# Seasonal variation in nutritive value of four browse species used by smallholder farmers for livestock in Eastern Cape Province, South Africa

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## Abstract

The use of browse plants as livestock feed during the dry season can improve deficiency of certain nutrients and sustain livestock production under small-scale farming system. This study was conducted to investigate the seasonal variation of nutrients of four browse species in the Eastern Cape Province. Samples (2kg) of fresh leaves from *Vachellia karoo, Prunus persica, Vepris lanceolata* and *Diospyros dichrophylla* were collected during winter, spring and summer. The experiment was a completely randomized design with three replicates for each species in each season. The chemical composition of these samples was determined using standard laboratory analytical techniques. The results indicate that, crude protein (CP) content range from 1.84% to 19.9% for winter and spring respectively. The average CP content was higher ($P < 0.05$) 16.0% in *P. Persica* compared to 15.29, 13.28 and 6.47% for *V. lanceolata, V. karoo and D. dichrophylla* respectively. A range of 1.06% to 34.9% and 5.9% to 20.5% values were recorded for ether extract (EE) and ash respectively, while the mean values for neutral detergent fibre (NDF) and acid detergent fibre (ADF) ranged from 17.4 to 69.54 and 17.59 to 37.11 respectively. The condense tannin (CT) content of browse species were observed to vary widely ($P < 0.05$) ranging from 0.12% (*P. persica*) to 28.89% (*V. Karoo*). The Ca, Na, P, and Fe contents were influenced by species while the Mg, Na, P, K Zn, Cu differed among seasons ($P < 0.05$). The results of this study showed that *Vachellia karoo, Prunus persica, Vepris lanceolata* contained adequate levels of nutrients to support ruminant animal production while *Diospyros dichrophylla* does not.

**Keywords:** Chemical composition, Diospyros dichrophylla, Prunus persica, Vachellia karoo, Vepris lanceolata.
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## Introduction

Livestock farming in communal grazing areas is mostly subsistence in nature and characterized by low inputs. Livestock farming is vital for the supply of meat and milk; it also serves as a source of additional income for livestock owners (Bettencourt *et al*., 2015). Despite the numerous benefits obtained from livestock under small-scale farming systems, feed inaccessibility and shortage are the major constraints for livestock production (Washaya *et al*., 2018). This becomes more serious especially during the long dry season when the little available feed standing forages are lignified (Olafadehan & Adewumi, 2009) and the crude protein (CP) content detoriates with adverse effects on voluntary intake, digestibility, productivity and reproductive performance (Lazzarini *et al*., 2009; Avornyo *et al*., 2019).

Browse plants constitute an abundant biomass in rangelands in the tropics and sub-tropics in Southern Africa. Okoli *et al*., (2000) reported that, browse species are commonly utilised wildely by small-holder livestock farmers for feeding small ruminants (Mapiye *et al.,* 2009; Gwaze *et al.,* 2010). Evidence is now inevitable that fodder trees are potent in increasing livestock production (Idamokoro *et al.*, 2016).

*V. karroo* is the most widespread among the acacias in Southern Africa. This browse species which is evergreen and preferred by goat is abundant mostly in communal rangelands. Historically, *V. karroo* was considered as an encroacher of these natural rangelands and much research work has focused on eradicating this browse tree (Nyamukanza & Scogings, 2008). However, Mapiye *et al.* (2011); Ngambu *et al.* (2013);

Brown et al. (2016) have reported a paradigm shift from an invader of the natural rangelands to a livestock feed, particularly for browse animal species.

These animals, particularly goats, utilize foliage, flowers and green pods. As reported by Orwa *et al* ., (2009) green foliage and pods contain an average 14-15% crude protein (CP) and this makes the species a good protein source for ruminants. Furthermore, *V. karroo* is reported to be the most widely spread Acacia species that is known to possesses an unparalleled potential to be used as feed for livestock (Idamokoro *et al.*, 2016) and that they meet the maintenance and production requirements of livestock (Ngambu *et al*., 2013).

*Diospyros dichrophylla*, which is commonly known as jackal berry, is a tree that grows up to 16 m high. In Africa, it is widely distributed in countries such as Senegal, Ethiopia, Kenya, South Africa, Swaziland, Nigeria and Namibia (Maitera *et al.*, 2018). It is valued for its fruits which are a delicacy for birds and animals (Nyambe *et al*., 2019). As reported by Adewuyi & Oderinde (2014), the species possess antibacterial and antifungal properties of the compounds isolated from the root have been reported.

The fruit of *D. mespiliformis* is also used in fermented drink and other meals. Little information is known about *V. lanceolata* save that it has adequate CP of 16% that can support ruminant production (Mthi *et al.*, 2016). *Prunus persica* has been considered in ruminant animal diets and much work has been centered on incorporating the leaves as ensiling material for use during lean periods (Salem *et al.*, 2013).

*P. persica* was reported to have the highest ruminal fermentation, highest microbial protein synthesis and efficiency, highest digestibility and metabolizable energy, compared to *L. esculenta*, *A. farnesiana* and *P. domestica* indicating that it is a high quality forage (Salem *et al.*, 2013). The species also possess antibacterial, antifungal, and antioxidant properties (Kant *et al*., 2018). Browse species have a potential to yield relatively higher levels of CP and minerals that are deficient in tropical grasses during dry season (Tavirimirwa *et al.*, 2019). Available feed resources during this period are generally deficient in nutrients such as protein, energy, minerals and vitamins, and hence cannot adequately meet the nutritional requirements of animal for maintenance (Brown *et al.,* 2018).

The challenge of feed supply to livestock seems to be huge and there is a need to investigate and search for alternative, less expensive and locally available sources of protein. Protein supply throughout the season is crucial for sustainable livestock production in sub Saharan Africa. The addition of new but cheaper sources to the world animal food supply could measurably reduce malnutrition and alleviate poor animal production performances (Ezeagu *et al*., 2002), which is happening across small scale production systems in sub Saharan Africa. The present study was therefore conducted to evaluate the nutritive value of *Vachellia karoo, Prunus persica, Diospyros dichrophylla* and *Vepris lanceolata* browse species as suitable alternative feed for livestock.

## Material and methods

Fresh leaves with of about 2kg were harvested from four-browse species *Vachellia karoo, Prunus persica, Diospyros dichrophylla* and *Vepris lanceolata* were collected over eight months (June 2014 – January 2015) from Goso indigenous forestry, which is located 15km East of Lusikisiki town SA. Leaf samples were collected randomly by hand picking from at least three trees until target weight was reached, once in each season (winter, spring and summer) for each browse species. The samples were oven dried to constant weight at $40^{0}$C for 48 hours. The browse species were collected based on the information obtained from respondents, who indicated that they were using these species to feed their livestock as fall back measures when grazing becomes inadequate or limited. Goso is situated within 31022'49.38"S longitude and 29035'48.57"E latitude. Vegetation is classified as Ngongoni Veld (Mucina & Rutherford, 2006). The most common trees/shrubs are *Acacia* species and *Agathisanthemum boreji*.

Then the samples for browse species were grounded separately in a Willey mill to pass through 1mm sieve for chemical and condensed tannins analysis. A sample of 500g per browse plants was kept in air-tight containers until used for analysis.

A sample of 2g was used to determine crude protein (CP; #954.01), crude fibre (CF; #932.02), ether extract (EE; #920.39), ash (#942.05) contents following standard procedures as described by AOAC (2002), Neutral and Acid Detergent Fiber were determined according to Van Soest *et al.* (1991). Anti-nutritional factors (condensed tannin) were determined by the method of Price *et al.* (1978). Furthermore, the mineral composition Calcium (Ca), Magnesium (Mg), Iron (Fe), Copper (Cu), Zinc (Zn), and Sodium (Na) were determined using atomic absorption spectrophotometer (Zohary, 1973). While the method of Goering &

Van Soest (1970) was used to estimate potassium (K). Phosphorous (P) concentration was determined calorimetrically as outline by Parkinson & Allen (1975).

A completely randomized design in 4x3 factorial arrangements (four treatment species and three seasons) was used. The data on proximate composition and CT were subjected to analysis of variance (ANOVA) using the General Linear Model of Genstat 18 Edition (2012). An F test at 5 % probability level was used to test for significance and means were separated using LSD test. The following model was used for data analysis:

$Y_{ijkl} = \mu + Ti + S_j + TS_{ij} + e_{ijkl}$.

Where $Y_{ijk}$ = response variable, CP, EE, Ash CT, etc.

$\mu$ = overall mean,

$T_i$ = effect of treatment species (i= *V. karoo, P. persica, V. lanceolata* and *D. dichrophylla*),

$S_j$ = effect of season (j= spring, winter and summer) and

$TS_{ij}$ = effect of interaction between treatments and season.

eijk = random error.

## Results

The results on the chemical composition for the browse species are shown in Table 1.

**Table 1** Seasonal changes in nutritional composition, fiber fraction and tannins of four browse plant species

| Seasons | Treatment | Chemical composition (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | CP | CF | Ash | EE | NDF | ADF | CT |
| Winter | *V. karoo* | 16.5$^{b}$ | 2.95$^{e}$ | 20.5$^{a}$ | 2.6 | 23.27$^{c}$ | 21.82$^{d}$ | 12.08$^{b}$ |
| | *D. dichrophylla* | 1.84$^{d}$ | 5.84$^{e}$ | 9.56$^{c}$ | 1.69 | 35.94$^{b}$ | 24.74$^{c}$ | 3.41$^{c}$ |
| | *V. lanceolata* | 16.94$^{b}$ | 15.7$^{c}$ | 10.8$^{bc}$ | 2.08 | 69.54$^{a}$ | 26.75$^{c}$ | - |
| | *P. persica* | 18.5$^{a}$ | 11.3$^{d}$ | 7.4$^{d}$ | 4.93 | 61.12$^{a}$ | 32.3$^{b}$ | 0.75$^{d}$ |
| Spring | *V. karoo* | 19.5$^{a}$ | 10.6$^{d}$ | 8.6$^{c}$ | 1.06 | 29.42$^{bc}$ | 19.74$^{d}$ | 28.89$^{a}$ |
| | *D. dichrophylla* | 7.3$^{c}$ | 13.5$^{cd}$ | 13.5$^{b}$ | 1.95 | 29.4$^{bc}$ | 26.54$^{c}$ | 7.36$^{bc}$ |
| | *V. lanceolata* | 14.9$^{b}$ | 19.2$^{b}$ | 7.5$^{d}$ | 1.3 | 29.41$^{bc}$ | 37.11$^{a}$ | - |
| | *P. persica* | 19.9$^{a}$ | 10$^{d}$ | 7.4$^{d}$ | 3.06 | 17.4$^{c}$ | 21.35$^{d}$ | 0.12$^{d}$ |
| Summer | *V. karoo* | 19.7$^{a}$ | 12.7$^{cd}$ | 7.5$^{d}$ | 1.85 | 19$^{c}$ | 20.8$^{d}$ | 27.57$^{a}$ |
| | *D. dichrophylla* | 6.1$^{c}$ | 15.3$^{c}$ | 5.9$^{d}$ | 2.52 | 31.27$^{b}$ | 22.7$^{cd}$ | 3.77$^{c}$ |
| | *V. lanceolata* | 18.5$^{a}$ | 25.7$^{a}$ | 7.8$^{cd}$ | 1.4 | 34.26$^{b}$ | 34.54$^{ab}$ | - |
| | *P. persica* | 16.2$^{b}$ | 13.4$^{cd}$ | 6.9$^{d}$ | 2.52 | 22.87$^{c}$ | 17.59$^{d}$ | 0.66$^{d}$ |
| Se | | 1.962 | 2.870 | 1.931 | 3.779 | 7.280 | 2.967 | 5.429 |
| P values | | | | | | | | |
| S | S | 0.001 | 0.001 | 0.073 | 0.001 | 0.037 | 0.002 | 0.049 |
| T | T | 0.005 | 0.094 | 0.014 | 0.004 | 0.001 | 0.528 | 0.006 |
| ST | ST | 0.001 | 0.001 | 0.026 | 0.001 | 0.012 | 0.058 | 0.745 |
| CV% | | 15.4 | 19.7 | 20.4 | 83.6 | 22.2 | 35.20 | 49.82 |

($^{abcdef}$) mean values within a column without a common letter differ ($P$<0.05)

There is an interaction between species and seasons for CP, CF, EE, Ash, NDF and ADF. *P. persica* showed higher CP, Ash, NDF and ADF in winter and spring with a significant drop in summer, the highest EE across all seasons, but the CT was not significant. *V. karoo* showed no significant difference for CP, NDF and ADF across all seasons ($P > 0.05$), while it showed the highest ash in winter, the highest CT in spring and summer ($P < 0.05$). *V. lanceolata* showed higher ($P < 0.05$) CP, CF and NDF in summer with a constant ($P > 0.05$) ash and EE among seasons and the highest ADF in winter. *D. dichrophylla* had the lowest CP, CF, NDF, ADF across all seasons, except for ash which was higher in spring ($P < 0.05$). The NDF content was significantly higher ($P < 0.05$) in winter for all species followed by summer and lastly spring. Species differences were also observed across seasons with *D. dichrophylla*, *V. lanceolata* and *P. persica* exhibiting the highest ($P < 0.05$) NDF values in winter, while *V. karoo* showed the highest NDF content in spring.

The ADF of *V karoo* and *D. dichrophylla* did not vary with season (P >0.05) while seasonal variations were observed for *V. lanceolata and P. persica*. The highest ADF content was obtained in *V. lanceolata* in spring while *P. persica* exhibited the highest ADL in winter. The analysis of condensed tannins indicated that *V. karoo* had the highest (P < 0.05) amount of tannins across all seasons with higher values occurring in summer and spring. The CT from *D. dichrophylla*, *V. lanceolata* and *P. persica* did not vary according to season (P>0.05). The micro and macro mineral content of browse species was evaluated and results are shown in Table 2.

**Table 2** Seasonal changes in macro and micro mineral content of four browse plant species

| Seasons | Treatment | Macro-minerals (%) | | | | | Micro-minerals (ppm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ca | Mg | K | Na | P | Zn | Cu | Fe |
| Winter | *V. karoo* | 3.87[a] | 0.38[c] | 1.48[a] | 0.072[e] | 0.105[e] | 5.6[d] | 11[b] | 174.3[d] |
| | *D. dichrophylla* | 1.84[d] | 0.2[e] | 0.81[b] | 3.70[e] | 0.07[f] | 1.36[d] | 7.6[c] | 74.3[d] |
| | *V. lanceolata* | 3.58[a] | 0.1[f] | 1.02[a] | 0.002[e] | 0.07[f] | 11.5[c] | 11[b] | 216.6[c] |
| | *P. persica* | 1.41[d] | 0.06[g] | 1.22[a] | 2.70[d] | 0.169[b] | 15.9[c] | 13[b] | 566.9[b] |
| Spring | *V. karoo* | 2.14[c] | 0.34[cd] | 1.22[a] | 94[c] | 0.24[a] | 9[d] | 41[a] | 446[b] |
| | *D. dichrophylla* | 1.25[d] | 0.31[d] | 0.71[b] | 163[b] | 0.11[d] | 20.07[c] | 40[a] | 419[bc] |
| | *V. lanceolata* | 2.65[c] | 0.29[d] | 0.95[b] | 31[c] | 0.12[d] | 41[b] | 39[a] | 157[d] |
| | *P. persica* | 2.92[bc] | 0.72[a] | 0.73[b] | 4[d] | 0.17[c] | 4[d] | 38[a] | 284[c] |
| Summer | *V. karoo* | 2.21[c] | 0.51[ab] | 0.11[d] | 13[d] | 0.17[c] | 16[c] | 1[d] | 236[c] |
| | *D. dichrophylla* | 1.63[d] | 0.46[b] | 0.79[b] | 289[a] | 0.1[e] | 13[c] | 4[c] | 279[c] |
| | *V. lanceolata* | 3.11[b] | 0.38[c] | 0.57[c] | 152[b] | 0.1[e] | 52[a] | 1[d] | 250[c] |
| | *P. persica* | 3.03[b] | 0.21[e] | 0.4[c] | 25[cd] | 0.14[d] | 50[a] | 20.0[b] | 789[a] |
| Se | | 0.416 | 0.089 | 0.183 | 56.43 | 0.024 | 7.243 | 9.023 | 80.6 |
| P-values | | | | | | | | | |
| | S | 0.001 | 0.299 | 0.721 | 0.001 | 0.002 | 0.006 | 0.936 | 0.001 |
| | T | 0.547 | 0.007 | 0.001 | 0.007 | 0.026 | 0.001 | 0.004 | 0.040 |
| | ST | 0.001 | 0.018 | 0.061 | 0.053 | 0.373 | 0.053 | 0.994 | 0.002 |
| CV% | | 17.6 | 28.1 | 21.8 | 64.06 | 18.2 | 35.20 | 54.16 | 26.6 |

([abcde]) mean values within a column without a common letter differ (*P*<0.05)

There is an interaction between season and species for Ca, Mg and Fe. The Ca, Na, P, and Fe contents were influenced by species while the Mg, Na, P, K Zn, Cu differed among seasons (P < 0.05). *V. karoo* had the highest (P<0.05) Ca value in winter followed by summer and lastly spring, while its MG and P were higher in summer compared to other seasons. The *V. lanceolata* maintained higher Ca values throughout the year yet its Mg, K, Na, P and zinc vary with respect to season. *P. persica* showed higher (P <0.05) Zn and Fe contents in summer compared to any other season, and low Ca and Mg values in winter. All species exhibited a significantly higher (P < 0.05) Cu value in spring.

## Discussion

The lower CP content for *D. dichrophylla* have also been reported by Mthi *et al.* (2016), indicating that the species is not adequate to support ruminant protein requirements as suggested by NRC (1985), (1996), (2001), and (2007) . The minimum level of CP required for optimal microbial function in the rumen is 8% (Norton 2003). Mero & Uden (1998) and Salem *et al.,* (2006) reported that differences in CP content between browse species may arise due to differences in protein accumulation in browse plants during growth. Additionally, soil type, the plant part, age of leaf and season at which the plants was harvested may cause variation in CP content of browse species. Expect for *D. dichrophylla* in spring, all other browse species in the study area have their CP level higher than the minimum recommended (7%) for ruminant maintenance and growth (NRC, 2001; NRC, 2007). The browse species had moderate to high CP content, than the minimum level of 7 to 8% required for optimum rumen function and feed intake in ruminant livestock (Kearl, 1982; Van Soest, 1994). In addition, plants species with high protein content can enhance intake, digestibility

(Washaya *et al*., 2018) and used as supplement with low quality feed such as grasses and crop residues (Baloyi *et al.*, 2006; Gusha *et al.*, 2013).

For ruminant animals, the NDF content at which feed intake and digestibility are severely affected is 600 g NDF/kgDM (Brown *et al.*, 2018). The NDF values in the current study are lower than the ones given by Gidado *et al.* (2013) which range from 39.23-58.63% except for *V. lanceolata* and *P. persica* in winter. Other readily available source of energy should be included if these two sources are used as sole diets during this period. Nonetheless all the species provide enough NDF to meet a minimum acceptable range of between 25 – 33% for dairy cows (NRC, 2001). Oni *et al.* (2008) reported that browse species have an NDF content above 50% has high proportions of soluble carbohydrates which are beneficial for proper rumen function. This is in contrast to results from the current study. Browse species with high NDF content may impose a limitation on feed intake or grazing animals especially if its' not digestible. The NDF concentration is negatively correlated with dry matter intake that is, as NDF increases, animals will consume less (Saha *et al.*, 2013). Furthermore, the digestible fraction of NDF (dNDF) impacts dry matter intake as well as the neutral detergent fibre digestibility (NDFD). Noratto *et al.* (2014), reported that the acceptable quantity of ADF that should be present in the feed falls within 16% to 19% while NRC, (2001) recommend a minimum of 17 – 21%. The average ADF values in the current study were higher than the ones reported by Gidado *et al.* (2013) however, these values still fall within the acceptable range for all ruminants (NRC, 1985, 1996, 2001, 2007). High ADF values are associated with decreased digestibility, therefore, a low ADF is better (Newman *et al.*, 2014).

Washaya *et al*. (2018) reported that a concentration of tannins above 5% cause rejection of browse plants by goats, whereas 2% and 5% concentration has negative effect in sheep and cattle (Mcleod, 1974). In a report by the maximum acceptable tannin levels should not exceed 100g/kgDM for ruminant animals, beyond this level tannins exhibit detrimental effects including reductions in live weight gain (Mkhize *et al.*, 2018), reduced plasma urea and glucose concentrations Wang *et al.* (2013), reduced protein availability for digestion and absorption (Min *et al.,* 2003), trigger nutrient body reserve depletion and thus negatively influence growth performance in long term (Ndlovu *et al.,* 2007) which is exhibited by an elevated blood NEF (Chimonyo *et al.,* 2000) .

Tannins play a significant role in the nutrition of animals, causing either adverse or beneficial effects on nutrient utilization, health and production (Schofield *et al*., 2001; Makkar, 2003; Mkhize *et al*., 2018). Tannins have also been shown to reduce enteric $CH_4$ production in ruminants (Hess *et al.,* 2011), promote high digestibility of nutrients (Yisehak *et al.,* 2014), and decrease the number of cellulolytic bacteria (McSweeny *et al.,* 2001). The results from our study showed that all browse species possess tannin levels below the detrimental level therefore can be utilized in ruminant diets. Although *V. lanceolata* can be used to supplement ruminants , it is to be used with caution as evidence from (Subratty *et al.,* 2005) show that levels of its phytochemicals (2 to 32 mg/ml) could be antibacterial against both gram positive and gram negative bacteria.

According NRC (2007), Ca content that meet metabolic requirements for range sheep and goats should be 5.1 and 3%, respectively. In the present study, Ca concentration compares favorably with other browse species (Bello & Abdu, 2011) and within the recommended range for goats (NRC, 2007) but in adequate for sheep. Variation in Ca during different seasons may be due to pH of the soil and carbonate content (Tripathi & Karim, 2008). Calcium is an essential component of plant cell wall offering support, rigidity and vigor to plant tissue. Ca is a very important mineral for ruminant animal growth, without which animal performance is severely affected.

The Mg content for all browse plants among different seasons are lower than the recommended metabolic requirements for range sheep and goats (1.5 and 1.6 % respectively) on dry matter bases (NRC, 2007). The low Mg content from browse species would likely subject ruminants to Mg deficiency which is exhibited as hypomagnesaemic tetany. Furthermore, Mayland & Wilkinson (1989) initially reported that high K concentration inhibits Mg translocation to upper parts of the plant, this was also later on confirmed by Mc Donald *et al.,* (2011). The interaction between Mg and K in magnesium tetany has also been reported by Mc Donald *et al.,* (2011). The K content of *V. Karoo, P. persica* and *V. lanceolata* (winter) and *V. karoo* and *V. lanceolata* (spring) was above recommended levels for grazing animals. The K concentration in browse species was outside the recommended range of 0.6% to 0.7% of DM for all kinds of beef cattle (NRC, 1996) and from 0.5% to 0.8% of DM for sheep (NRC, 2007).

In the current study, we observed that Na concentrations was higher during the summer compared to winter and spring seasons. In addition, the Na content in *D. dichrophylla* were much higher than the values of 0.06% to 0.08%DM required for beef cattle (NRC, 1996) and 0.09%-0.18% DM required for sheep (NRC, 1985). Whereas the Na content of *V. Karoo* was within DM requirements for beef cattle, the values for *P. persica* and *V. lanceolata* were below DM required for cattle and sheep. This in in agreement with findings of Greene (2000) and Mountousis *et al*. (2009) that native forages do not meet Na requirements of grazing animals. The interaction of minerals in ruminant diets has been discussed (McDonald *et al.,* 2011). High dietary cations, for example Na+ and K+ reduce the sensitivity of bone to parathyroid hormone and can limit the release of Ca, such conditions have led to metabolic conditions like milk fever in dairy animals. In principle, minimizing foods high in potassium and sodium are recommended to achieve an acid-base balance that favors productivity. The highest P concentration recorded for *V. karroo* in the current study compared to the rest of the browse species is indicative of its nutritive value. This is in agreement with Brown *et al.* (2016); Idamokoro *et al.* (2016) and Brown *et al.*, (2018).

According to NRC (1994), the recommended levels of P for all classes of ruminants range between 0.12 to 0.48%. In the current study, the P concentration for all browse species was within the recommended levels except for *D. dichrophylla* and *V. lanceolata, which* had lower concentrations. Of all minerals, P has the most known functions in the animal's body ranging from bone formation, milk production to fertility of ruminant animals (McDonald *et al.,* 2011). According to results, the concentration of zinc (Zn) was highest in *V. lanceolata* (52) in summer compared to other browse species. The content of Zn ranged from 1.36 to 52 among browse species in the current study, and these are considered lower compare to the ones reported for forage pastures (Mc Donald *et al.,* 2011) and only *P. persica* and *V. lanceolata* had the optimum required value for dairy animals as reported by NRC (2001) in summer. The minimum Zn requirements for goats is 10 ppm and levels above this will be toxic goats (NRC, 2001). Howver, lactating dairy cows require at least 63mg/kg Zn (NRC, 2001).

The Cu content observed in the current study during spring and winter was above the recommended levels (4-10%) required by goats (NRC, 1981) and that recorded in summer was also above the recommended levels (0.1%) for sheep and goats (NRC, 1984). Copper toxicity has been reported for especially lactating dairy goats (Bozynski *et al*., 2009). Copper can generally be regarded as a cumulative poison. The results imply that farmers should watch out for Cu toxicity throughout the year for their grazing animals in the study area. However, a deficiency of copper impairs the animal's ability to absorb iron, mobilize it from the tissues and utilize it in hemoglobin synthesis. On the other hand, Cu plays a vital role in many enzyme systems; for example, copper is a component of cytochrome oxidase, which is important in oxidative phosphorylation, it is also a component of superoxide dismutase, which forms part of the cell's antioxidant system.

The Fe content for all browse plant was above the minimum requirement for dairy (NRC 2001), beef cattle (NRC, 1978) and sheep (NRC, 1984), for all the seasons. The NRC (1981) recommended that dietary iron not exceed 1000 mg/kg DM. The high content and variation among species could be a result of genetics, variation in uptake of minerals between browse species, stage of maturity and proportion of leaf samples taken for analysis (Minson, 1990). It could also have emanated from variation in nature of soils, soil fertility and mineral status of the soil (Lukhele & van Ryssen, 2003). Iron has been reported to interfere with the absorption of other minerals, primarily copper and zinc (NRC 2001; 2007; McDonald *et al.,* 2007). The absorption of dietary iron depends on the binding capacity of transferrin and lactoferrin in blood and tissues, the excess lead to free iron. This free iron is very reactive and cause generation of reactive oxygen species, lipid peroxidation, and free radical production all of which results to oxidative stress, thereby increasing anti-oxidant requirements of the animal (NRC, 2001).

**Conclusion**

The proximate composition, mineral and CT content of browse species show that they have a potential to sustainably feed ruminant animals with the exception of *D. dichrophylla, which* is generally below average for most nutrients. There is the need to expand the study to other anti-nutritional factors such as phytin, hydrogen cyanide, oxalate, nitrite saponnins and alkaloids as well as incorporating leaves into a mixed silage for dairy animals. These plants species should be cultivated and protected as special forages for livestock to overcome the harsh conditions and the sever fluctuation in the nutritional status especially during the dry season.

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## Authors' contribution

Conception and design: SM and JR; data collection: SM and TM; data analysis: SM. SW and DW; drafting of paper: SM; critical revision: JR. TM. SW. DW and BS; final approval of version to be published: SM. JR. TM. SW. DW and BS.

## Conflict of interest

There is no conflict of interest associated with this manuscript.

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