.50^{cd}
O.europaea	92.81^{a}	6.47^{c}	10.56^{de}	46.28^{c}	25.6^{a}	8.66^{bc}	58.74^{bc}
E. schimperi	85.22d	8.75^{ab}	13.13^{bc}	53.16^{b}	20.08^{c}	11.94^{b}	49.79^{d}
D. viscosa	89.19^{bc}	6.57^{c}	17.73^{a}	24.40^{h}	10.17^{f}	5.74^{de}	70.47^{a}
Dry season							
A.saligna	88.30^{bc}	4.84^{d}	14.25^{b}	37.99^{e}	18.94^{c}	10.08^{bc}	56.00^{c}
C. edulis	90.44^{b}	9.48^{a}	8.2^{e}	42.01^{d}	19.94^{c}	9.68^{bc}	49.48^{d}
O. europaea	93.60^{a}	8.05^{bc}	8.12^{ef}	41.46^{d}	21.36^{bc}	6.24^{d}	55.46^{c}
E. schimperi	87.36^{c}	6.12^{c}	10.76^{d}	57.80^{a}	23.41^{b}	14.34^{a}	44.23^{e}
D. viscosa	90.33^{b}	8.6b	12.43^{cd}	28.69^{g}	12.09^{e}	4.64^{e}	62.92^{b}
SEM	0.46	0.189	0.514	0.75	0.626	0.45	0.87
P-value	0.093	<0.0001	0.017	<0.0001	<0.0001	<0.0001	0.229
Species							
A.saligna	88.62^{c}	3.73^{c}	15.08^{a}	36.18^{d}	17.97^{b}	9.47^{b}	57.75^{b}
C. edulis	90.10^{b}	8.92^{a}	9.26^{c}	40.92^{c}	18.59b	10.49^{b}	50.49^{c}
O. europaea	93.20^{a}	7.26^{b}	9.34^{c}	43.83^{b}	23.48^{a}	7.45^{c}	57.10^{b}
E. schimperi	86.29^{d}	7.43^{b}	11.94^{b}	55.48^{a}	21.74^{a}	13.14^{a}	47.01^{c}
D. viscosa	89.75^{bc}	7.58^{b}	15.08^{a}	26.54^{e}	11.13^{c}	5.19^{d}	66.69^{a}
SEM	0.326	0.134	0.36	0.53	0.44	0.32	0.87
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Means with different superscripts (a, b, c, d, e. f, g, h) in the same column are significantly different (P<0.05), SEM=standard error of mean, IVDMD=Invitro dry matter digestibility, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL= acid detergent lignin, DM=dry matter

Dry Matter Intake, Digestibility and Relative Feed Values of Tree/Shrub Species

Dry matter intake, dry matter digestibility and relative feed value of tree/shrub species are shown in Table 2. The values for dry matter intake, DMDigt and relative feed value were varied due to season, species and the interaction of species and season. However, there is no significant difference in metabolizable energy of tree/shrub species due to the interaction of species and season. Overall among the tree/shrub species dry matter intake, dry matter digestibility (DMDigt) and relative feed value (RFV) were significantly (p<0.05) higher for *D. viscosa* and lowest for *E. schimperi*. The dry matter digestibility was higher in the wet season than in the dry season except in *O. europea* and its value ranges from 68.95% to 80.97% in the wet season and 70.66% to 79.48% in the dry season. This was similar to the value of 52.5% to 76.3% in the wet season and 43.1%–67.2% in the dry season reported by Ravhuhali et al., (2022) but it was higher than the value 64.75- 72.54 and 62.5-125.7

reported by Kazemi et al. (2012) and Geleti et al. (2013) respectively. Metabolizable energy of tree/shrub species was higher in wet season than in dry season and its value ranges from 7.11-7.86MJ. Metabolizable energy (ME) were significantly ($p<0.05$) higher for *D.viscosa* and lowest for *E. schimperi* (ranges from 5.99 to 9.3MJ/kg). This is similar to the value (8.3MJ/kg) reported by Belete et al. (2024). The relative feed value of browse species in this study was similar to the value of 100.94-246.88 reported by Kazemi et al. (2012) and Mayouf & Arbouche (2014). The studied tree/shrub species had relative feed value above the 151 value quality standard and could be classified in to quality standard of prime forage (high quality standard) except for *E. schimperi* in both seasons and *O.eurpoea* in the wet season which are classified into the quality standard premium (1) and good (2) quality forages.

Table 2. Dry Matter Intake, Digestibility and Relative Feed Values of Tree/Shrub Species

Season	Estimated parameters			
	DMI(%LW)	DMDigst (%)	RFV	ME(MJ/kg)
Wet	3.259^{a}	74.87^{a}	191.59^{a}	7.86^{a}
Dry	3.035^{b}	73.98^{b}	175.61^{b}	7.11^{b}
SEM	0.035	0.218	2.25	0.094
P-value	0.0001	0.0001	0.0001	0.0001
Species *Season				
Wet season				
A. saligna	3.49^{b}	75.71^{c}	205.32^{c}	8.11^{bc}
C. edulis	3.01^{c}	75.46^{c}	176.35^{e}	6.75^{d}
O.europea	2.59^{d}	68.95^{g}	138.84^{gh}	7.98^{b}
E. schimperi	2.25^{f}	73.25^{d}	128.18^{h}	6.46^{de}
D. viscosa	4.92^{a}	80.97^{a}	309.27^{a}	9.98^{a}
Dry season				
A. saligna	3.16^{bc}	74.14^{cd}	181.6^{d}	7.52^{c}
C. edulis	2.85^{d}	73.36^{d}	162.46^{f}	6.41^{de}
O.europea	2.89^{e}	72.25^{e}	162.17^{f}	7.42^{cd}
E.schimperi	2.07^{g}	70.66^{f}	113.78^{i}	5.51^{f}
D. viscosa	4.19^{a}	79.48^{b}	258.12^{b}	8.69^{ab}
SEM	0.078	0.488	5.03	0.211
P value	0.0001	0.0001	0.0001	0.229
Species				
A. saligna	3.33^{b}	74.93^{b}	193.46^{b}	7.81^{b}
C. edulis	2.93^{c}	74.41^{b}	169.41^{c}	6.58^{c}
O.europea	2.74^{c}	70.60^{c}	150.47^{d}	7.70^{b}
E.schimperi	2.16^{d}	71.96^{c}	120.98^{e}	5.99^{c}
D.viscosa	4.55^{a}	80.22^{a}	283.70^{a}	9.33^{a}
SEM	0.055	0.34	3.55	0.15
P-value	0.0001	0.0001	0.0001	0.0001

Means with different superscripts (a, b, c, d, e. f, g, h) in the same column are significantly different ($P<0.05$), SEM=standard error of mean, DMI = Dry matter intake; DDM = Digestibility of dry matter; RFV = Relative feed value.

Chemical Composition and *in vitro* Dry Matter Digestibility of Cactus Cultivars

The chemical composition and *in vitro* dry matter digestibility of cactus cultivars are shown in Table 3. Cactus cultivars' chemical composition and *in vitro* dry matter digestibility differed according to season, species, and the interaction of season and species. The DM content of Keyh in the wet season and Lematse in the dry season was significantly ($p<0.05$) higher than the other cactus cultivars. Cactus cultivars in this study ranged in dry matter content from 88.31% to 90.89%. This was comparable to the results of earlier findings (Negussie et al., 2015; Teklu et al., 2023) that reported DM content in the 89.38%–90.3% range. The DM content of Keyh, Lematse, and Tsaeda's DM was similar to the findings of Teklu et al. (2023) who reported values of 91.88%, 91.02%, and 89.35% for Keyh, Lematse, and Tsaeda, respectively.

Keyh in the dry season had significantly ($p<0.05$) higher ash content than Dekik and Lematse. The cultivars with the lowest ash content during the wet season were Korem and Tsaeda. The ash content of cactus in this study was consistent with the previous studies (Amogne et al., 2006; Bazie et al., 2019) who reported a range value of 7.22%-26%. The ash and mineral concentrations of spineless cacti can be greatly affected by variables like the moisture and mineral contents of the soil. Cacti are prone to accumulating calcium in their cladodes when they experience water scarcity and high soil Ca compound levels (Nobel, 2002). Ben Salem (2014) and Salem et al, (2010) suggested that forage's high ash content also indicates its comparatively low energy content.

In the wet season (11.17%), cultivar Lematse had the highest CP content, followed by Keyh (10.72%), Lematse (10.13%), and Dekik (10.26%) in the dry season. The CP content of cactus cultivars was higher in the wet season than in the dry season. This was similar to the findings of Amogne et al. (2006) and Hassen et al. (2017), who reported, 7.3% and 5.24% for wet season and 4.3% and 3.24% for dry season respectively. The CP content of cultivars ranged from 7.8% to 11.17%, which is above the CP minimum maintenance requirement of ruminant animals. Sanon et al. (2008) concluded that forage consumed by goats that have CP content greater than 10 g/100 of DM has the ability to increase ruminant N levels. Thus, based on CP results of the studied cultivars, to increase N in ruminant animals, Lematse in the dry and the wet seasons and Keyh and Dekik in the wet season should be used. As suggested by Misra et al.(2006) diets containing cactus cladodes should be supplemented with protein source feeds like *A.saligna* in order to satisfy production requirements of ruminant animals.

In the dry season Lematse had significantly ($p<0.05$), the highest NDF content (24.86%) followed by Korem (24.16%) then Keyh (23.72%). The NDF content of cactus is higher in the dry season than in the wet season. Consistent with this study, Hassen et al. (2017), reported a higher NDF content of cactus cladodes in the dry season than in the wet season 58.5% and 55.2%, respectively. However, Dias et al. (2023) reported a higher NDF content of cactus in the wet season (33.12%) than in the dry season (19.75%), respectively. The higher NDF content of cactus cladodes in the dry season might be due to sunlight exposure, and low moisture content and maturity stage of cactus (Retamal et al., 1987).The variation in NDF content between different studies may be due to the site of sample collection, season, age of cactus cladodes, soil fertility, and other climate-related conditions. Jafari et al. (2015) and Kholif et al. (2016), stated that an NDF content in forage feeds above the critical level of 60% decreases voluntary feed intake, feed conversion efficiency, and the retention time of feeds in the gastrointestinal tract in livestock. Based on this justification, the studied cultivars might not affect feed intake or feed conversion efficiency of animals.

Cactus cultivars' ADF content was not significantly affected by interaction of cultivar and season. Nonetheless, the ADF content of Dekik during the dry season was significantly ($p<0.05$) higher than that of the other cactus cultivars. Lematse, had the lowest ADF content (12.12%) in the wet season. The dry season's lowest ADF content, was recorded in Lematse (12.12%). Acid detergent fiber content of cultivars varied from 12.12% to 19.66% .This was similar to the values range of 15% to 25%, reported in previous studies (Batista et al., 2009; Negussie et al., 2015; Teklu et al., 2023). The ADF content of cactus cladodes was higher in the dry season than in the wet season. This coincides with the findings of Hassen et al. (2017) and Dias et al. (2023), which reported higher ADF content in the dry season (49.5% and 14.8%) than in the wet season (43.3% and 12.46%), respectively.

The acid detergent lignin content of cactus cladodes ranged from 2.45% to 4.26%. This is similar to the value of 3.06% reported by Amogne et al. (2006). The acid detergent lignin content of cactus cladodes in this study was higher in dry season (3.81%) than in the wet season (3.54%). This was similar to the finding of Hassen et al. (2017), who reported higher ADL contents in the dry season (17.2%) than in the wet season (15.4%).

The *in vitro* dry matter digestibility (IVDMD) of cactus was significantly higher in Keyh in the wet season then followed by Lematse and Korem in the wet season. The *in vitro* dry matter digestibility (IVDMD) of cactus in this study was within the range of 57-78.61% reported by previous studies (Hassen et al., 2017; Teklu et al., 2023; Bazie et al., 2019; Silva et al., 2022). The variation in digestibility might be due to the age of cactus cladodes, the fertility of the soil and its management, and the climatic conditions of the area. Cactus cultivars have a greater IVDMD during the wet season than in the dry season. The results of Hassen et al.(2017), who reported 50.8% in the dry season and 63.2% in the wet season, are consistent with the results of this study. Cactus cladodes' nutritional quality varies due to plant type (variety), cladode age, sampling season, soil type, climate, growth stage and portion of the plant (Retamal et al., 1987; Mondragón-Jacobo & Pérez-González, 2001; Scalisi et al., 2016; Mounir et al., 2020; Kumar et al., 2021). Based on the Standard assigned by Hay Market Task Force of American Forage and Grassland Council all cactus cultivars are classified under quality standard 4 (based on NDF and ADF value) and standard quality prime(1)(based on relative feed value)

Table 3. Chemical Composition in % DM and *in vitro* Dry Matter Digestibility of Cactus cladodes Cultivars

Season	Chemical Composition						
	DM%	Ash	CP	NDF	ADF	ADL	IVDMD
Wet season	89.05^{b}	17.02^{b}	10.077^{a}	19.72^{b}	15.36^{b}	3.52^{b}	67.83^{a}
Dry season	89.26^{a}	19.60^{a}	8.61^{b}	23.10^{a}	17.34^{a}	3.80^{a}	62.99^{b}
SEM	0.05	0.096	0.055	0.044	0.118	0.049	0.119
P-value	0.012	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001
Cultivar*Season							
Wet season							
Dekik	88.54^{cd}	18.22^{c}	10.26^{b}	18.44^{f}	17.63^{b}	3.09^{c}	65.78^{c}
Keyh	90.89^{a}	17.16^{d}	10.72^{ab}	21.30^{d}	14.97^{d}	3.60^{b}	70.59^{a}
Korem	89.27^{bc}	16.41^{e}	9.38^{c}	21.70^{d}	15.88^{c}	3.14^{c}	67.84^{b}
Lematse	89.057^{c}	17.10^{d}	11.17^{a}	19.06^{e}	12.12^{f}	2.45^{d}	68.76^{b}
Tsaeda	88.31^{d}	16.18^{e}	8.84d	18.09^{g}	16.18^{c}	3.72^{b}	66.20^{c}
Dry season							
Dekik	88.87^{c}	20.13^{b}	7.87^{e}	21.67^{d}	19.66^{a}	4.26^{a}	61.61^{e}
Keyh	89.54^{b}	21.43^{a}	9.17^{c}	23.72^{c}	16.83^{bc}	4.19^{a}	63.20^{d}
Korem	89.75^{b}	17.40^{c}	7.8^{e}	24.16^{b}	18.24^{b}	3.52^{b}	63.64^{d}
Lematse	89.78^{a}	20.0^{b}	10.13^{b}	24.86^{a}	14.11^{e}	3.63^{b}	65.19^{c}
Tsaeda	88.35^{d}	19.05^{c}	8.06^{e}	21.07^{d}	17.84^{b}	4.137^{a}	61.32^{e}
SEM	0.119	0.215	0.122	0.099	0.26	0.07	0.26
P-value	<0.0001	0.0001	<0.0001	<0.0001	0.76	<0.0001	<0.0001
Cultivar							
Dekik	88.70^{c}	19.18^{ab}	9.06^{c}	20.05^{c}	13.11^{d}	3.82^{b}	63.70^{c}
Keyh	89.81^{a}	19.29^{a}	9.94^{b}	22.51^{b}	15.90^{c}	4.04^{a}	66.90^{a}
Korem	89.51^{ab}	16.91^{d}	8.59^{d}	22.93^{a}	17.01^{b}	3.48^{c}	65.74^{b}
Lematse	89.42^{b}	18.55^{b}	10.65^{a}	21.96^{d}	17.05^{b}	3.04^{d}	66.97^{a}
Tsaeda	88.33^{d}	17.61^{c}	8.45^{d}	19.58^{e}	18.64^{a}	3.92^{ab}	63.76^{c}
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SEM	0.08	0.15	0.08	0.07	0.18	0.05	0.19

Means with different superscripts (a, b, c, d, e. f, g, h) in the same column are significantly different (P<0.05), SEM=standard error of mean, IVDMD=Invitro dry matter digestibility, NDF=neutral detergent fiber, ADF=acid detergent fiber, ADL= acid detergent lignin, DM=dry matter

Dry Matter Intake, Digestibility and Relative Feed Values of Cactus Cultivars

Dry matter intake, dry matter digestibility and relative feed value of cactus cultivars are shown in Table 4. Dry matter intake and relative feed value of cactus cultivars varied due to season, cultivar and interaction of season and cultivar. But, there was no interaction effect of season and cultivar on dry matter digestibility of cactus cultivars. Dry matter intake and relative feed value were significantly (p<0.05) higher for cultivar Tsaeda in the wet season than the rest of the cultivars. Dry matter digestibility of Lematse (78.68%) was significantly (p<0.05) higher than the other cultivars and followed by Keyh (76.52%). Metabolizable energy of cactus cultivars was significantly higher in Keyh in the wet season than in the other cactus cultivars. The lowest metabolized energy was recorded in Tsaeda and Dekik in the dry season. The relative feed value for all cultivars was higher than the 151 value standard quality and classified as prime standard quality (high quality) forages.

Table 4. Dry Matter Intake, Digestibility and Relative Feed Values of Cactus Cultivars

Season	Parameters			
	DMI	DMDigst	RFV	ME(MJ/kg)
Wet season	6.119[a]	76.93[a]	364.88[a]	9.53[a]
Dry season	5.216[b]	75.39[b]	304.60[b]	8.71[b]
SEM	0.11	0.092	0.81	0.02
p-value	0.0001	0.0001	0.0001	0.0001
Species *Season				
Wet season				
Dekik	6.50[b]	75.16[c]	379.20c	9.18[e]
Keyh	5.63[d]	77.23[b]	337.31[d]	10.00[a]
Korem	5.53[e]	76.52[c]	328.0[e]	9.53[c]
Lematse	6.29[c]	79.45[a]	387.69[b]	9.68[bc]
Tsaeda	6.63[a]	76.29[c]	392.19[a]	9.25[d]
Dry season				
Dekik	5.53[e]	73.15[e]	315.82[f]	8.47[h]
Keyh	5.05[f]	75.78[c]	297.16[g]	8.74[f]
Korem	4.96[g]	74.68[d]	287.56[h]	8.81[f]
Lematse	4.82[h]	77.9[b]	291.43[h]	9.08[e]
Tsaeda	5.69[d]	74.99[d]	331.06[d]	8.42[h]
SEM	0.025	0.206	1.82	0.045
P-value	0.0001	0.76	0.0001	0.0001
Cultivar				
Dekik	6.022[b]	74.37[d]	347.51[b]	8.82[c]
Keyh	5.346[d]	76.51[b]	317.23[d]	9.37[a]
Korem	5.248[e]	75.60[c]	307.78[e]	9.17[b]
Lematse	5.56[c]	78.68[a]	339.56[c]	9.38[a]
Tsaeda	6.16[a]	75.64[c]	361.62[a]	8.84[c]
SEM	0.18	0.145	1.82	0.032
P-value	0.0001	0.0001	0.0001	0.0001

Means with different superscripts (a, b, c, d, e. f, g, h) in the same column are significantly different ($P<0.05$), SEM=standard error of mean, DMI = Dry matter intake; DDM = Digestibility of dry matter; RFV = Relative feed value.

Relationship between Chemical Components and *in vitro* Dry Matter Digestibility of Cactus Cultivars and Tree/Shrub Species

The relationship of chemical components and *in vitro* dry matter digestibility in cactus cultivars and tree/shrub species are shown in Tables 5 and 6, respectively. The CP content and IVDMD of the studied plants (among cultivars and species) were positively correlated. However, their CP content and IVDMD were negatively correlated with the fiber content (NDF, ADF and ADL). This coincides with the findings of Melaku et al. (2010); Mokoboki et al. (2019); Teklu et al. (2023); Mahyuddin (2008) who reported *in vitro* dry matter digestibility was positively correlated with crude protein and negatively correlated with fiber content. The CP content of tree/shrub species was negatively correlated with ash content of tree/shrub species. In line with this finding of Oko et al. (2016), the reported crude protein content was negatively correlated with ash ($r = -0.680$; $p<0.01$) and ADF ($r= -0.497$; $p<0.05$).

Table.5. Correlation Coefficient(r) of the Relationship between Chemical Components and IVDMD of Cactus Cultivars

	DM	Ash	CP	NDF	ADF	ADL	IVDMD
DM							
ASH	0.11						
CP	0.27	-0.225					
NDF	0.69***	0.53**	-0.27				
ADF	-0.26	-0.29	-0.81***	0.12			
ADL	-0.25	0.25	-0.12***	-0.12	0.49**		
IVDMD	0.35	-0.65***	0.80***	-0.33	-0.70***	-0.41*	

Table.6. Correlation Coefficient(r) of the Relationship between Chemical Components and IVDMD of Tree/Shrub Species

	DM	Ash	CP	NDF	ADF	ADL	IVDMD
DM	1						
ASH	0.11						
CP	-0.47**	-0.57***					
NDF	-0.27	0.14	-0.50**				
ADF	0.138	-0.022	-0.59***	0.83***			
ADL	-0.56**	-0.078	-0.18	0.79***	0.55***		
IVDMD	0.27	-0.24	0.61***	-0.84***	-0.66***	0.79***	1

Notice: astrix in superscripts of the numbers indicates that significance of the correlated parameters: (*level of significance: p<0.05,**level of significance: p<0.01, ***level of significance: p<0.001).

CONCLUSIONS

In conclusion, all tree/shrub species have CP level above the maintenance requirement for ruminant animals, especially A. saligna and D. viscosa have good potential as livestock feed and particularly as protein supplement for low quality roughages during the dry season. Based on relative feed value and fiber contents, they are also categorized as high quality forages. Cactus cultivars are better in metabolizable energy when compared to tree/shrub species. With the exception of some tree /shrub species they were also shown to have potential in terms of their IVDMD and energy contents. However, these results need to be further confirmed using animal feeding trial experiments to examine whether the potential could be translated into animal performance. Further research is also needed on mineral and ant- nutritional contents of the studied browse species.

CONFLICTS OF INTEREST

Authors declare that they have no conflicts of interest regarding the publication of this paper with the Journal of Science and Development.

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