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Forage Availability and Nutrient Quality of Common Warthog (*Phacochoerus africanus*) in Gassi and Haro Aba Diko Controlled Areas, Western Ethiopia

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Abstract

Study on forage availability and nutrient quality of common warthog (*Phacochoerus africanus*) was conducted in Gassi and Haro Aba Diko controlled areas, Western Ethiopia in 2018-2019. Forage availability was determined using feeding quadrat method whereas seasonal variations of nutrient quality of common warthog were measured using clipped plant samples and fecal droppings. Dietary and fecal contents of C, N, P, neutral and acid detergent fiber were analyzed. Crude protein content was measured using Kjeldhal method. In HADCHA (Haro Aba Diko Controlled Hunting Area), 28 and in GCHA, (Gassi Controlled Hunting Area) 24 seasonally available forage species contributed ≥ 1% in the diet of common warthog during the wet and dry seasons. The top four seasonal availability proportion forage species of both study areas showed similarity in *C. nlemfuensis*, *H. rufa, H. hirta* and *C. dactylon,* but differed by *Eragrostis* spp. and *D. abyssinica*. The mean proportion of fecal and dietary nitrogen contents of common warthog showed significance difference ($F_{1\ 15} = 35.02$, $P < 0.05$) and positively correlated (Spearman $r = 0.31$; $P > 0.05$; $N = 16$) in both study areas. Neutral detergent fiber (NDF) content of feces of common warthogs was higher in HADCHA (74.28 ± 3.92) than in GCHA (71.01 ± 0.12) and revealed significant variation ($F_{1\ 3} = 5.27$, $P < 0.05$). Therefore, a wider range of plant species were available in the diet of common warthog. Nevertheless warthogs foraged 1311 mg/100g and 1489.2 mg/100g dietary phosphorous concentration, which were below the minimum threshold level leading to high risk of sterility and population decline in both study areas. Dietary C, P, N, crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of common warthogs regulated the entire metabolic activity of the animal and these were calibrated more in dietary than in the fecal dropping of the animals.

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Keywords

Common warthog, dietary concentration, dry matter, fecal content, fiber; forage categories

Introduction

Seasonal variation in resource availability and other environmental conditions help animals to determine which habitat types to be used (Borger *et al.,* 2006). Availability of palatable forage species has an important effect on the diet preference of animals and permit animals to select a wider range of plant species with little or no risk of nutritional stress (Zweifel–Schielly *et al.,* 2012). Decrease in the availability of forage species results in the use of less desirable forage species (Anderson *et al.,* 2010), which elevate metabolic costs of locomotion and limits survivorship of the animal (Hanley and McKendrick, 1983). The proportion and number of plant species incorporated in the diet indicate the breadth of an animal's food niche and represent diet quantity (Gutbrodt, 2006; Butt and Turner, 2012). Diet content of nitrogen, carbon, phosphorous, crude protein, fiber content (neutral detergent fiber (NDF) and acid detergent fiber (ADF) indicate diet quality (Clauss *et al.,* and Codron *et al.,* 2007). Non–ruminant ungulates are more efficient in processing low quality food (high fiber content) than ruminants (Kartzinel *et al.,* 2015). They compensate a less nutrient extraction of low-quality foods by foraging more such food items (Codron *et al.,* 2007; Cromsigt *et al.,* 2009; Codron *et al.,* 2016). Due to this extent of food quality tolerance, non–ruminant ungulates use a wider variety of habitats than ruminants (Cromsigt *et al.,* 2009; Kahana *et al.,* 2013). On the other hand, ungulates directly speed up nutrient turnover for uptake by microbes and plants by excreting nutrients in the form of readily available (Metcalfe *et al.,* 2014). Furthermore, they can influence nutrient yield by modifying the quality and quantity of plant debris available for decomposition indirectly (Hobbs, 1996; Metcalfe *et al.,* 2014). Therefore, nutritional status of plants and plant eating animals is essential for wildlife population and their habitat management (Treydte *et al.,* 2006).

Common warthogs show particular adaptation of high crowned teeth to its special dietary niche and long ingesting retention times (Clauss *et al.,* 2007 and 2008). Hence, they are particularly efficient in fiber digestion like grazing ruminants. Thus, to obtain a nutritionally adequate diet and high mineral concentrations, they tend to forage on a variety of plant species (Dearing *et al.,* 2000; Mphinyane *et al.,* 2015). On the other hand, intake of N, P and C of common warthogs can be maximized to a far greater degree by foraging grasses in neglected glades than relative to surrounding plant communities (Augustine, 2004). A plant species, which is low in nitrogen may be high in digestible energy, whereas another species, may be high in sodium, but low in digestible energy (Lyons *et al.,* 1999; Dearing *et al.,* 2000). Foraging high protein and low fiber content not only optimize energy and nutrient intake, but also minimize retention time, thus increasing intake capacity (Zweifel –Schielly *et al.,* 2012). Therefore, forage availability and nutrient quality of common warthogs were the major inquiries of the present study.

Materials and Methods

Description of the study areas

One of the eastern African countries, Ethiopia is rich in fauna and flora diversities. The experimental animal, common warthogs are commonly distributed throughout Gassi Controlled Hunting Area (GCHA) and Haro Aba Diko Controlled Hunting Area (HADCHA) toward western side of the country. *Combretum- Terminalia*, open grassland and riparian forest characterized the study areas. Different Medium and large sized mammalian species are common in various parts of the study areas (Edossa *et al.,* 2020; 2021).

Gassi Controlled Hunting Area (GCHA)

Gassi Controlled Hunting Area (GCHA) is situated approximately 600 km west of Addis Ababa in the Oromia Regional State, Buno Bedelle Administrative Zone. Most of the study sites lie, along the Banks of the Dabena River of Meko and Dabo hanna districts. It is positioned in the southwestern part of Dabena Valley Forest (DVF), between 8º′ 15″ and 8º52′ 30″ N latitude and 35º55′ 30″ and 36º7′ 15″ E longitude. The altitude ranges from 1538 to 1689 masl (Fig. 1). Miesso and Gassi rivers drain in Dabena River. Dabena Valley Forest (DVF) is located within the Didessa River sub-basin. Dabus and Didessa Rivers are the first top two catchment area of Abay basin, the biggest drainage of the upper Blue Nile River Basin (Merid, 2002; Awulachew *et al.,* 2007). Didessa and Dabus Rivers drain the southwestern part of the basin, and subsidize one third of the total flow of the Grand Ethiopian Renaissance Dam (Betrie *et al.,* 2011), which is the highest sediment source of the Nile River (Ali, 2021). The study area was demarcated as a controlled hunting area in 2007 with an estimated total area of 24,000 ha that comprises *Combretum-Terminalia* woodland and, riparian forest (Edossa *et al.,* 2020; 21).

Tropical savanna zone (kola) climatic condition characterizes study area and it receives a unimodal annual rainfall. The wet season is short and covers from June to October with the highest rainfall between June to August. The dry season is longer and extends from November to May. The average annual rainfall of the area from 2007 to 2017 was 1536.6 mm, with the highest mean monthly rainfall certified in August (370.6 mm) and the lowest in December (13.3 mm). The mean monthly maximum temperature documented was 32.3 ºC in May and the mean minimum was 11.5 ºC in December (Source: National Meteorological Agency of Ethiopia). Edossa *et al.,* 2020; 21).

Haro Aba Diko Controlled Hunting Area (HADCHA)

Haro Aba Diko Controlled Hunting Area is situated about 550 km west of Addis Ababa on the southern side of Addis Ababa in the Oromia Regional State, Buno

Bedelle Administrative Zone. It is positioned along the northeastern part of Dabena Valley Forest (DVF) between 8° 35′ 20″ and 8°45′ 55″ N latitude and 36° 15′ 45″ and 36°20′ 10″ E longitude. The altitude ranges from 1646 to 1720 masl (Fig. 2). The study area was demarcated in 2007 with an approximated total area of 53,841 ha that contains savanna woodland, and riparian forest. HADCHA is one of the controlled hunting areas in western Ethiopia which could be used as the forthcoming carbon sequestration center of the country (Edossa *et al.,* 2020; 21).

Tropical savanna zone (kola) climatic condition characterizes the study area and it receives a unimodal annual rainfall. The wet season is short and ranges from June to October with the highest rainfall between June to August. The dry season is longer and covers from November to May. The average annual rainfall of the area from 2007 to 2017 was 1434.1 mm, with the highest mean monthly rainfall documented in August (285.4 mm) and the lowest in December (15.9 mm). The average monthly maximum temperature was 35.2 ºC recorded in May and the mean minimum was 12.3 ºC certified in January (Edossa *et al.,* 2020; 21).

Methods

Forage availability analysis

Forage availability of common warthog was determined using feeding quadrat method (Grobler, 1983; Magome *et al.,* 2008). In the feeding stations where common warthog foraged grasses and herbs, 1 x 1m quadrats were surveyed (Bullock, 2006). In shrubs foraging sites 1 x 10 m quadrats were analyzed as recommended by Greenwood and Robinson (2006). A total of 1152 quadrats were laid in the area where common warthogs were observed feeding plant materials and in the feeding sites were confirmed by scars of plant and fresh fecal deposit made by common warthog (Augustine, 2004; Krebs, 2006; Ahrestani *et al.,* 2012). Feeding stations spaced 5 m apart for grass species, which were assumed to be independent (Macandza *et al.,* 2004). For remaining forged plant species, quadrats were spaced at 15 to 20 m intervals in the feeding sites of the animal. Each day, 15 to 20 quadrats were surveyed and all plant species consumed by common warthog were collected (Macandza *et al.,* 2004; Arsenault and Owen–Smith, 2008) and this was repeated every month of the study period. All of the plant species within each quadrat were identified and both recent and fresh grazing sites were noted. Fresh plant materials, which were cut during 2018 and 2019 dry and wet seasons of the study periods, pressed for the preparation of reference slides, seasonal nutrient quality measurement and identification purposes (Macandza *et al.,* 2004). From HADCHA, 45 and from GCHA 41 plant materials were identified as the diet of common warthogs. In the same way, 28 from HADCHA and 24 from GCHA plant species contributed ≥1% in the diet of common warthog during the wet and dry seasons (appendix I)

Nutrient quality analysis

Seasonal variations of foraging quality of common warthogs were measured using plant materials, which were sampled seasonally during the wet and dry seasons of 2018 to 2019 study periods based on procedures mentioned earlier. The clipped plant samples were dried under shade and milled through a 0.75–mm screen (Treydte *et al.,* 2006; Zweifel –Schielly *et al.,* 2012). Fecal analysis was also used to get better information about common warthog's diet quality (Treydte *et al.,* 2006; Ahrestani *et al.,* 2012) because fecal analysis studies of plant fragments revealed which plant species were consumed by the animal (Stewart, 1967). A total of 320 fresh fecal samples, which were less than two days old each weighing about70 g (Bekhuis *et al.,* 2008) were collected during the wet and dry seasons of 2017and 2018 study periods and processed.

The content of NDF was measured after digestion with α–amylase and ADF were determined according to the Association of Analytical Communities (AOAC) International (Zweifel –Schielly *et al.,* 2012). Crude protein (CP) content was measured using Kjeldhal method and their concentration were estimated by multiplying the nitrogen concentration value by 6.25 (Buys, 1990; Gutbrodt, 2006; Ahrestani *et al.,* 2012). Phosphorus was determined by wet digestion and measured by a spectrophotometer (Codron *et al.,* 2005).Carbon composition was determined using a Carlo–Erba elemental analyzer (NCS 2500; Carlo–Erba, Milan, Italy). N, P, and C contents of plants and feces were used as total dry matter percentages (Treydte *et al.,* 2006).

Data analyses

Seasonal forage availability was calculated by dividing the number of microscopic slides in which the species was found by the total number of microscopic slides examined (Venter and Watson, 2008) at the Animal Biotechnologty Laboratory of Holeta National

Biotechnology Center. The differences in seasonal dietary availability of different forage categories to the diet of common warthog were calculated using Chi–square test (Muposhi *et al.,* 2014). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and total nitrogen contents of all fecal samples and plant materials were analyzed at the Nutrition Laboratory of Holeta Agriculture Research Center. Crude protein (CP). Phosphorous and organic carbon contents of foraged plants and feces were analyzed at the Nutrition Laboratory of Ethiopian Public Health Institute Addis Ababa. Seasonal variations in diet and patterns of diet changes were tested using a Chi–square test and One –way ANOVA (Muposhi *et al.,* 2014).

Results and Discussion

In GCHA, graminoids were the most frequently available forage species of common warthog population during the wet season (87.1. % ±7.21) and during the dry seasons (83.3% ±5.99) (Fig. 3). Herbs formed 10.1%±0.11 during the wet season and 16.7%±1.27 during the dry season available foraged species. Shrubs and climbers were the less available foraged species during both seasons. Hence, forage categories available were significantly different ($F_{3\ 4}$ = 124.9, P < 0.05) during the wet and dry seasons. In HADCHA, graminoids were the most frequently available foraged categories of common warthogs during the wet season (88.3% ±5.74) and during the dry season (90.9% ±4.74) (Fig.4).

Herbs formed 9%±0.28 during the wet and 9.1%±0.89 during the dry season. Shrubs and climbers were the less available foraged categories during the wet and dry seasons. Therefore, forage categories available were significantly different ($F_{3,\ 4}$ = 137.4, P < 0.05) between the wet and dry seasons. Conversely, the two study areas did not show significant variation (χ2 = 0.43, df = 1, P >0.05) in the available foraged categories.

Seasonal forage availability of 24 species, which contributed ≥1% in the diet of common warthogs during the wet and dry seasons were identified in GCHA (Fig.5). Ten foraged species were available during both seasons, seven plant species were available during the wet season and the other seven forage species were available only during the dry season. The top five forage species *C. nlemfuensis* (18.6%), *H. rufa* (17.55%), *H. hirta* (15.1%), *C. dactylon* (13.3%), and *D. abyssinica* (5.1%) covered 69.65% of the available forages to common warthogs during both seasons. The proportion of seasonal availability of *C. nlemfuensis* (χ2 = 0.34, df = 1, P > 0.05), *H. rufa* (χ2 = 0.23, df = 1, P > 0.05), *H. hirta* (χ2 = 0.39, df = 1, P > 0.05), *C. dactylon* (χ2 = 0.38, df = 1, P > 0.05), and *D. abyssinica* (χ2 = 0.06, df = 1, P > 0.05) were not significantly different during the wet and dry seasons.

In HADCHA, 28 seasonally available forage species, which contributed ≥1% in the diet of common warthog during the wet and dry seasons were identified (Fig. 6). Twelve forage species were available during both seasons, nine species were available only during the wet season and seven species were accessible only during the dry season. The top five forage species *Eragrostis* spp (15%), *H. rufa* (14.1%), *C. nlemfuensis* (13.65%), *H. hirta* (12.65%), and *C. dactylon* (12.05%), accounted for 67.45% of the available forage during both seasons. The seasonal availability during the wet and the dry seasons of *Eragrostis* spp (χ2 = 0.003, df = 1, P > 0.05), *H. rufa* (χ2 = 0.029, df = 1, P > 0.05), *C. nlemfuensis* (χ2 = 0.006, df = 1, P > 0.05), *H. hirta* (χ2 = 0.029, df = 1, P > 0.05), and *C. dactylon* (χ2 = 0.002, df = 1, P > 0.05), were not significantly different.

The top four seasonal availability proportion forage species of both study areas showed similarity in *C. nlemfuensis*, *H. rufa, H. hirta* and *C. dactylon,* but differed by *Eragrostis* spp and *D. abyssinica*. *Eragrostis* spp was one of the most available forage species in HADCHA, whereas *D. abyssinica* was the more available forage species in GCHA. Moreover, the two study areas were not significantly different (χ2 = 1.12 df = 1, P > 0.05) in the seasonal availability proportion of forage species of common warthogs.

In GCHA, the mean proportion of fecal carbon (FC) content of common warthog was 23.5% during the wet season and 23.1%) during the dry season. Hence, they did not show significant difference ($F_{1\ 3}$ = 0.027, P > 0.05). Likewise, in HADCHA the mean proportion of fecal carbon content was 25.04% during the wet season and 25.62% during the dry season. Hence, they revealed insignificant variation ($F_{1\ 3}$ = 0.022, P > 0.05) (Fig. 7). Therefore, the mean fecal carbon content of common warthog did not show significance difference (t = –1.01, df = 7, P>0.05) between the two study areas. On the other hand, in GCHA, mean proportion of dietary carbon (DC) content of common warthog was 8.74% during the wet season and 16.6% during the dry season. Hence, they were significantly different ($F_{1\ 3}$ = 5.76, P < 0.05). However, in HADCHA the mean proportion of dietary carbon content was 15.06% during the wet season and 16.52% during the dry season and they were insignificantly different ($F_{1\ 3} = 0.033$ $P > 0.05$) (Fig. 7). On the other hand, the mean fecal carbon content of common warthog did not reveal significance difference ($t = –0.75$, $df = 7$, $P>0.05$) between the two study areas. Moreover, the mean proportion of fecal and dietary carbon contents of common warthog showed considerable variation ($F_{1\ 14} = 19.44$, $P <0.05$) and negatively correlated (Spearman $r = −0.17$; $P>0.05$; $N = 16$) in GCHA and HADCHA.

The mean proportion of fecal nitrogen (FN) contents of common warthog was 13.29 % during the wet season and 12.64% during the dry season. However, they were not significantly different ($F_{1\ 3} = 0.56$, $P > 0.05$). In HADCHA, the mean proportion of fecal nitrogen content was 13.66% during the wet season and 12.67% during the dry season. Hence, they showed insignificant variation ($F_{1\ 3} = 1.37$, $P <0.05$) (Fig. 8). However, the mean fecal nitrogen contents of common warthog did not show significant variation ($t = –0.39$, $df = 7$, $P>0.05$) between the two study areas. On the other hand, in GCHA, the mean proportion of dietary nitrogen (DN) content of common warthog was 11.6% during the wet season and 9.11% during the dry season. They revealed significant difference ($F_{1\ 3} = 7.58$, $P <0.05$). Similarly, in HADCHA the mean proportion of dietary nitrogen content was 10.5% during the wet and 9.86 % during the dry season. But they revealed insignificant variation ($F_{1\ 3} = 0.78$ $P > 0.05$) (Fig.8).The mean fecal nitrogen contents of common warthog did not show significant difference ($t = 0.22$, $df = 7$, $P>0.05$) between GCHA and HADCHA. Moreover, the mean proportion of fecal and dietary nitrogen contents of the animal showed considerable disparity ($F_{1\ 15} = 35.02$, $P <0.05$) and positively correlated (Spearman $r = 0.31$; $P>0.05$; $N = 16$) in both study areas.

Fecal phosphorous (FP) contents of common warthogs was found more in GCHA (1369.7 mg/100g± 911.22) than in HADCHA (1311 mg/100g ± 1221.6). Nevertheless, they did not show significance difference ($F_{1\ 3} = 0.52$ P, > 0.05). On the other hand, dietary phosphorous (DP) content consumed warthogs attributed more in GCHA (1489.2 mg/100g± 1.762) and less in HADCHA (1312 mg/100g ± 490) (Fig. 9). However, they revealed insignificant differences ($F_{1\ 3} = 0.279$, $P > 0.05$).The seasonal difference in the mean fecal and dietary phosphorous contents of common warthogs was not significant ($t = –0.39$, $df = 7$, $P>0.05$) but the fecal and dietary phosphorous contents were highly correlated (Spearman $r = 0.916$; $P>0.05$; $N = 16$) in both study areas.

The mean proportion of fecal crude protein (FCP) content was 85.37% during the wet and 79% the dry seasons in GCHA. Hence, they were significantly different ($F_{1\ 3} = 5.01$, $P <0.05$). In HADCHA, seasonal mean proportion of FCP content was 83.05% during the wet and 79% during the dry seasons and showed insignificant variation ($F_{1\ 3} = 0.56$, $P > 0.05$) (Fig. 10). The difference in the mean FCP contents between the two study areas was not significant ($t = 0.39$, $df = 7$, $P>0.05$). On the other hand, in GCHA the mean proportions of dietary crude protein (DCP) content of common warthog was 65.4% during the wet and 61.6% during the dry seasons and revealed insignificant differences ($F_{1\ 3} = 0.78$, $P > 0.05$). However, in HADCHA, the mean proportion of DCP content was 72.52% during it was the wet and 56% during the dry season and showed significant difference ($F_{1\ 3} = 7.57$, $P <0.05$) (Fig. 10).Therefore, the mean DCP content of common warthogs was insignificantly different ($t = –0.22$,$df = 7$, $P>0.05$) between the two study areas. Furthermore, the mean proportion of FCP and DCP contents of the animal showed significant differences ($F_{1\ 15} = 35.09$, $P <0.05$) and negatively correlated (Spearman $r = –0.242$; $P>0.05$; $N = 16$) in both study areas.

Neutral detergent fiber (NDF) content of feces of common warthogs was higher in HADCHA (74.28 ± 3.92) than in GCHA (71.01 ± 0.12) and revealed significant variation ($F_{1\ 3} = 5.27$, $P <0.05$). On the other hand, NDF content of forage energy consumed by the animals attributed less from GCHA (69.93 ± 4.47) than from HADCHA (71.58 ± 13.62) (Table.1). However, they revealed insignificant differences ($F_{1\ 3} = 0.299$, $P >0.05$). The seasonal difference in the mean NDF content of feces and forage energy utilized by common warthogs were not significantly different ($t = 1.09$, $df = 7$, $P>0.05$), but the NDF contents of feces and forage energy were highly correlated (Spearman $r = 0.767$; $P>0.05$; $N = 8$).

Acid detergent fiber (ADF) content of feces of common warthogs was higher in HADCHA (59.68 ± 0.03) than in GCHA (55.61 ± 4.96) and showed significant difference ($F_{1\ 3} = 6.65$ $P <0.05$). However, ADF content of forage energy consumed by these animals was higher in GCHA (48.37 ± 17.28) than in HADCHA (47.53 ± 15.34) and showed insignificant variation ($F_{1\ 3} = 0.04$, $P > 0.05$) (Table 1). Seasonal difference in the mean ADF content of feces and forage energy utilized by common warthogs were significantly different ($t = 4.53$, $df = 7$, $P>0.05$). On the other hand, the ADF contents feces and forage energy consumed by common warthogs were highly correlated (Spearman r = 0.75; P>0.05; N = 8). However, there were no seasonal significant differences between the fecal dry matter and forage dry matter contents of common warthog percentage (F1 7 = 0.28, P > 0.05) of the two study areas. The seasonal percentage of fecal organic matter and forage organic matter of the two study areas were significantly different (F1 7 = 103.9, P <0.05) (Table 1).

Common warthogs are selective in their forage in a savanna landscape to realize their nutrition requirements and go for patches of high quality grasses, particularly when there is nutrient shortage during the dry season (Treydte*,* 2004). Hence, warthogs are recognized as committed grazers (White, 2010; Hjertlöv, 2015) because they have unique multi–cusped hypsodont third molar and reduced premolars that are well Adapt to grazing (Mgqatsa, 2010). In the former rangeland of Mkwaja North of Tanzania, 77% common warthog diet was covered by grass and in the former Saadani Game Reserve, Tanzania, grass contributed 98 % of the animals diet (Treydte, 2004). On the other hand, grasses formed 87.4% of common warthog diet in the Addo Elephant National Park of South Africa. Other study also found 64% of common warthog diets were contributed by grass species in Kichwa Tembo, Kenya (Hjertlöv, 2015). Similarly, in the present study, the annual diet composition of common warthog constituted by grass was comparable in GCHA and in HADCHA. They also include some browse such as woody shrubs, herbs and fallen fruits in their diet (Treydte *et al.,* 2006; Mgqatsa, 2010). Other study also observed common warthog consumed herbs in Mount Meru Game Reserve, Tanzania (Kahana *et al.,* 2013), in Kichwa Tembo, Kenya herb (Hjertlöv, 2015) and in the Addo Elephant National Park of South Africa as diet of the animal (Mgqatsa, 2010). In the present study, herbs contributed common warthog annual diet in GCHA and HADCHA

Availability of palatable forage species has an important effect on the diet preference of animals and permit animals to select a wider range of plant species with little or no risk of nutritional stress (Zweifel–Schielly *et al.,* 2012). Decrease in the availability of forage species results in the use of less desirable forage species (Anderson *et al.,* 2010), which elevate metabolic costs of locomotion and limits survivorship of the animal (Hanley and McKendrick, 1983). In the present study, comparable seasonally available forage species, which contributed ≥1% in the diet of common warthog were identified in GCHA and HADCHA during the wet and dry seasons. *Cyodon nlemfuensis*, *H. rufa, H. hirta* and *C. dactylon* are the most available forage species of the study areas. On the other hand, *Eragrostis* spp in HADCHA and *D. Abyssinica* in GCHA were the most available forage species during the wet and dry seasons. *Cyodon dactylon* and *Eragrostis* spp were also particularly abundant in the diet of common warthogs in Mkwaja Ranch in Tanzanian (Treydte *et al.,* 2006).

Nutrition directly affects life–history traits, such as survival, fertility, body mass, litter size, longevity, as well as demography and population dynamics of ungulates (Wrench *et al.,* 1997; Owen–Smith, 2002; Gil–Jiménez *et al.,* 2015; Holá, 2016). Hence, determination of nutritional status of animals is significant for wildlife population and habitat management (Wrench *et al.,* 1997; Treydte *et al.,* 2006). Forage quality estimates through fecal analyses and plant materials collected from feeding quadrats were used to determine nutritional status of animals (Holecheck, 1982; Wrench *et al.,* 1997). Therefore, C, P, N, crude protein (CP), fiber content; neutral detergent fiber (NDF) and acid detergent fiber (ADF) in the feces and diet of common warthogs have been used to track changes in diet quality (Treydte *et al.,* 2006; Codron *et al.,* 2007). In African savannas, common warthogs forage grasses (C4 plants) and the non–grass component (C3 plants) to obtain organic carbon (Treydte, 2004; Treydte *et al.,* 2006). In the present study, the amount of dietary carbon that common warthogs consumed was less in GCHA and high in HADCHA during the wet season. On the other hand, the amount of fecal carbon of common warthogs calibrated in GCHA and HADCHA was consistent. Fecal and dietary carbon of these animals was negatively correlated.

This might be due to microhistological analyses of feces provided the most detailed information about the plant species that common warthog consumed than plant materials collected from feeding quadrats. The finding of both study areas was consistent with Treydte *et al.,* (2006), who reported (fecal carbon = 26%) in Mkwaja Ranch in Tanzania. On the other hand, dietary carbon of GCHA was comparable with Treydte *et al.,* (2006), who measured (dietary carbon = 9.8%) and Clauss *et al.,* (2008) who calibrated (dietary carbon = 9.3%) for captive common warthog at Rotterdam Zoo.

Hence, fecal carbon calibrated showed that the animals did not suffer from shortage of dietary carbon in both study areas (Treydte, 2004).

Fig.1 Location map of Gassi Controlled Hunting Area.

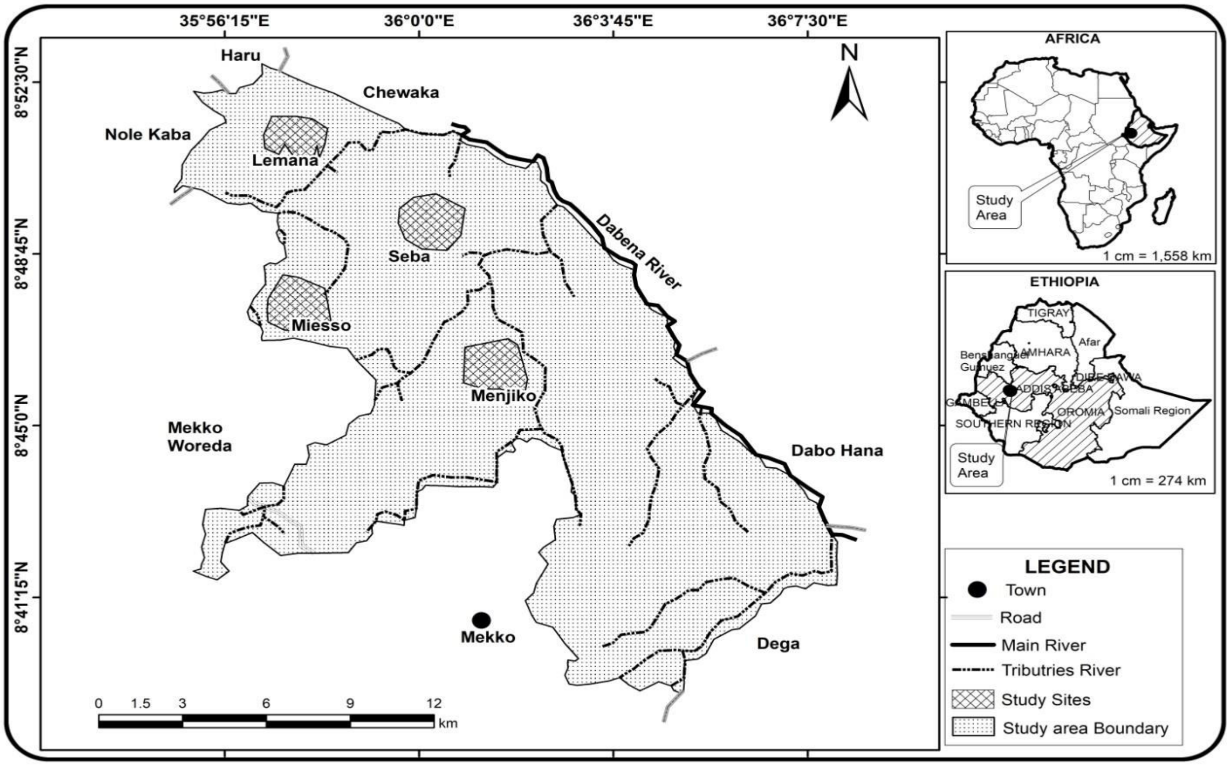

Fig.2 Location map of Haro Aba Diko Controlled Hunting Area.

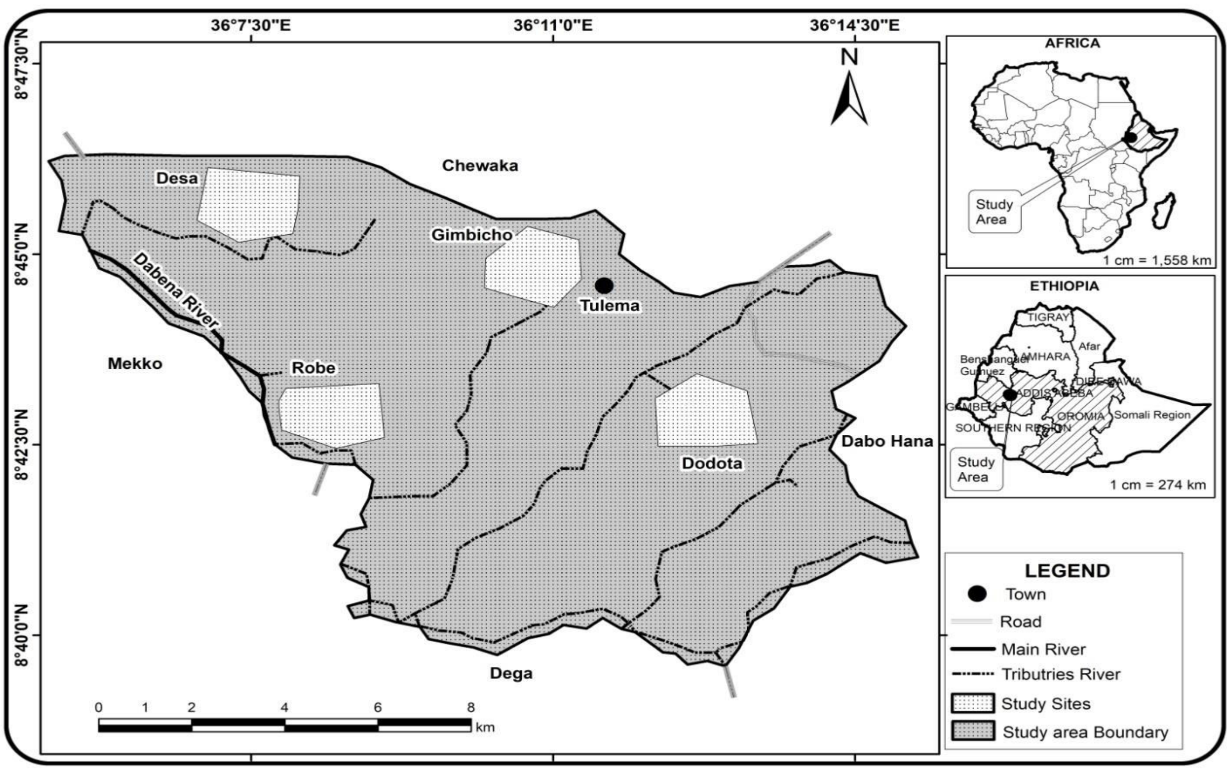

Figure.3 Forage categories (%) available in GCHA during the wet and dry seasons.

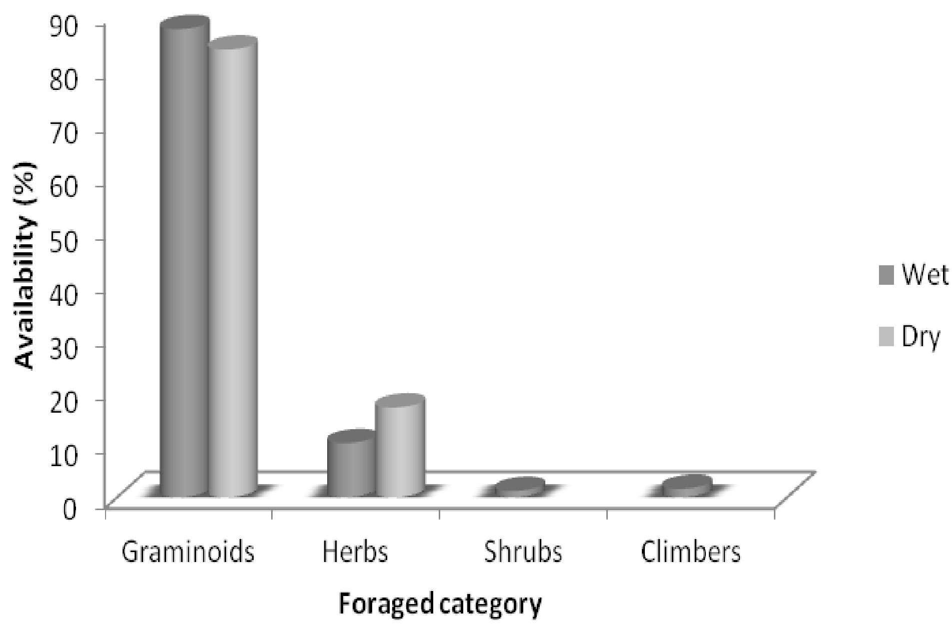

Figure.4 Forage categories (%) available in HADCHA during the wet and dry seasons.

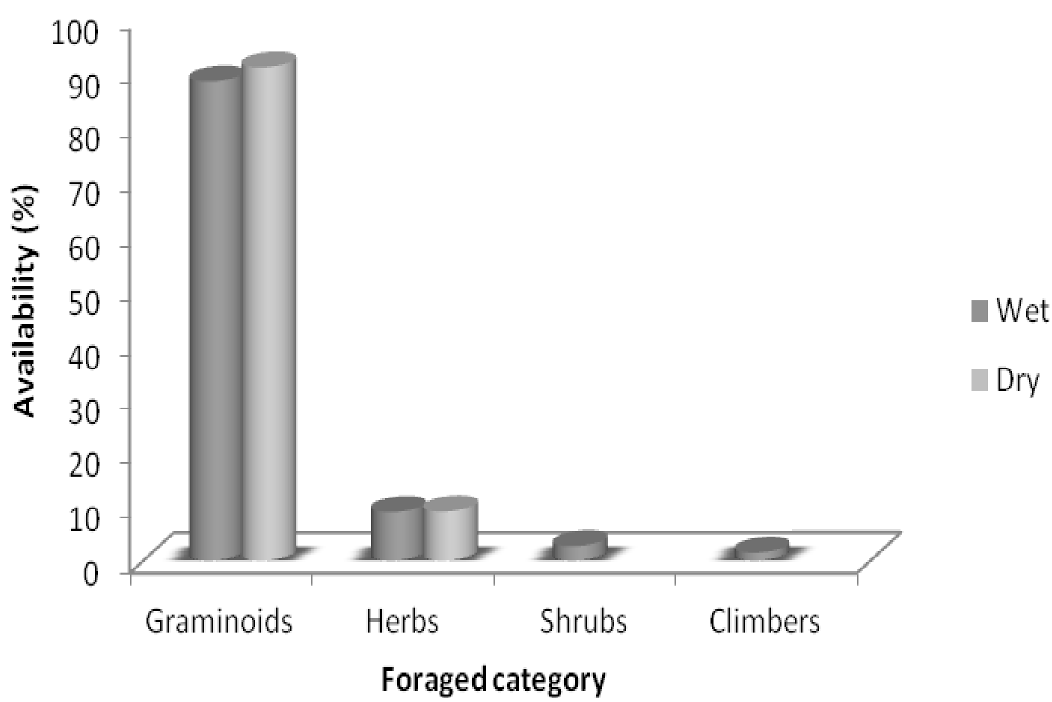

Figure.5 Seasonal changes in the availability (%) of forage species recorded in more than 5 quadrats that contributed ≥1% in the diet of common warthog either during the wet or dry seasons in GCHA (a = *C. fischerianus*, b = *D. abyssinica*, c = *E. tef*, d = *Z. mays*, e = *S. bicolor*, f = *E. coracana*, g = *C. dactylon*, h = *C. nlemfuensis,* i = *H. rufa*, j = *H. hirta,* k = *P. maximum*, l = *P. nubicwn*, m = *A.abyssinicus,* n = *B. ethiopum*, o = *T. brownie*, p = *C. benghalensis*, q = *D. steudneri*, r = *S. sesban,* s = *F. sycomorus,* t = *F. sur*, u = *F. vasta,* v = *S. mucronata*, w = *D. africanum*, x = *S.abyssinica*).

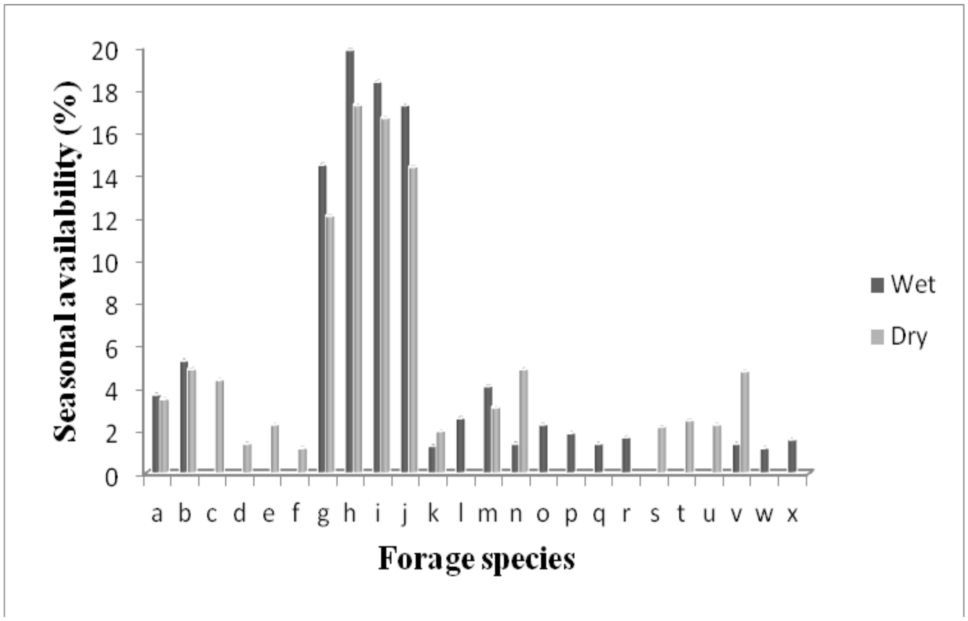

Figure.6 Seasonal changes in the availability (%) of forage species recorded from more than 5 quadrats and contributed ≥1% in the diet of common warthog either during the wet or dry seasons in HADCHA (a = *C. fischerianus*, b = *D. abyssinica*, c = *E. tef*, d = *Z. mays*, e = *S. bicolor*, f = *E. coracana*, g = *C. dactylon*, h = *C. nlemfuensis,* i = *H. rufa*, j = *Eragrostis spp,* k = *H.hirta,* l = *H.varibilis,*m = *P. maximum*, n = *P. nubicwn*, o = *S. poiretiana,* p = *A.abyssinicus,* q = *B. ethiopum*, r = *T. brownie*, s = *C. benghalensis*, t = *D. steudneri*, = u. *sesban,* v = *F. sycomorus,* w = *F. sur*, x = *F. vasta,* y = *S. mucronata*, z = *D. africanum*, a' = *H. macranthus*, b' = *S.abyssinica*)

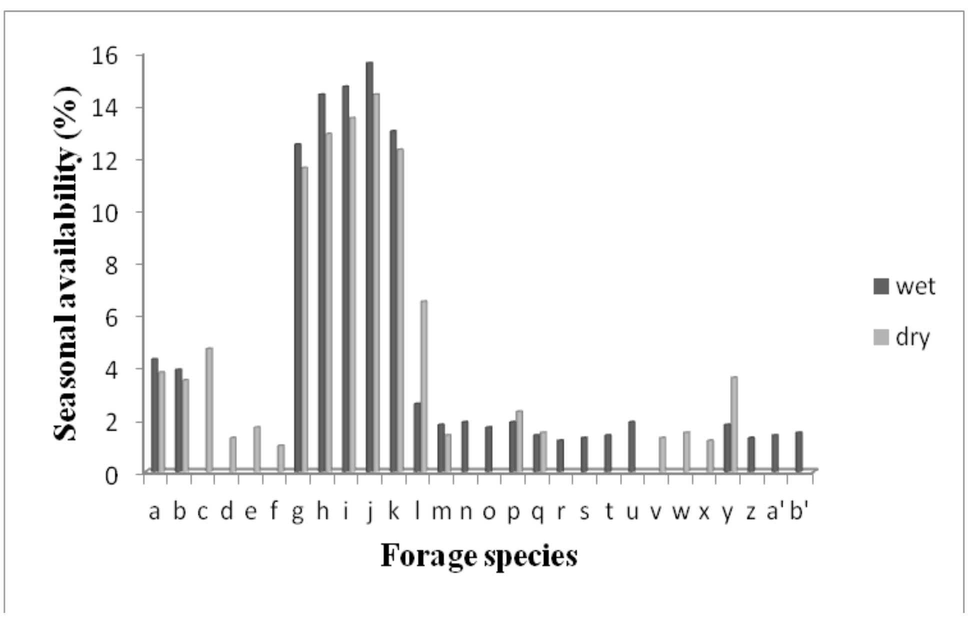

Figure.7 Mean seasonal fecal carbon (FC) and dietary carbon (DC) contents of common warthogs in GCHA and HADCHA

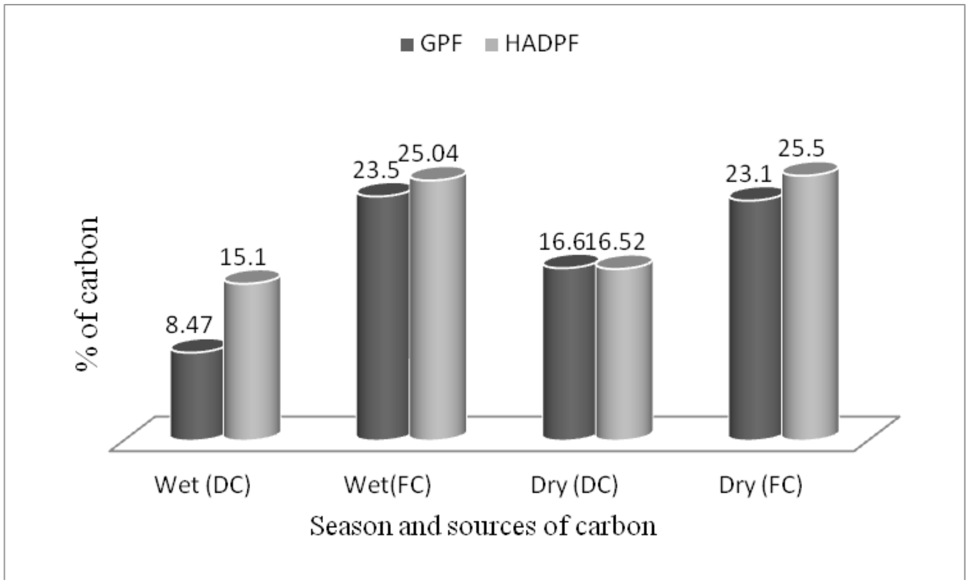

Figure.8 Mean seasonal fecal nitrogen (FN) and dietary nitrogen (DN) contents of common warthogs in GCHA and HADCHA

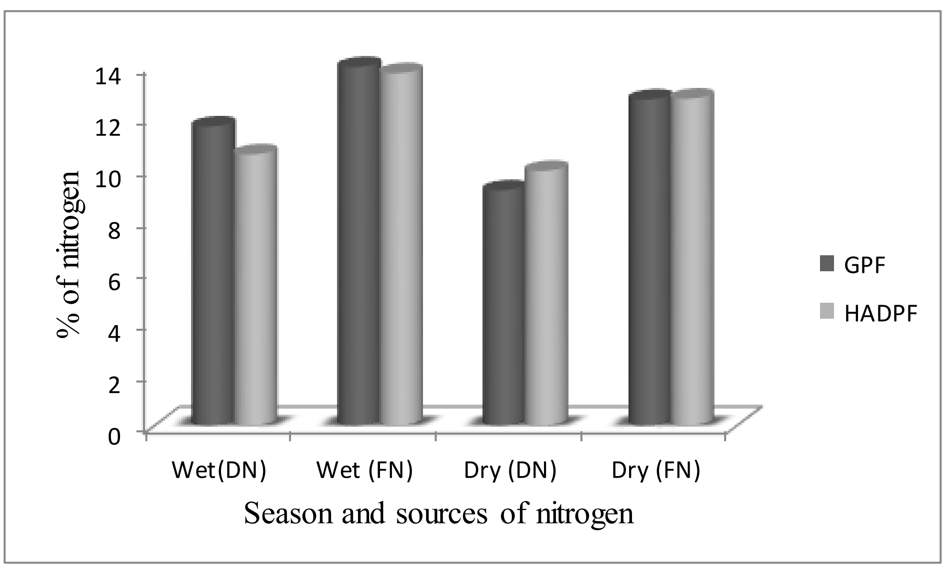

Figure.9 Mean seasonal fecal phosphorous (FP) and dietary phosphorous (DP) contents of common warthogs in GCHA and HADCHA.

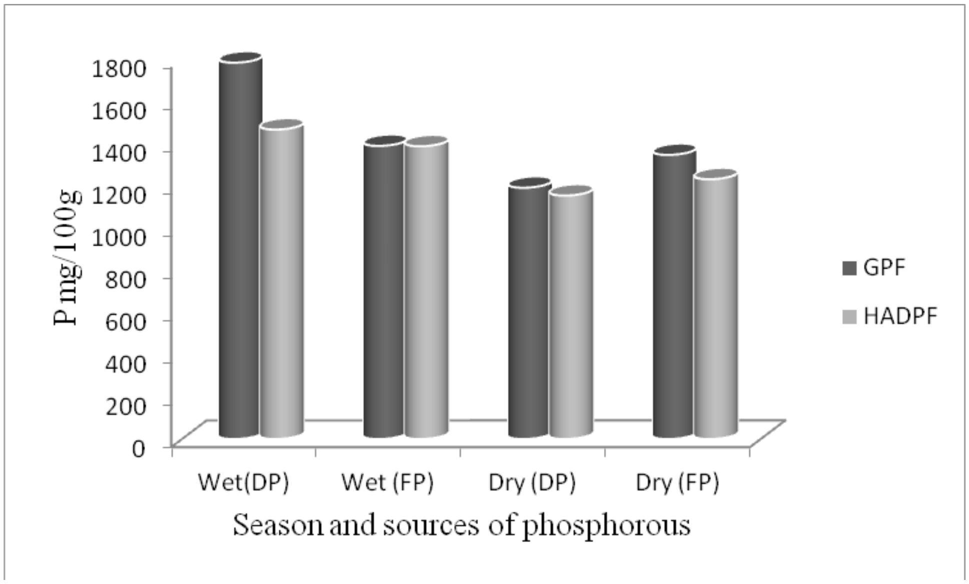

Figure.10 Mean seasonal fecal crude protein (FCP) and dietary crude protein (DCP) contents of common warthogs in GCHA and HADCHA

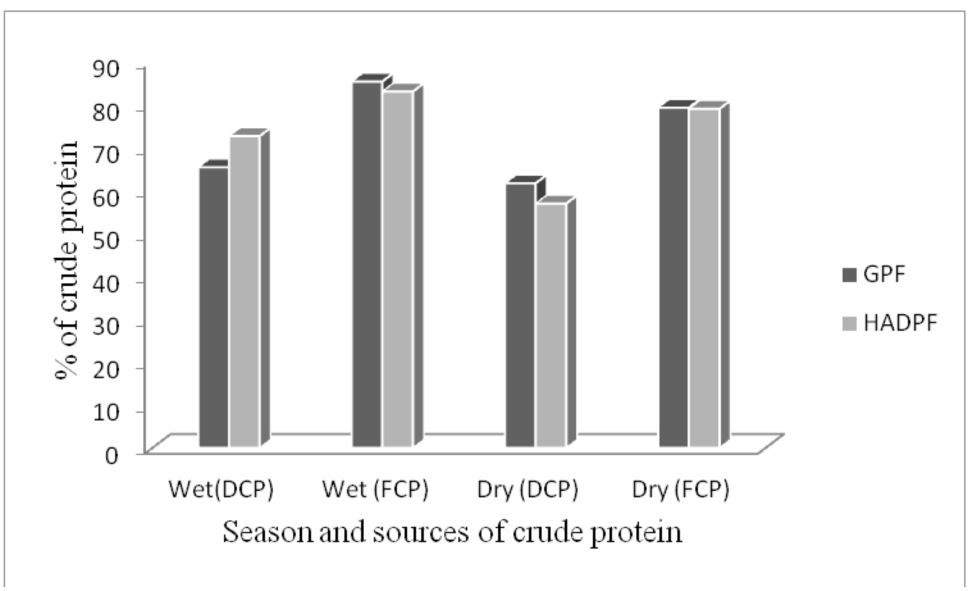

Table.1 Fibers measured from feces and diet of common warthog in GCHA and HADCHA

	GCHA		HADCHA	
Nutrients	Wet	Dry	Wet	Dry
Fecal				
DM%	92.83	92.75	92.32	92.11
OM%	76.16	70.64	75.03	75.12
NDF%	71.26	70.77	75.68	72.88
ADF%	54.03	57.18	59.56	59.8
Forage				
DM%	92.23	92.92	92.29	92.02
OM%	90.46	89.26	90.57	87
NDF%	71.43	68.44	74.19	68.97
ADF%	45.43	51.31	44.76	50.3

DM = dry matter, OM = organic carbon, NDF = neutral detergent fiber, ADF = acid detergent fiber

Appendix 1: Table.1 Forage species (mean ± SE) that contributed ≥ 1% to the diet of common warthog either during the wet or dry season in GCHA.

Family	**Forage species**	**Wet%**	**Dry%**	**Mean**
Graminoids = 13				
Cyperaceae	*Cyperus fischerianus*	3.7	3.5	3.6
Poaceae	*Digitaria abyssinica*	5.3	4.9	5.1
Poaceae	*Eragrostis tef*	0	4.4	2.2
Poaceae	*Zea mays*	0	1.4	0.7
Poaceae	*Sorghum bicolor*	0	2.3	1.15
Poaceae	*Eleusine coracana*	0	1.2	0.6
Poaceae	*Cynodon dactylon*	14.5	12.1	13.3
Poaceae	*Cynodon nlemfuensis*	19.9	17.3	18.6
Poaceae	*Hyparrhenia rufa*	18.4	16.7	17.55
Poaceae	*Hyparrhenia hirta*	17.3	14.4	15.85
Poaceae	*Panicum maximum*	1.3	2	1.65
Poaceae	*Pennisctum nubicwn*	2.6	0	1.3
Poaceae	*Andropogon abyssinicus*	4.1	3.1	3.6
Herbs = 9				
Arecaceae	*Borassusa ethiopum*	1.4	4.9	3.15
Combretaceae	*Terminalia brownii*	2.3	0	1.15
Commelinaceae	*Commelina benghalensis*	1.9	0	0.95
Dracaenaceae	*Dracaena steudneri*	1.4	0	0.7
Fabaceae	*Sesbania sesban*	1.7	0	0.85
Moraceae	*Ficus sycomorus*	0	2.2	1.1
Moraceae	*Ficus sur(F. capensis*	0	2.5	1.25
Moraceae	*Ficus vasta*			
Salicaceae	*Salix mucronata*	1.4	4.8	3.1
Shrub = 1				
Apiaceae	*Diplolophium africanum*	1.2	0	0.6
Climber = 1	*Stephania abyssinica*	1.6	0	0.8
	Total	100	100	100

Ungulates need continuous intake of dietary nitrogen (Holá, 2016). Dietary nitrogen is the most limiting nutrient compared to other food components, such as fat, especially during critical periods of the animal life cycle, such as pregnancy, lactating and fetal development for grazers (Grant *et al.,* 2000; Gil–Jiménez *et al.,* 2015). Dietary nitrogen is also the most common constituent of feces used to assess diet quality of foraging animals (Holechek, 1982; Kamler and Homolka, 2005; Monteith *et al.,* 2014; Rayn, 2016). Hence, in the present study, common warthogs consumed more mean proportion of dietary nitrogen during the wet season than during the dry seasons in GCHA. This could be due to in semi–arid savanna ecosystem, large proportions of available forage species become lignified and hard to digest during the dry season than the during wet season. Thus, the protein content of these forage species declines below 1.1% and fail to provide sufficient dietary protein (Mphinyane *et al.,* 2015; Rayn, 2016). The variation in dietary nitrogen is also closely related to phenology of the forage species (Jianzhang *et al.,* 1999). During the present study, common warthogs defecated more mean proportion of fecal nitrogen during the wet season than during the dry season in HADCHA. This might be due to fecal nitrogen was likely related to the consumption of forage species and season. Hence, it is the main factor which affects their availability and quality (Mphinyane *et al.,* 2015). The mean fecal nitrogen calibrated in GCHA and HADCHA was comparable during the dry season. The finding of the present study was strongly conflicted with Treydte et al. (2006), who measured lower fecal nitrogen (1.5%). On other hand, in the present study, fecal nitrogen defecated by common warthog was higher than dietary nitrogen utilized by warthogs in both study areas. This might be due to salt licking habit which supplemented the fecal nitrogen of the common warthogs. On the other hand, high fecal nitrogen calibrated indicated that the animals did not suffer from shortage of dietary nitrogen in both study areas (Treydte, 2004). However, the fecal and dietary nitrogen of the study areas were positively correlated. Several studies also reported positive linear relationship existed between fecal and dietary nitrogen in feeding activity of ungulates (Holecheck, 1982; Irwin *et al.,* 1993; Kamler and Homolka, 2005; Jean *et al.,* 2014; Holá, 2016).

Dietary phosphorousis essential for bacterial degradationof dietary fibers (Metzler and Mosenthin, 2008; dos Passos, 2014). It is also important for grazing ungulates reproductive process and may even restrict animal distributions (Grant *et al.,* 2000). Dietary phosphorous was predicted from forage species of animals (Wrench *et al.,* 1997; Augustine, 2004; Codron *et al.,* 2005). In the present study, fecal phosphorous concentration of common warthog varied between 1311 mg/100g and 1489.2 mg/100g. This showed that common warthog population of both study areas suffered from shortage of dietary phosphorous. This restricts reproductive process and animal distribution over long period of feeding. Because fecal phosphorous concentration 1900 mg/100g to 2000 mg/100g indicated that dietary phosphorous minimum threshold level animal consumed (Grant *et al.,* 2000). This might be lead to low reproductive rates and population decline of these animals in Dabena Valley Forest. On the other hand, dietary phosphorous utilized by common warthogs and fecal phosphorous concentration defecated did not show significant variation between seasons and the study areas.

Ungulates require dietary crude protein (DCP) to maintain their body weight (Mgqasta, 2010). In the present study, seasonal mean proportion of DCP foraged was higher during the wet season than during the dry season in HADCHA. This could be due to the decline in quality and quantities of foods during the dry season (Mgqasta, 2010; Thorp, 2012). The result of the present study contradicted with Clauss *et al.,* (2008), who measured smaller DCP (period 1 = 14.6%, period 2 = 15%) for captive common warthogs at Rotterdam Zoo. On the other hand, during the present study, seasonal mean proportion of fecal crude protein (FCP) content of common warthog was higher during the wet than during the dry season in GCHA. The finding of the present study was similar with Clauss et al. (2008), who measured FCP (period 1 = 82%, period 2 = 79%). The mean proportion of FCP was higher than DCP common warthogs ingested in both study areas and they were negatively correlated. This might be due to common warthog additionally ingested soil licks and wood shavings (Clauss *et al.,* 2008).

Among common warthogs and other wild pigs, dietary fiber is an inevitable component of their diets (Metzler and Mosenthin, 2008), and important for intestinal health (Mahenya, 2016). They use microbes in their cecum and colon to extract energy from a fibrous diet (Zervanos, 2009). Soluble dietary fiber may promote digestive functions and absorption of nutrients (Clauss *et al.,* 2008; Zijlstra *et al.,* 2015). Insoluble fiber diets also improve gut morphology by increasing villi length and stimulating mucosal enzyme activity (Metzler and Mosenthin, 2008). Likewise, common warthogs are more efficient than other wild suids and peccaries in terms of fiber digestion (Clauss *et al.,* 2008). Neutral detergent fiber (NDF) content of feces used as a predictor for digestible energy of the diet and NDF might be used to identify the most digestible plant species (Jean *et al.,* 2014). Hence, in the present study, NDF content of forage energy utilized by common warthog was consistent in GCHA and HADCHA. The finding of the present study was not far from the threshold value calibrated (60–65%) for grazers (Kamler and Homolka, 2005; Monteith *et al.,* 2014). Therefore, common warthog utilized reasonable forage energy of NDF in the study areas (Metzler and Mosenthin, 2008). However, the finding of the present study was contradicted with Clauss et al. (2008), who measured forage energy of NDF smaller during period 1 = 20.6% and NDF during period 2 = 21% for captive common warthogs at Rotterdam Zoo. On the other hand, common warthog NDF content feces was comparable in HADCHA and GCHA. The finding of the present study was little higher than the value measured for NDF content of feces by Clauss *et al.,* (2008), 66% and 63% during different periods.

Acid detergent fiber (ADF) is the least digestible fiber in most herbivores (Monteith *et al.,* 2014; Holá, 2016). It has long been used to estimate energy content of forage species (Zweifel–Schielly *et al.,* 2012). Hence, ADF is used as a predictor of forage digestibility as NDF is an estimator of forage intake of animals (Monteith *et al.,* 2014). The upper threshold level of ADF content of forage is 50% for grazers (Holá, 2016). Likewise, the forage content of ADF that common warthog utilized was consistent in GCHA and HADCHA. Hence, forage contents of ADF, common warthog consumed in both study areas showed modest digestibility (Kamler and Homolka, 2005). The finding of the present study was very far from Clauss *et al.,* (2008), who calibrated the feces content of ADF 11.6% and 11.9% during period 1 and 2, respectively. Moreover, ADF content of feces the animal defecated was higher in GCHA and less in HADCHA. This finding was very close to the finding of Clauss *et al.,* (2008), who measured 62% and 59% ADF content of feces during period 1 and 2, respectively.

In conclusion, diet analysis and microhistological study indicated that they common warthogs population were not suffered from poor nutritional quality intake except dietary phosphorous concentration in both study areas. Common warthog populations are currently foraged dietary phosphorous concentration below the minimum threshold level, which gradually affects the fertility and population size of the animal in the study areas. Common warthogs are highly efficient in dietary fibers (ADF and NDF) digestion. On the other hand, there were significant variations between dietary C, N, CP, and fecal contents of C, N, and CP because of salt licking behavior of common warthog's population.

Data statement

The research data is confidential.

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Author Contributions

Professor Afework Bekele is the primary mentor of the research work and Dr. Habte Jebessa is the primary field mentor during data collection periods

Conflict of interest

We declare that our manuscript is free of conflict of interest.

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