INTRODUCTION

Bohor reedbuck (*Redunca redunca*) is a medium-sized African endemic antelope species placed under the genus *Redunca*, family Bovidae (Huffman, 2013; IUCN SSC Antelope specialist group, 2008). It was first described by German zoologist and botanist Peter Simon Pallas in 1767 (Estes, 1991; IUCN SSC Antelope Specialist Group, 2008). Five sub-species of Bohor reedbuck are known namely *R. redunca*
redunca, R. r. nigeriensis, R. r. cottoni, R. r. bohor, and R. r. wardi. The five sub-species of Bohor reedbuck are mostly known to occur in equatorial region of Africa (from Senegal (west) to Ethiopia (east)) (Kingdon, 2015). Among the five sub-species of Bohor reedbuck, Redunca redunca bohor is found in west, central, and southeast Ethiopia and Blue Nile of Sudan.

In Ethiopia, Bohor reedbuck populations have wide distribution from lowlands to high peak mountains (Afework et al., 2009; Girma, 2018; Habtamu et al., 2012; Yalden et al., 1984). They have been recorded as low as 400 m asl in the woodland and floodplain grasslands and as high as above 3,200 m asl in the open, swamp, and bushy montane grasslands (Afework et al., 2009; East, 1999; Yalden et al., 1984). Bohor Reebuck prefers water abundant areas and associated inundated grasslands (Kingdon & Hoffmann, 2013). Bohor reedbucks are mixed feeders. Open grassland and swamp grasslands are the preferred feeding sites of Bohor reedbucks. They are herbivores, they prefer grasses and tender reed shoots with high-protein and low-fiber content (Estes, 1991). The feeding ecology of Bohor reedbuck varies in season, for example in the dry season the diet of Bohor reedbuck consisted mainly of dicots, and they eat forbs and leaves of woody plants (Estes, 1991; Gutbrodt, 2006), and also, the amount of time spent while grazing in a particular area is possibly related to the availability and quality of grasses there in different season (Kingdon & Hoffmann, 2013).

Numerous food preference indices have been developed to compare use and availability of foods in the field of study of diets of wild ungulates. However, little attention has been given to laboratory analysis for comparing food preferences of a species across different ecosystems, regions, among others (Girma, 2016; Rodgers, 1990). Little is known about the nutritional content of plants consumed by Bohor reedbucks and how food nutritional composition determines their diet selection. Studies on feeding ecology of Bohor reedbuck in Ethiopia addressed only the diet composition and preferences without addressing the nutritional composition of the plants consumed by the species (Afework et al., 2009; Habtamu et al., 2012).

Feeding ecology is vital ecological phenomenon that describes the interaction between plant communities and herbivores. Foraging behavior is governed by various plant attributes such as plant availability and palatability and plant nutritional composition (Clauss et al., 2010; Tanentzap et al., 2009). Studies have indicated that selective foraging on high-protein and low-fiber content plants boost nutrient and energy intake and also decrease retention time, ultimately increasing intake capacity and fitness (Mysterud et al., 2001; Zweifel-Schielly et al., 2012). It has been reported that for herbivores the level of nutrients and toxins in a plant or its neighbors are key factors that determine the palatability of the plant to be consumed (Provenza et al., 2002). Since, all plants contain some amount of toxin herbivores cannot completely avoid toxins, but have to regulate the intake of toxins (Foley et al., 1999). Ultimately the interaction between plant chemistry and herbivore learning determines the coexistence of plants and animals affecting sustainable biodiversity conservation (Provenza, Villalba, Dziba, Atwood, & Banner, 2003). Furthermore, animal factors such as body size, digestive physiology and experience determine foraging behavior (Clauss & Hummel, 2005; Clauss et al., 2008; Parker & Bernard, 2006).

Studies on feeding behavior are necessary to enable estimates of the coexistence of wild animals in a particular ecosystem (Gutbrodt, 2006). The behavior of individuals and the strategies they adopt to maximize fitness plays an important role when a species’ natural behavior can lead to conservation problems in habitats altered by humans (Festa-Bianchet & Marco, 2003). Information on nutritional composition of herbivores is vital for better understanding of resource requirements and offers intuition into herbivore influences on an ecosystem as well as animal populations (Parker & Bernard, 2006; Tanentzap et al., 2009). Clear nutritional composition analysis is crucial for clear understanding of animal normal growth and the maintenance of good health (Clauss et al., 2010). Therefore, this study aimed to determine the nutritional composition and preferences of Bohor reedbuck in the compound of Alage Agricultural College (AAC), Central Rift Valley of Ethiopia.

2 | MATERIALS AND METHODS

2.1 | Description of the study area

Alage Agricultural College is located at about 217 km south west of Addis Ababa in Central Rift Valley zone of Ethiopia. The college shares its boundaries between two administrative regions, namely, Oromia and South Nations Nationalities and Peoples Regional States (Figure 1). The study area is geographically situated between 7°35’0” to 7°37’30”N latitude and 38°25’0” to 38°27’30”E longitude (Figure 1).

The topography of the area is characterized by midland with altitude ranging from 1,580 to 1,650 m above sea level. The area is characterized by bimodal rainfall pattern. It receives most of its rain in the months of June to September, with minor erratic rainy season during the months of March and April. The average annual rainfall is 708–900 mm (Ethiopian National Meteorological Agency, 2017). The mean maximum and minimum annual temperature is 30.19°C and 8.1°C respectively (Ethiopian National Meteorological Agency, 2017).

The total area of the college is 29.46 km². Jido River surrounds the vast majority of the area in the north, east and north east directions. As described by Water Works Design and Supervision Enterprise (WWDSE) (WWDSE, 2013) the land cover is dominated by acacia wooded grassland (55%) followed by riverine and plantation forest (6.1%), open grasslands (8.4%) and farmlands, residential and other service areas (19.2%). Only the small part of the college is fenced. Furthermore, there was no management plan for flora and fauna. Particularly, there were no stocking plan for vertebrates and planting plan for vegetation (WWDSE, 2013), implying that the study area is more or less natural habitat.

Dominant tree species in the area are; Acacia senyal, Dicrostaches cineria, Acacia tortolis, Acacia mellifera, Acacia macrostachia, Eucaluptus spp, Balanite aegyptica, and Aloe spp. In addition, characteristic
grass species such as *Cynodon aethiopicus*, *Hyparrhenia cymbaria*, *Cynodon dactylon*, *Chloris gayana*, and *Panicum maximum* dominate the open grassland areas (WWDSF, 2013). Mammals such as wart-hog (*Phacochoerus aethiopicus*), Bohor reedbuck (*Redunca redunca bohor*), African civet cat (*Civeticus civetta*), spotted hyena (*Crocuta crocuta*), grivet monkey (*Cercopithecus aethiops*), Abyssinian hare (*Lepus habessinicus*), and anubis baboon (*Papio anubis*) are frequently sighted from the area (First author personal observation, 2018).

### 2.2 Methods

#### 2.2.1 Sampling design

Four easily recognizable and approachable groups of Bohor reedbuck populations were selected during reconnaissance survey representing the four dominant habitat types namely: Acacia dominated wooded grassland, Riverine forest, Open grass land and Farm land. Recognizable groups (known group size, natural marks, known home range and activity) of Bohor reedbuck were selected and observed in each of the four different habitat types. Individuals observed up to 50 m far from the group was counted as the member of the same group (Caro, 1999).

The dietary data of Bohor reedbuck were collected through continuous focal animals observation of individuals (ranged from 5 to seven individuals per group, the number of individuals varied based on the habitat type) of the same group that were not reproductively active (all individuals targeted were available during the whole data collection period) (Altman, 1974). Focal animals’ observation was carried out through following up all individuals of one selected easily recognizable and approachable groups of Bohor reedbuck population at a time (Yihune & Bekele, 2012). Observation of focal individuals was carried out for 30 min in 10 min sampling interval during morning hours (7:00 a.m. to 11:00 a.m.) and late afternoon hours (3:00 p.m. to 5:00 p.m.) when the animals were actively foraging, for each recognizable group at each habitat type during both dry and wet seasons. A total of 82 hr in 10 days (both in wet and dry seasons) were spent observing the focal animals. In each season a total of 41 hr in five days were spent observing the focal animals. For each group in each habitat type equal numbers of hours were spent observing the focal animals. The observations were carried out with a distance (between 50 and 200 m) approaching the group from different directions (Afework et al., 2009; Tekalign & Bekele, 2012). All individuals in a group were observed at the same time with a help of trained personnel of the Bohor reedbuck identification techniques, the method of sampling and plant consumed. Field assistants were B.Sc. graduates in wildlife management and related natural resource management disciplines.

The frequency of occurrence of the plant species in the study area that was consumed by Bohor reedbuck and not consumed but available to Bohor reedbuck was estimated using 21 plots (4 m by 4 m) established along 7 transect lines. Transect lines and sampling plots were established proportionally to the size of each habitat type. Accordingly in Acacia dominated wooded grass land 3 transects and 12 plots were established, whereas in riverine, open grasslands and farmlands 1 line transect that consist of 3 sampling plots in each habitat type were established. Transects and plots were established representing each habitat types and in a way it captures all of the plants consumed by the Bohor reedbuck. The area is sparse in its vegetation diversity (mostly covered by bare soil), and few sampling
plots could exhaustively capture the available plant species in the area. The distance between each transect was 0.5 km, and also, the distance between each plot was 0.5 km and the length of each transect was 2 km.

2.2.2 | Data collection

The data on groups of feeding Bohor reedbuck were recorded particularly; the type of plant species consumed and the type of food item preferred (young leaves, mature leaves, shoots, flowers and fruits) during both wet and dry seasons. To minimize any disturbance effect caused by the observer camouflaging clothes were used. Furthermore, the animals were approached walking gently and quietly against the direction of wind movement to avoid being scented by the animals. Once the animals were approached to observable distance, before collecting information they were allowed to become acclimated and resume feeding for a minimum of 10 min following Hochman and Kotler (2006), Tadesse and Kotler (2011), Tadesse and Kotler (2013), & Girma (2016). Close investigation of the feeding site were made for verification of plant species consumed. Close investigation of the feeding site was carried out after the 30 min continuous observation ended up during 10 min interval break. Evident, green, moist, freshly severed tissue characteristics were considered as a confirmation of a particular plant species consumed by the ungulates (Girma, 2016; Pienaar, 2013). The plant species were identified by the guide; Flora of Ethiopia and Eritrea (Phillips, 1995) and by comparison with archived specimens from the collection housed at the National Herbarium in Addis Ababa University.

The untouched fresh (both young and mature leaves, but not old dried ones) plant leaves and shoots, flowers and fruits for only grass species consumed by the Bohor reedbuck from the four habitat types were collected in a plastic bag for the proximate analysis. All plant parts were mixed together for the proximate analysis, no classifications in to plant parts were made. Forage quality analysis was carried out based on wet season data and across habitat due to logistic constraints. Thus, seasonal or habitat variations were not tested. The proximate analysis of 15 plant species (five from highly preferred, five from moderately preferred and 5 from rarely consumed and avoided) consumed by Bohor reedbuck was used as forage quality test. As part of the proximate analysis Moisture, Dry Matter, Organic Dry Matter, Ash, Nitrogen/Crude protein, Neutral Detergent Fiber (NDF), and Acid Detergent Fiber (ADF) was analyzed following AOAC (1995) analytical procedures. According to AOAC (1995) the following procedures were used to carry out the laboratory analysis for all proximate analysis.

Before proceeding to the analysis the weight of sampled items were weighed using electronic balance and then fresh forage samples were dried for 48 hr at 60°C in an air-circulation oven to obtain air dried samples ready for grinding. The weight of dried sample was recorded with electronic balance and also the dried samples were grounded to 1mm particle size with a Wiley mill. Dried and ground samples were stored in airtight containers away from heat and light to avoid moisture in take. The dry matter content of the sample plant were determined through adding approximately 2 g of ground sample to the crucible and drying it overnight at 105°C with in the oven dry, then the percentage of dry matter (DM) was calculated. The ash content of the sample was determined by igniting dry matter samples overnight at 550°C in a muffle furnace, and then percent ash was calculated. Determination of total nitrogen (crude protein) was conducted mixing 0.2g sample with equal amount of catalyst and digesting the sample in sulfuric acid using K2SO4/ CuSO4 as a catalyst. Then, N was converted into NH4 then the distilled solution was trapped in boric acid and titrated with H2SO4, then Percent of Crude Protein (CP) was calculated. Determination of the Neutral Detergent Fiber (NDF) was carried out through adding 0.5 g sample (Ws) in 600 ml Berzelius beaker and adding 100 ml of neutral detergent solution and 0.5 g sodium sulfate (Na2SO4). Then the mixture was boiled for one hour in refluxing apparatus and was poured through glass crucibles and vacuum was admitted, residues were ashed for three hours at 550°C and cooled to room temperature in desiccators. Determination of Acid Detergent Fiber (ADF) was conducted through adding 0.5 g sample (Ws) and 100 ml of acid detergent in 600 ml Berzelius beaker solution. Then the mixture was boiled for one hour in refluxing apparatus and poured through glass crucibles and admitted vacuum, ash residues for three hours at 550°C and cool to room temperature in desiccators.

The relative density and frequency of occurrence of the plant species that was consumed by the Bohor reedbuck and not consumed, but available to Bohor reedbuck were recorded through estimating their density and occurrence in different plots and extrapolating the average to the size of the total study area.

2.2.3 | Data analysis

Microsoft Excel 2010 was used for data summarization and to organize results into tables and figures. All statistical tests were analyzed using SPSS version 23 computer software program. Mann–Whitney rank test analysis was used to examine the relationship between relative frequency of consumption of species and its availability (i.e., relative frequency of occurrence) following Johnson (1980).

The food preference indices (FPI) for each plant species consumed by Bohor reedbuck was calculated and ranked to determine the most preferred plants. The feeding preference index (FPI) of Bohor reedbuck for each plant species was calculated by the Equations (1–3);

\[
FPI = \frac{\text{frequency of usage the plant species}}{\text{frequency of occurrence}}
\]  

(1)

\[
\text{Frequency of usage of the plant species} = \frac{\text{number of record the plant species consumed}}{\text{Total number of sample records}}
\]  

(2)

The frequency of occurrence (FO) of the plant species in the area also was calculated using equation (3) below
The absolute density (density) of the plant species in the area is calculated using Equation (4) below:

$$\text{Density} = \frac{\text{Number of individuals}}{\text{Sum of plot areas}}$$  \hspace{1cm} (4)

The Relative Density (RD) of the plant species in the area was calculated by Equation (5):

$$\text{RD} = \frac{\text{Total estimated density of a given specie} \times 100}{\text{Total density of all consumed species}}$$  \hspace{1cm} (5)

Percentage preference of Bohor reedbuck to plant parts (%PPP) was computed by Equation (6):

$$\%\text{PPP} = \frac{\text{Number of samples the plant parts consumed} \times 100}{\text{Number of samples the plant spp. consumed}}$$  \hspace{1cm} (6)

Sørenson’s similarity (Ss) index between the plant species consumed by Bohor reedbuck during wet and dry season was made following (Kent & Coker, 1992) (Equation 7).

$$\text{Ss} = \frac{2a}{(2a + b + c)}$$  \hspace{1cm} (7)

where $a =$ number of species consumed in both seasons, $b =$ number of species unique to wet season $c =$ number of species unique to dry season.

Chi-square test was used to examine frequency of each plant species consumed among habitat type.

According to AOAC (1995) the percentage values of all the proximate analysis were calculated by the Equations (8)–(14);

a. $\%M = \left( \frac{\text{wt}_{\text{sample + dish before drying}}}{\text{wt}_{\text{sample}}} \right)$ \hspace{1cm} (8) (Method 930.04)

where $\%M =$ percentage of Moisture, $\text{wt}_{\text{sample + dish before drying}} =$ wt of sample + dish before drying, $\text{wt}_{\text{sample}} =$ wt of sample + dish after drying, $\text{wt}_{\text{s}} =$ Wt of sample taken.

b. $\%\text{DM} = \left( \frac{\text{wt}_{\text{oven-dry crucible + sample}}}{\text{wt}_{\text{oven-dry crucible}}} \right)$ or $\%\text{DM} = 100 - \%\text{Moisture}$ \hspace{1cm} (9) (Method 2001.2)

where $\%\text{DM} =$ Percentage of dry matter, $\text{wt}_{\text{oven-dry crucible + sample}} =$ Weight oven-dry crucible + sample, $\text{wt}_{\text{oven-dry crucible}} =$ Weight oven-dry crucible, and $\text{wt}_{\text{s}} =$ record weight.

c. $\%\text{Ash} = \left( \frac{\text{wt}_{\text{sample + dish before drying}}}{\text{wt}_{\text{oven-dry crucible}}} \right)$ \hspace{1cm} (10) (Method 942.05)

where $\%\text{Ash} =$ weight ignited crucible + sample, $\text{wt}_{\text{oven-dry crucible}} =$ Weight oven-dry crucible, $\text{wt}_{\text{oven-dry crucible}} =$ (Weight oven-dry crucible + sample), $\text{wt}_{\text{s}} =$ Weight oven-dry crucible.

d. $\%\text{NDF} = \left( \frac{\text{wt}_{\text{oven-dry crucible}}}{\text{wt}_{\text{oven-dry crucible}}} \right)$ \hspace{1cm} (13) (Method 2002.04)

e. $\%\text{ADF} = \left( \frac{\text{wt}_{\text{oven-dry crucible}}}{\text{wt}_{\text{oven-dry crucible}}} \right)$ \hspace{1cm} (14) (Method 973.18)

where $\%\text{NDF} =$ percentage of Neutral detergent fiber, $\text{wt}_{\text{oven-dry crucible}} =$ Weigh sample and crucible, $\text{wt}_{\text{oven-dry crucible}} =$ Weigh oven-dry glass crucible and $\text{wt}_{\text{s}} =$ weight of sample.

Since nutrient requirement data for Bohor reedbuck is not available, the nutrient requirements of common bushbuck (MacLeod et al., 1996) were used to determine an ideal or optimal nutritional profile. Common bushbuck was selected due to availability of published data on nutritional profile and relatively closes relation of the species to Bohor reedbuck.

Multivariate hierarchical clustering procedure was carried out to classify the plant species consumed by Bohor reedbuck into forage quality groups based on percent crude protein and moisture content from proximate analysis and percent frequency of usage of plants consumed data calculated using the formula above (Equation 2). The amalgamation steps used the Euclidean distance and complete linkage (furthest neighbor) to calculate the inter-cluster distances and the final partitioning presented in a Dendrogram.

### 3 | RESULTS AND DISCUSSION

#### 3.1 | Diet composition

Bohor reedbucks consumed a total of 15 species of plants out of 35 plant species available in the study area (WWF, 2014); 12 species of herbs, 1 shrub and 2 tree species. The selective feeding strategy of Bohor reedbuck (Gutbrodt, 2006) could be the reason for reduced (15) number of plant species in their feed. Similarly, greater kudu selected 17 plant species out of 38 species available in the miombo woodland adjacent to Umfurudzi Park in Zimbabwe (Chinomona et al., 2018). Furthermore, elephants have been observed to selectively browse on 22 plant species out of 35 plant species available (Biru & Bekele, 2012). However, disparate finding to
this study is a study conducted in Dinder National Park of Sudan indicated that Bohor redbucks observed to consume a wide variety (25) of plant species in their diets (more than 85% of available plants) (Ahmed, 2005). Similarly, the generalist feeder common warthog has been observed to forage on about 83% of available plants in Tanzanian savanna (Treydte et al., 2006). The reduced variety of plant consumed in the present area could be attributed to the reduced floral diversity and poor nutritional quality of plants available in the present study area (WWDSE, 2013). The present study area is characterized by infertile sandy soil and erratic rainfall that promote sparse vegetation diversity and less nutritional quality feed. Furthermore, since the area is less protected as compared to Dinder National Park disturbances such as human activities, livestock grazing could reduce both the diversity of plant species and foraging opportunity of the species. The majority (50%–55%) of plant species avoided by Bohor reedbuck in the study area was lowest in nutritional composition (low crude protein, which is likely accompanied by increased carbohydrate) as compared to the benchmarked species common bushbuck (MacLeod et al., 1996) and rarely occurs during dry season (WWDSE, 2013). Furthermore, as the dry season progresses the nutritional content (protein content, which is likely accompanied by increased carbohydrate) of the forage species decline and hence, become less preferred and attractive (Omphile et al., 2004). Several studies have indicated that floral diversity of a particular area may influence feeding composition of ungulates and shape their selective feeding behavior (Clauss et al., 2007; Codron et al., 2007; Owen-Smith, 1994). Bohor reedbucks were both grazers and browsers but they were more grazers than browsers. Grasses comprised 73% of the plant species consumed by Bohor reedbuck and it contributed 94.3% of dry matter of their feed (Table 1). The predominant selective grazing of grass species over other plant species available by Bohor reedbuck was an indicator of their grazing behavior (Cerling et al., 2003; Estes, 1991; Kingdon, 1997). Similarly, Ahmed (2005) and Gutbrodt (2006) reported grasses comprised the highest proportion of Bohor reedbuck feed. The selective grazing behavior of the species implies the need for conservation of the selectively grazed plant species in the compound of the college for sustainable conservation of populations of Bohor reedbuck in the college.

A total of 11 and 13 species of plants were consumed during the wet and dry seasons respectively (Table 1). Despite the fact that plant species Panicum infestum, Pennisetum ciliare, Acacia seyal, and Balanites aegyptiaca were available in the study area during both dry and wet seasons, they were only consumed during dry season (Table 1). Cenchrus ciliaris and Hyparrhinia hirta were available as forage only during wet season and consequently consumed only during wet season (Table 1). Sorenson's similarity index of plant species consumed by Bohor reedbuck during wet and dry seasons was 0.75. According to Ratliff (1993), Sorenson's similarity index values in a range of 0.51 to 0.75 indicates high similarly of species, implying considerably high degree of Bohor reedbuck dietary overlap between wet and dry seasons in the study area. Similarly, about 60% dietary overlap was recorded in the diet of Bohor reedbuck between dry and wet seasons in humid coastal savanna in Tanzania (Halsdorf, 2011). The significantly high diet overlap between dry and wet seasons could be explained by the year round availability of most consumed species in the study area. The slight increase in plant species consumed during dry season could be due to the fact that during dry season, the forage availability and quality of most plant species consumed decline and, hence the species had to include few more species to meet up the compromised forage quality and availability. Since the area receives little rainfall during dry season (WWDSE, 2013), grass species like Pennisetum ciliare and Hyparrhinia hirta were dried and were not readily available for consumption. The number of plant species consumed by Bohor reedbuck during wet and dry seasons at Alage Agricultural College, Ethiopia

| Plant species                  | Family       | Habit/growth form | Seasons | Relative density (%) |
|-------------------------------|--------------|------------------|---------|----------------------|
| Cynodon aethiopicus           | Poaceae      | Herb             | Both    | 21.27                |
| Cynodon daucylon              | Poaceae      | Herb             | Both    | 20.73                |
| Chloris gayana                | Poaceae      | Herb             | Both    | 12.04                |
| Panicum maximum               | Poaceae      | Herb             | Both    | 8.83                 |
| Doctyoctenium aegyptium       | Poaceae      | Herb             | Both    | 6.17                 |
| Panicum infestum              | Poaceae      | Herb             | Dry     | 5.38                 |
| Bothriochloa insculpta         | Poaceae      | Herb             | Both    | 5.21                 |
| Pennisetum ciliare            | Poaceae      | Herb             | Dry     | 4.45                 |
| Cenchrus ciliaris             | Poaceae      | Herb             | Wet     | 3.55                 |
| Digitaria abyssinica          | Poaceae      | Herb             | Both    | 3.33                 |
| Hyparrhinia hirta             | Poaceae      | Herb             | Wet     | 3.1                  |
| Acacia seyal                  | Fabaceae     | Tree             | Dry     | 2.22                 |
| Rhynchosia minima             | Fabaceae     | Herb             | Both    | 1.38                 |
| Rhus quartiniana              | Anacardiaceae| Shrub            | Both    | 1.18                 |
| Balanites aegyptiaca          | Balanitaceae | Tree             | Dry     | 1.1                  |

Note: “Both” indicate the plant species consumed during the two (wet and dry) seasons.
species in the diet of Bohor reedbucks increased during the dry season coinciding with decreasing quality of available forage (Omphile et al., 2004; Wolfson & Tainton, 1999). As selective feeders Bohor reed buck depend on sufficient food quality and select the nutrient richest forage (Gutbrodt, 2006), it may include alternative foods during the dry season to meet their nutritional requirements.

The findings of feeding preference and proximate analysis indicated that crude protein and moisture content were the potential driving forces for selective grazing/browsing (Tables 2 and 3). Bohor reedbucks were selecting for a consistent nutrient profile (mainly crude protein and moisture) each season. Species highly preferred were those with relatively higher crude protein and high moisture contents during both dry and wet seasons. However, during dry season moisture content was found to highly determine selective foraging. For instance, Acacia seyal was exclusively browsed in dry season due to its better moisture content potential, despite its lowest crude protein content. Acacia seyal is typical arid tree species that conserve moisture in its leaves due small sized and waxy cuticle (Mohammed & Röhle, 2011).

### 3.2 | Feeding preference

Among the plant species consumed by Bohor reedback *Digitaria abyssinica* (1.19 FPI) and Cynodon dactylon (1.13 FPI) were the most preferred species during the study period followed by *Panicum maximum* (0.76 FPI), whereas *Acacia seyal* (0.17 FPI) and *Centuries cilaries* (0.19 FPI) was the least preferred species (Table 2). Food preference is highly determined by availability and quality of food (Kingdon & Hoffmann, 2013). Mann–Whitney rank test analysis indicated that there is significant correlation between frequency of use of plants consumed and availability (relative frequency of occurrence) ($W = 180.0, p = .03$). For instance, *Digitaria abyssinica* is among the least available species, but has the highest crude protein (CP) content (23.75% CP) and contains relatively higher moisture (13.6%) and less fiber (61.19% Neutral Detergent Fiber (NDF) and 27.8% Acid Detergent Fiber (ADF)) (Table 3). Several authors have reported that selective grazing is highly governed by nutritional content such as CP, moisture, NDF and ADF (e.g., Chinomona et al., 2018; Gutbrodt, 2006; Kingdon & Hoffmann, 2013; Omphile et al., 2004). The plants species such as *Cynodon dactylon* (0.89 frequency of usage) and *Chloris gayana* (0.54 frequency of usage) were frequently consumed plant species during both seasons (Table 2). However, *Digitaria abyssinica* (0.86 frequency of usage) and *Daicyocticum aegyptium* (0.75 frequency of usage) were the most commonly consumed during the wet season. On the other hand, *Pennisetum ciliare* (0.85 frequency of usage) and *Panicum infestum* (0.76 frequency of usage) were frequently consumed during dry season. It has been reported that diet composition of many ungulate species varies substantially among seasons (Ego et al., 2003; Halsdorf, 2011). There was also statistically significant variations in the frequency of each plant species consumed among habitat types during both dry ($X^2 = 24.23, df = 3, p = .01$) and wet ($X^2 = 17.27, df = 3, p = .01$) seasons. This is mainly attributed to the change in availability of a particular species and change in nutrition content, a general decline of nutrient content as dry season continues (Ombabi et al., 2001). Particularly, all those species frequently consumed during the dry seasons were available during both seasons. Both *Pennisetum ciliare* and *Panicum infestum* were frequently consumed during the dry seasons mainly due to their highest moisture (11.97 and 11.54% respectively) content (Table 3).

| Plant species                      | Frequency of usage | Rank | Frequency of occurrence | Rank | FPI       | Rank |
|------------------------------------|--------------------|------|-------------------------|------|-----------|------|
| *Digitaria abyssinica*             | 0.56               | 3    | 0.47                    | 9    | 1.19      | 1    |
| *Cynodon dactylon*                 | 0.89               | 1    | 0.79                    | 3    | 1.13      | 2    |
| *Panicum maximum*                  | 0.57               | 2    | 0.75                    | 4    | 0.76      | 3    |
| *Chloris gayana*                   | 0.54               | 4    | 0.81                    | 2    | 0.67      | 4    |
| *Daicyocticum aegyptium*           | 0.35               | 5    | 0.55                    | 6    | 0.64      | 5    |
| *Panicum infestum*                 | 0.26               | 6    | 0.51                    | 7    | 0.51      | 6    |
| *Balanites aegyptiaca*             | 0.04               | 14   | 0.08                    | 15   | 0.50      | 7    |
| *Bothriochlo ainsculpta*            | 0.26               | 7    | 0.68                    | 5    | 0.38      | 8    |
| *Pennisetum ciliare*               | 0.15               | 9    | 0.45                    | 10   | 0.33      | 9    |
| *Rhus quadriniana*                 | 0.05               | 13   | 0.16                    | 14   | 0.31      | 10   |
| *Cynodon oethiopicus*              | 0.24               | 8    | 0.90                    | 1    | 0.27      | 11   |
| *Hyparrhinia hirta*                | 0.09               | 11   | 0.39                    | 11   | 0.23      | 12   |
| *Rhynchosia minima*                | 0.06               | 12   | 0.26                    | 12   | 0.23      | 12   |
| *Cenchrus cilaries*                | 0.10               | 10   | 0.53                    | 8    | 0.19      | 13   |
| *Acacia seyal*                     | 0.04               | 15   | 0.23                    | 13   | 0.17      | 14   |

**Note:** Rank usage refers to the frequency of use of a particular plant species by the Bohor reed buck, and rank FPI is a factor of frequency of use and availability of a particular plant species consumed by the Bohor reed buck.
Proximate analysis of plant species

Balanites aegyptiaca (17.53%) and Panicum maximum (11.66%) had the lowest moisture contents (Table 3). Digitaria abyssinica (23.75%) and Daucyctcenium aegyptium (21.74%) species had the highest crude protein content, whereas Cynodon ethiopicus (10.41%) and Acacia seyal (10.59%) had the least nitrogen and crude protein content. The NDF of Chloris gayana (69.77%) and Bothriochloa insculpta (67.77%) was highest, while was least in Balanites aegyptiaca (28.91%) and Acacia seyal (29.11%). Panicum maximum (49.3%) and Panicum infestum (45%) had the highest ADF, while Rhynchosia minima (19.8%) and Acacia seyal (27.5%) had the least (Table 3).

The final partition of the cluster group analysis clustered all the observations at 66.7% similarity in to three clusters. Cluster 3 has the highest number of observations (8), while cluster 1 has the least number of observations (2) (Table 4, Figure 2). The three clusters are highlighted in different color in Figure 2.

The 2 species clustered in cluster one had higher crude protein, moderate NDF and ADF, the 5 species under cluster two had moderate moisture, crude protein highest, NDF and ADF proportion. On the other hand, species under cluster three had the lowest moisture, crude protein, NDF and ADF proportions (Table 5).

The most preferred species (with relatively highest protein content); Digitaria abyssinica and Cynodon dactylon followed by Panicum maximum and Chloris gayana contribute the highest proportion (60.57%) of the diet of Bohor reedbuck. The report from Sudan at Dinder National Park (Bordering Ethiopia) by Ahmed (2005) shows that Cynodon dactylon is the first ranked species to be consumed by Bohor reedbuck and also this plant species contributed the highest proportion to the diet of nyala (Tragelaphus angasi) in southern Africa (Pienaar, 2013). For herbivores, foraging preferences are shaped by multiple constraints, such as the availability of the food, nutritional quality of the food and the requirements of the animals (Sinclair et al., 2006). The feeding preference of Bohor reedbucks might be influenced by the nutritional quality, especially crude protein and moisture content and frequency of occurrence of the plant species. The first rank preferred plant species by Bohor reedbuck (Digitaria abyssinica and Cynodon dactylon) illustrate the above statement. Digitaria abyssinica was preferred by its high nutritional quality (high crude protein and the lowest ADF) as evidenced by proximate

### Table 3

| Plant species             | %M   | %DM  | %Ash | %ODM | %CP  | %NDF | %ADF | FPI  |
|---------------------------|------|------|------|------|------|------|------|------|
| Digitaria abyssinica      | 13.6 | 86.4 | 19.37| 80.63| 23.75| 61.19| 27.8 | 1    |
| Cynodon dactylon          | 11.71| 88.29| 19.32| 80.68| 18.56| 66.75| 30.3 | 2    |
| Panicum maximum           | 11.66| 88.34| 21.23| 78.77| 11.02| 62.64| 49.3 | 3    |
| Chloris gayana            | 12.98| 87.02| 21.83| 78.17| 21.17| 69.77| 34.5 | 4    |
| Daucyctcenium aegyptium   | 14.07| 85.93| 18.39| 81.61| 21.74| 67.01| 42.2 | 5    |
| Panicum infestum          | 16.51| 83.49| 19.78| 80.22| 14.43| 60.62| 45.0 | 6    |
| Balanites aegyptiaca      | 17.53| 82.47| 20.12| 79.88| 17.94| 28.91| 31.0 | 7    |
| Bothriochloa insculpta     | 10.08| 89.92| 20.06| 79.94| 17.5 | 67.77| 37.1 | 8    |
| Pennisetum ciliare         | 16.97| 83.03| 19.99| 80.01| 9.89 | 52.99| 39.9 | 9    |
| Rhus quartiniana           | 11.83| 88.17| 14.01| 85.99| 21.85| 33.17| 34.7 | 10   |
| Cynodon aethiopicus       | 13.11| 86.89| 15.64| 84.36| 10.41| 47.87| 43.2 | 11   |
| Hyparrhinia hirta          | 11.45| 88.55| 18.95| 81.05| 18.07| 64.59| 32.1 | 12   |
| Rhynchosia minima          | 12.21| 87.79| 19.95| 80.05| 15.05| 36.30| 19.8 | 13   |
| Cenchrus ciliaries         | 11.96| 88.04| 21.64| 78.36| 20.25| 60.85| 28.8 | 14   |
| Acacia seyal              | 14.21| 85.79| 17.59| 82.41| 10.6 | 29.11| 27.5 | 15   |

Note: % ADF = percent acid detergent fiber, % Ash = percent ash, % CP = percent crude protein, % DM = percent dry matter, % M = percent moisture, % NDF = percent nitrogen detergent fiber, % ODM = percent organic dry matter, FPI = food preference index. Note that all data are on dry matter basis.

### Table 4

| Clusters | Number of observations | Within clusters sum of square | Average distance from centroids | Maximum distance from centroids |
|----------|------------------------|-------------------------------|---------------------------------|--------------------------------|
| Cluster 1| 2                      | 20.254                       | 3.1823                          | 3.1823                         |
| Cluster 2| 5                      | 605.737                      | 10.2922                         | 16.0826                        |
| Cluster 3| 8                      | 593.586                      | 8.0485                          | 12.5933                        |

Note: The clusters are indicated by different colors in the Dendrogram (Figure 2).
Cynodon dactylon had moderate nutritional quality (18.56% CP and 11.71% moisture) but its high occurrence could make it be the more frequently consumed. Furthermore, the optimal foraging theory states that animals maximize fitness through a foraging strategy that incur low cost and with maximum energy gain, maximizing the net energy gain. Particularly, Cynodon dactylon (0.79 frequency of occurrence) followed by Panicum maximum (0.79 frequency of occurrence) and Chloris gayana (0.81 frequency of occurrence) are the most available forage species in the area and Chloris gayana is the second highest in terms of CP content (Table 4). Hence, a feed with second highest nutritionally quality (Chloris gayana, 21.17% CP) and that is readily available (low energy cost) maximize net energy gain and will have high potential for selective grazing. But, frequency of occurrence by itself might not affect the feeding preference of Bohor reedbuck; Cynodon aethiopicus demonstrates this. It was the least preferred species despite its highest frequency of occurrence (0.90) in the area. This is possibly due to the lower digestibility and food quality of the plant species; nutritionally this species had the lowest crude protein (10.41%) and the highest ADF (43.2%) that makes it more indigestible and less palatable. Furthermore, the presence of anti-nutritional factor such as secondary metabolites (flavonoids, tannin etc) determines selective grazing (Reed, 1995). Particularly, Cynodon aethiopicus could be least preferred due to its high concentration of toxic substance. It has been reported that C. aethiopicus has the potential to produce high levels of prussic acid (HCN) any time during the growing season up to 250 ppm (Harlan et al., 1970). Furthermore, Rhus quartiniana had the highest CP content (21.85%), but among the least preferred. This is probably attributed to its high concentration of tannin in the leaves and barks (Miller et al., 2001).

Bohor reedbucks preferred to consume young leaves and shoots (comprised over 95% of their consumption) of the plants during the study period, while flowers (1.33%) (few grass species) and fruits (2.90%) (few grass species) of the plant species were the least preferred (Figure 3). Seasonally, Bohor reedback’s preference to consume young leaves was similar during both wet and dry seasons, but a slight difference was observed with the consumption of other plant parts. There was higher consumption of shoots of plants during the wet season than the dry season whereas leaves consumption increased during the dry season (Figure 3).
Both plant species availability and nutritional quality determine food preference of Bohor reedbuck. The feeding preference of Bohor reedbuck to graze grass species having high-quality nutritional profile implies the need for promoting sustainable conservation and growth of those preferred plant species as an input for sustainable conservation of the Bohor reedbuck. Further in-depth research needs to be done on ecological importance of Bohor reedbuck.

ACKNOWLEDGMENTS
We would like to acknowledge Technical, Vocational and Educational Training Coordination Office of the Ethiopian Ministry of Agriculture and Natural Resources for financing the data collection. We are highly indebted to Tezazu Animaw for his kind support during laboratory work.

CONFLICT OF INTERESTS
We the authors declare that we have no competing interests.

AUTHOR CONTRIBUTION
Yonas Derebe: Conceptualization (equal); Data curation (lead); Formal analysis (lead); Funding acquisition (lead); Investigation (equal); Methodology (supporting); Project administration (equal); Resources (lead); Software (supporting); Supervision (supporting); Validation (supporting); Visualization (equal); Writing-original draft (equal); Writing-review & editing (supporting). Zerihun Girma: Conceptualization (lead); Data curation (supporting); Formal analysis (equal); Funding acquisition (supporting); Investigation (equal); Methodology (lead); Project administration (equal); Resources (supporting); Software (lead); Supervision (lead); Validation (equal); Visualization (equal); Writing-original draft (equal); Writing-review & editing (lead).

DATA AVAILABILITY STATEMENT
I will here confirm that I will avail the data that support the findings of this study up on after publication of the manuscript. Particularly, the data that support the findings will be available in Bohor reedbuck diet analysis file name at Zenodo data repository following the date of publication.

ORCID
Zerihun Girma https://orcid.org/0000-0002-2789-1881

REFERENCES
Alefwerk, B., Bekele, B., & Balakrishnan, M. (2009). Population status, structure and activity patterns of Bohor reedbuck Reduncaredunca in the north of the Bale MountainsNational Park, Ethiopia. African Journal of Ecology, 48, 502–510.
Ahmed, M. A. (2005). The biology of the Reedbuck (Redunca redunca Pallas, 1764) in Dinder National Park. M. Sc thesis, University of Khartoum, Khartoum, Sudan. 88p.
Altmann, J. (1974). Observational study of behaviour: Sampling methods. Behaviour, 49, 227–267.
Association of Official Analytical Chemists (AOAC) (1995). Official methods of analysis (16th ed., 685 p). Association of Official Analytical Chemists.
Association of Official Analytical Chemists (AOAC) (2019). Determination of dry matter in animal feed, grain, and forage (plant tissue) (method 2001.2) (21st ed.). Association of Official Analytical Chemists.
Association of Official Analytical Chemists (AOAC) (2019). *Determination of Moisture in Plant (method 930.04)* (21st ed.). Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2019). *Determination of organic matter in Plants (method 967.05)* (21st ed.). Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2019). *Determination of ash of animal feed (method 942.05)* (21st ed.). Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2019). *Determination of nitrogen (total) (crude protein) in animal feed (method 978.04)* (21st ed.). Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2019). *Determination of neutral detergent fiber in animal foods (method 2002.04)* (21st ed.). Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2019). *Determination of fiber (acid detergent) and lignin in animal foods (method 973.18)* (21st ed.). Association of Official Analytical Chemists.

Clauss, M., & Hummel, J. (2010). Evolutionary adaptations of plant herbivory in ruminants and their potential relevance for modern production systems. *African Antelope Database 1998–2001*. IUCN SSC Antelope Specialist Group.

Foley, W. J., Iason, G. R., & McArthur, C. (1999). Role of plant secondary metabolites in the nutritional ecology of mammalian herbivores: How far have we come in 25 years? In H. G. Jung, & G. C. Fahey (Eds.), *Proceedings of the Fifth International Symposium on the Nutrition of Herbivores, Nutritional Ecology of Herbivores, American Society of Animal Science, IL* (pp. 130–209).

Girma, Z. (2016). Habitat use, diet and conservation of the mountain Nyala and Menelik’s bushbuck, Arsi mountains national park, south eastern Ethiopia. Ph.D. Thesis University of Buea, Buea, Cameroon. 218p.

Girma, Z. (2018). Habitat Preferences of the Bohor Reebuck (Redunca redunca) and Common Warthog (Phacochoerus africanus) in Arsi Mountains National Park, South eastern Ethiopia. *International Journal of Ecology and Environmental Sciences*, 44(3), 227–237.

Gutbrodt, B. (2006). Diet composition of wildebeest, waterbuck and reedbuck in relation to food quality in a moist savannah of Tanzania (p. 79). M.Sc. Thesis, Swiss Federal Institute of Technology, Switzerland.

Habtamu, T., Bekele, A., & Belay, B. (2012). The ecological and behavioural studies of Bohor Reebuck in Jimma Airport Compound, South-western Ethiopia. *Asian Journal of Animal Sciences*, 6, 278–290.

Halsdorf, S. (2011). Patterns of resource use by grazers in a humid coastal savanna in Tanzania. PhD Dissertation, ETH Zurich University, Zürich, Switzerland.

Harlan, J. R., de Wet, J. M. J., & Rawal, K. M. (1970). Geographic distribution of the species of Cyndonon L. C. Rich (Graminaceae). *East African Agricultural and Forestry Journal*, 36, 220–226.

Hochman, V., & Kotler, B. P. (2006). Effects of food quality, diet preference and water on patch use by Nubian ibex. *Oikos*, 112, 547–554.

Huffman, B. (2013). Bohor reebuck. [www.ultimateungulates.com]. On 28 September 2019

Huskie, N. P., Oelofse, A., Duodu, K. G., Bester, M. J., & Faber, M. (2010). Nutritional value of leafy vegetables of sub Saharan Africa and their potential contribution to human health: A review. *Journal of Food Composition Analysis*, 23, 499–509.

IUCN Ssc Antelope Specialist Group (2008). Redunca redunca; IUCN Red List of Threatened Species, Version 2011. [http://www.iucnredlist.org/apps/redlist/v3/19392/0]

Johnson, D. H. (1980). The comparison of usage and availability measurements for evaluating resource preference. *Ecology*, 61, 65–71.

Kent, M., & Coker, P. (1992). *Vegetation description and analysis* (p. 363). John Wiley & Sons Ltd.

Kingdon, J. (1997). *The Kingdon Field Guide to African Mammals* (415 p). Academic Press.

Kingdon, J. (2015). *The Kingdon Field Guide to African Mammals* (2nd ed., 640). UK Princeton University Press.

Kingdon, J., & Hoffmann, M. (2013). Redunca redbuck: effects of the mountain Nyala and Menelik’s bushbuck on vegetation. In I. D. Hume, & J. Hummel (2010). *Evolutionary adaptations of herbivory in ruminants and their potential relevance for modern production systems*. *African Antelope Database 1998–2001*. IUCN SSC Antelope Specialist Group.

Mohammed, M. H., & Röhle, H. (2011). Evaluation of Height Functions for Acacia seyal Del. *Variety Seyed in Natural Stands, South Kordofan Sudan*. *International. Journal of Sustainable Agriculture*, 3, 88 96.

Mysterud, A., Langvatn, R., Yoccoz, N. G., & Stenseth, N. C. (2001). Plant growth rate, body size, gastrointestinal capability and food intake by sheep of two ryegrass species during primary growth. *Journal of Animal Physiology and Animal Nutrition*, 385, 385–405.

Oliveh, U. J., Aganga, A. A., Tshireletso, K., & Nkele, R. (2004). *Strategies of Sheep and Goats under Semi-Intensive Management in Botswana*. *South African Journal of Animal Science*, 34, 120–122.

Owen-smith, N. (1994). Foraging responses of kudus to seasonal changes in food resources: Elasticity in constraints. *Ecology*, 75, 1050–1062.
Parker, D. M., & Bernard, R. T. (2006). A comparison of two diet analysis techniques for a browsing mega herbivore. *Journal of Wildlife Management, 70*(5), 1477-1480.

Phillips, S. (1995). POACEAE (GRAMINEAE). In *Flora of Ethiopia and Eritrea* (vol. 7, 420 p). Uppsala, Sweden and Addis Ababa, Ethiopia: Addis Ababa University and Uppsala University.

Pienaar, R. C. (2013). *The feeding ecology of extralimital Nyla (Tragelaphus angasii) in the arid mosaic thicket of the southern cape*. M.Sc. Thesis, Nelson Mandela Metropolitan University, South Africa. 128p.

Provenza, F. D., Villalba, J. J., & Bryant, J. P. (2002). Making the match: From biochemical diversity to landscape diversity. In J. A. Bissonette, & I. Storch (Eds.), *Landscape ecology and resource management: Making the match* (pp. 387–421). Island Press.

Provenza, F. D., Villalba, J. J., Dziba, L. E., Atwood, S. B., & Banner, R. E. (2003). Linking herbivore experience, varied diets, and plant biochemical diversity. *Small Ruminant Research, 49*, 257–327.

Ratliff, R. D. (1993). Viewpoint: Trend assessment by similarity – a demonstration. *Journal Range Management, 46*, 139–141.

Reed, J. D. (1995). Nutritional toxicology of tannins and related polyphenols in forage legumes. *Journal of Animal Science, 73*, 1516–1528.

Rodgers, A. R. (1990). Evaluating preference in laboratory studies of diet selection. *Journal Zoology, 68*, 188–190.

Sinclair, A. R., Fryxell, J. M., & Caughley, G. (2006). *Wildlife ecology, conservation, and management* (2nd ed., p. 462). Blackwell Publishing Ltd.

Taddesse, S., & Kotler, B. P. (2011). Seasonal Habitat Use by Nubian Ibex (Capra Nubian) Evaluated with Behavioural Indicators. *Israel Journal of Ecology and Evolution, 57*, 223–246.

Taddesse, S., & Kotler, B. P. (2013). Habitat use by mountain Nyla Tragelaphus buxtoni determined using stem bite diameters at point of browse, bite rates, and time budgets in the Bale Mountains National Park, Ethiopia. *Current Zoology, 59*, 707–717.

Tanentzap, A. J., Burrows, L. E., Lee, W. G., Nugent, G., Maxwell, J. M., & Coomes, D. A. (2009). Landscape- level vegetation recovery from herbivory: Progress after four decades of invasive red deer control. *Journal of Applied Ecology, 46*(3), 1064–1072.

Tekalign, W., & Bekele, A. (2012). Population status, foraging and diurnal activity patterns of oribi (Ourebiourebi) in Senkele Swayne’s Hartebeest Sanctuary, Ethiopia. *Ethiopia Journal of Science, 34*, 29–38.

Treydte, C. A., Bernasconi, M. S., Kreuzer, M., Edwards, P. J. (2006). Diet of the Common Warthog (Phacochoerus africanus). On Former Cattle Grounds In A Tanzanian Savanna. *Journal of Mammalogy, 87*(5), 889–898.

Water Works Design and Supervision Enterprise (WWDSE) (2013). Draft feasibility report on irrigation development watershed management. Unpublished. Alage, Ethiopia: Alage Agricultural Technical Vocational Educational and Training College. 20 + 159p.

Woie, B. M. (1984). Influence of frequency and intensity of clipping on forage yield, crude protein content and digestibility of six Kenyan range grasses. Ph.D. thesis, A and M University, Texas, USA. 98p.

Wolfson, M. M., & Tainton, N. M. (1999). *The morphology and physiology of the major forage plants* (p. 387). University of Natal Press.

Yalden, D. W., Largen, M. J., & Kock, D. (1984). Catalogue of the mammals of Ethiopia. *Artiodactyla Monitore Zoology International, 190*, 67–221.

Yihune, M., & Bekele, A. (2012). Population Status, Feeding Ecology and Activity Patterns of Grant’s gazelle (Gazella granti) in Abijata-Shalla Lakes National Park, Ethiopia. *Asian Journal of Biological Sciences, 5*, 20–29.

Zweifel-Schielly, B., Leuenberger, Y., Kreuzer, M., & Suter, W. (2012). A herbivore’s food landscape: Seasonal dynamics and nutritional implications of diet selection by a red deer population in contrasting Alpine habitats. *Journal of Zoology, 286*, 68–80.