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Effect of method of preservation on the chemical composition of *Enterolobium cyclocarpum* leaves

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Abstract

Enterolobium cyclocarpum leaves are less acceptable by ruminants due to their high contents of anti-nutritional factors. The effect of preserving Enterolobium cyclocarpum leaves as hay and silage or silage: hay combinations on the proximate, fibre fractions, anti-nutritional factors, minerals and vitamins compositions were investigated in this study. Six experimental treatments consisting of 100% fresh Enterolobium cyclocarpum leaves, 100% ensiled Enterolobium cyclocarpum leaves, 100% sun dried Enterolobium cyclocarpum leaves, 75% silage: 25% hay, 50% silage: 50% hay and 25% silage: 75% hay were formulated. Each treatment was replicated 3 times and analyzed for chemical composition. The crude protein content ranged from 14.70 – 22.05%, which significantly differed ($p<0.05$) across treatments with the highest value in the fresh leaves. The values for neutral detergent fibre ranged from 56.64 – 57.92 %, acid detergent fibre from 37.14 – 39.87 % and acid detergent lignin from 13.30 – 14.96 %, they all differed significantly ($p<0.05$) across treatments with highest values in the 100% ensiled treatment. Preservation as silage significantly ($p<0.05$) reduced the concentrations of tannin, phytate and hydrocyanic acid, while preservation as hay significantly ($p<0.05$) reduced the concentration of saponin. The mineral contents of the EC leaves preserved as silage, hay and silage: hay combinations (Treatments 2 - 6) compared favourably with the mineral contents of the fresh leaves (Treatment 1). Preserved EC leaves (Treatments 2 – 6) had significantly ($p<0.05$) higher concentrations of vitamin C (444.21 –657.60 mg/100g) than the fresh leaves (308.79mg/100g). Thus preservation of E. cyclocarpum leaves as silage or hay improved its chemical composition and reduced its contents of anti-nutritional factors.

Keywords: *Enterolobium cyclocarpum*, chemical composition, ensiling, sun drying, mineral composition, vitamin contents.

Introduction

Enterolobium cyclocarpum is a species of flowering tree in the pea family Fabaceae. Guanacaste tree is native to the tropical regions of the Americas including Brazil, Colombia, Guyana, Mexico, United States of America and Venezuela (Wikipedia, 2018). Caro caro tree is also abundant in Guanacaste Province of Costa Rica. It is widespread in tropical parts of both Americas, in the Caribbean Islands and in Florida, Puerto Rico, Cuba, Dominican Republic, Haiti, Jamaica and Hawaii (Wikipedia, 2018). It has been introduced into many other tropical areas of the world such as Nigeria, Sumatra, Indonesia, and Australia (Orwa *et al.*, 2009; Wikipedia, 2018). Ear pod tree is naturally found in humid and sub humid regions especially in coastal areas and river banks (Andreu *et al.*, 2015). Like other plants, both primary and secondary plant organic metabolites are

present in Enterolobium plants. The primary compounds are directly involved in the plant's growth and development. On the other hand, plant secondary metabolites (PSM) are not directly involved in the plant's development or nutrition (Crozier *et al.*, 2006). These less beneficial PSM are bioactive compounds/anti-nutritional factors (ANFs) which functions include protective defense mechanisms against pathogens, discouraging consumption by herbivorous animals, imparting some degree of toxicity to herbivores, altering the foraging behaviour of herbivores, affecting feed digestibility, nitrogen fixation in a symbiotic relationship with beneficial microorganisms and transportation of metals within the plant (Waghorn, 2008; Demain and Fang, 2000). These PSM include tannins, saponins, steroids, mimosine, coumarin, phenols, phytate, oxalate, hydrocyanide flavonoids, triterpenes, anthocyanidins, reducers and alkaloids (Galindo *et al.*, 2014). The most abundant PSM are tannins and saponins. Tannins are bitter tasting plant polyphenols that bind and precipitate proteins. Tannins are usually grouped into two: hydrolysable tannins (HT) and condensed tannins (CT). Before now, it was generally claim that tannins and saponins are harmful and toxic to ruminant animals. However with the beneficial usage of tannins in drinks and foods for humans and the use of saponins in human diet for controlling cholesterol, ruminant's research nowadays focused on the use of these PSM either as extracts or whole plants to explore its potentials and risks (Broderick and Albrecht, 1997; Carulla *et al.*, 2005; Soliva, 2007; Stewart, 2018). *Enterolobium cyclocarpum leaf is rich in nutrients,* containing 15.59 – 18.6 % crude protein (CP), 8.16 – 48.2 % crude fibre (CF), 2.21 – 11.00 % ether extract (EE), 4.90 – 11.80 % ash, 51.4 – 63.94 % neutral detergent fibre (NDF); 31.90 – 42.99 % acid detergent fibre (ADF), 8.6 % acid detergent lignin (ADL) (Babayemi, 2006; Isah *et al.,* 2011; Galindo *et al.,* 2014; Aderinboye *et al.,* 2016). However, its acceptability by ruminant is low due to its contents of ANFs (Koenig *et al.,* 2007; Isah *et al.,* 2011).

Materials and methods

The study was carried out at the Teaching and Research Farms, University of Uyo, Uyo, Akwa Ibom State, Nigeria. Uyo is located between latitudes 4˚59´ and 5˚04´ N and longitudes 7˚52´ and 8˚00´ E. Uyo is located within the tropical rainforest zone which characterizes the South South agro-ecological zone of Nigeria. The annual rainfall in Uyo ranges from 800 mm – 3,200 mm per annum. Rains begin in March and continue till October with peaks in June and September and two weeks of break in August (August break), then followed by dry season from November till February. Annual temperature varies between 23 – 28 ^{0}C (Ifut and Mbaba, 2014). The leaves of *Enterolobium cyclocarpum* were harvested and divided into three portions. One of the portions was taken immediately to the laboratory for chemical analyses. The second portion was ensiled while the third portion was sundried to hay. At the end of the ensiling and sun drying periods, representative samples of the ensiled and sundried *Enterolobium cyclocarpum* leaves were subjected to chemical analyses. Additionally, the ensiled and sundried leaves were mixed in different proportions to form experimental diets which were also analyzed for their chemical compositions. *Enterolobium cyclocarpum* leaves were ensiled in 4-liter mini silos. Individual leaves of EC (devoid of the petioles) were quickly packed into the silos lined with polythene bags. The mass was manually compacted to expel air. Further air expulsion was achieved by covering the

mass with polythene bags and pressing down with sand bags. The silos were also covered using their lids. The ensiling lasted for 21 days. The fresh and treated (silage, hay and silage x hay combinations) *Enterolobium cyclocarpum* leaves were used to formulate six (6) sole and combined experimental treatments as follows:

Treatment 1: 100 % fresh *Enterolobium cyclocarpum* leaves (FENT)

Treatment 2: 100 % ensiled *Enterolobium cyclocarpum* leaves (ENENT)

Treatment 3: 100 % sun dried *Enterolobium cyclocarpum* leaves (DENT)

Treatment 4: 75 % ensiled + 25 % sun dried *Enterolobium cyclocarpum* leaves (ENENT 75)

Treatment 5: 50 % ensiled + 50 % sun dried *Enterolobium cyclocarpum* leaves (ENENT 50)

Treatment 6: 25 % ensiled + 75 % sun dried *Enterolobium cyclocarpum* leaves (ENENT 25)

The treated leaves were analyzed for proximate, fibre fractions, minerals, vitamins composition and anti-nutritional factors. Each treatment was replicated three times. Dry matter (DM), crude protein (CP), crude fibre (CF), ash, ether extract (EE) and Nitrogen free extract (NFE) were determined according to the method of AOAC (1990). The fibre fractions - neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) - were determined using the procedures of Van Soest *et al*. (1991). Cellulose was calculated as the difference between ADF and ADL while hemicellulose was calculated as the difference between NDF and ADF. Tannins were determined by the Folin-Dennis Spectrophometric method (Pearson, 1976). The saponin content of the sample was determined by the Double Solvent Extraction Gravimetrical Method (Harborne, 1973). Phytate was analyzed by the procedure of McCance and Widdowson (1953). Ammonia nitrogen (NH_3N) was determined by Nessler's Colorimeter Method (AOAC, 1990). The mineral contents were determined by the dry ash extraction method, following which specific mineral elements were analyzed. Phosphorus was determined by the vanadomolybdate (yellow) spectrophotometry method (AOAC, 1980). Calcium and magnesium were determined by the Versanale EDTA complexiometric titration method (Pearson, 1976). Potassium and sodium were determined by flame photometry (AOAC, 1990). Data obtained were subjected to analysis of variance using SAS (2000) Statistical software. Significant means were separated using Duncan Multiple Range Test of the same Statistical package.

Results and discussion

The proximate composition of fresh and treated EC leaves is shown in Table 1. Values obtained for dry matter (DM) were significantly different ($p<0.05$) from each other. The values obtained for the fresh, ensiled and dried samples were 34.93, 38.56 and 93.35% respectively. Dry matter values for differently preserved EC leaves combinations were 49.75, 59.45 and 77.69% for diets 4 (ENENT 75), 5 (ENENT 50) and 6 (ENENT 25) respectively. The 34.93 % DM for fresh EC leaves reported in this study is slightly lower than the value (39.08%) reported by Babayemi (2006), slightly higher than the value (32.15%) reported by Isah *et al.* (2011) and compares favvourably with the value of 34.40% reported by Aderinboye *et al.* (2016) for fresh EC leaves. The variation might be as a result of soil type, weather and differences in eco-climatic zone. The DM value of 93.35% for dried EC leaves obtained in this study also compares favourably with the

value (93.20%) reported by Koenig *et al.* (2007) for dried EC leaves. The crude protein contents obtained in this study which were significantly different ($p<0.05$) across treatment were 22.05% for the fresh EC leaves and values of 14.53 – 17.93% in treatments 2 to 6. The CP values were within the range of values reported by other authors for EC leaves (Babayemi, 2006; Isah *et al.,* 2011; Aderinboye *et al.,* 2016) and the range of values (13.65 – 31.51%) reported for other browse plants (Ahamefule *et al.,* 2006; *Asaolu et al., 2012; Isah et al., 2012; Ogunbosoye, 2013;* Bassey *et al.,* 2014; Galindo *et al.,* 2014; Obua, 2014; Okpara *et al.,* 2014; Oyedele *et al.*, 2016). Olorunnisomo and Fayomi (2012) reported a similar CP of 21.1% for fresh EC leaves. The CP values obtained in this study was above the minimum CP value (8%) required for effective rumen function (Norton, 1998). The range of CP values obtained in this study was also above the minimum protein requirement of 10 – 12% for ruminant animals (ARC, 1984). The CP (14.70%) for the ensiled EC leaves is lower than the CP (22.05%) for fresh EC leaves. This occurs because the soluble carbohydrates in EC leaves were not enough to favour effective fermentation. Additionally, the high buffering capacity of the leaves made them to resist changes in pH, thus exposing the CP to proteolysis. This corroborates the findings of McDonald *et al.* (1995), Babayemi (2009), Falola *et al.* (2013) and Ekanem *et al.* (2017).

Table 1: Proximate composition (% DM) of fresh and treated *Enterolobium cyclocarpum* leaves

Parameters	FENT	ENENT	DENT	ENENT 75	ENENT 50	ENENT 25	SEM
Dry matter	34.93^{f}	38.56^{e}	93.35^{a}	49.75^{d}	59.45^{c}	77.69^{b}	5.06
Crude protein	22.05^{a}	14.70^{d}	17.85^{b}	14.53^{a}	16.22^{c}	17.93^{b}	0.62
Crude fibre	3.10^{f}	5.12^{b}	5.32^{a}	4.34^{c}	4.27^{d}	4.11^{e}	0.18
Ether extract	3.23^{e}	3.37^{d}	3.18^{f}	4.71^{a}	3.95^{c}	4.50^{b}	0.15
Ash	4.40^{f}	7.61^{b}	7.91^{a}	6.38^{c}	6.13^{d}	6.04^{e}	0.28
NFE	66.57^{e}	69.20^{c}	65.74^{f}	70.04^{a}	69.44^{b}	67.42^{d}	0.39

$^{a-f}$ Means on the same row with different superscripts are significantly different ($p<0.05$); FENT = 100% Fresh *Enterolobium cyclocarpum* leaves; ENENT = 100% Ensiled *Enterolobium cyclocarpum* leaves; DENT = 100% Sundried *Enterolobium cyclocarpum* leaves; ENENT 75 = 75% Ensiled + 25% Sundried *Enterolobium cyclocarpum* leaves; ENENT 50 = 50% Ensiled + 50% Sundried*Enterolobium cyclocarpum* leaves; ENENT 25 = 25% Ensiled + 75% Sundried *Enterolobium cyclocarpum* leaves; SEM = Standard error of mean. NFE = Nitrogen free extract.

The crude fibre values (3.10 – 5.32%) obtained in this study for fresh and treated EC leaves were also significantly different ($p<0.05$) across treatment. The highest CF value was obtained in the dried EC leaves (Treatment 3). These CF values were within the range of values (2.10 - 28.57 %) reported by various authors for browse plants (Ahamefule *et al.,* 2006; *Asaolu et al., 2012; Isah et al., 2012; Ogunbosoye, 2013;* Bassey *et al.,* 2014; Galindo *et al.,* 2014; Obua, 2014; Okpara *et al.,* 2014; Oyedele *et al.*, 2016). The CF value in this study for fresh EC is slightly higher than CF value of 2.10% reported by Ahamefule *et al.* (2006) for *Alchornea cordifolia*. However, the range of CF values obtained in this study is generally lower compared to CF values obtained by other authors for EC and other browse leaves. Babayemi (2006) reported a CF value of 48.20% for fresh EC leaves. Isah *et al.* (2011) reported a CF value of 8.16% for fresh *Enterolobium cyclocarpum*. In the case of other browse plants, *Asaolu et al. (2012) reported a* CF content of 12.16% *for dried Leucaena*

leucocephala, while Oyedele *et al.* (2016) reported a CF value 16.37% for fresh leaves of *Gliricidia sepium*. *Asaolu et al. (2012) on the other hand reported a CF value of 10.70% for dried Gliricidia sepium. Crude fibre values reported for fresh leaves of Moringa oleifera were* 10.34% (Oyedele *et al.*, 2016) and 14.04% (Tona *et al.*, 2014). For dried leaves of *Moringa oleifera, Asaolu et al. (2012) reported a CF value of 11.03%.* The range of values obtained in this study for ether extract (EE) was 3.18 – 4.71%, with Treatment 4 (75% ensiled + 25% dried *Enterolobium cyclocarpum* leaves combination) recording the highest value. The EE values were significantly different *(p<0.05)* across treatments and were within the range of values (0.50 - 28.40 %) reported for browse plants. The following similar EE range of values obtained in this study was reported in literature: 2.21% (Isah *et al.,* 2011) for EC leaves; *3.30% for Pentaclethra macrophyla (*Obua, 2014) and 0.50% for *Gmelina arborea (*Okpara *et al.,* 2014). Higher EE values than those obtained in this study reported in literature for browse plants include: *11.0% for Enterolobium cyclocarpum (*Babayemi, 2006); 28.40% for fresh *Moringa oleifera* (Oyedele *et al.*, 2016); 14.58% for fresh *Moringa oleifera leaves* (Tona *et al.*, 2014); 8.06% for *dried Moringa oleifera leaves (Asaolu et al., 2012); 6.25% for Azadirachta indica (Isah et al., 2012); 6.67% for Ficus exasperate leaves (Isah et al., 2012); 12.00% f*or *Gliricidia sepium* (*Ogunbosoye, 2013); 5.67% for dried Leucaena leucocephala* leaves *(Asaolu et al., 2012); 12.00% for fresh leaves of Leucaena leucocephala* (*Ogunbosoye, 2013); 10.10% for Gmelina arborea (*Ahamefule *et al.,* 2006); 11.81% for *Spondias mombin*, 10.34% for *Manniophyton fulvum*, 12.22% for *Palisota hirsuta* and 10.54% for *Rauvolfia vomitoria* (Bassey *et al.,* 2014). Ash values of 4.40 – 7.90%, which were significantly different ($p<0.05$) from each treatment were obtained for EC leaves in this study. Treatment 1 (100% fresh EC leaves) had the least ash contents, while Treatment 3 (dried EC leaves) had the highest ash contents. The ash values recorded in this study was comparable to the values of 4.90% and 7.85% reported by Babayemi (2006) and Isah *et al.* (2011) respectively for the fresh leaves of *Enterolobium cyclocarpum*. The range of values for ash in this study was also within the range (*2.20 - 19.18*%) reported for other browse plants (Ahamefule *et al.,* 2006; *Asaolu et al., 2012; Isah et al., 2012; Ogunbosoye, 2013;* Bassey *et al.,* 2014; Galindo *et al.,* 2014; Obua, 2014; Okpara *et al.,* 2014; Oyedele *et al.*, 2016). The soluble carbohydrates (NFE) present in fresh and treated leaves of EC ranged from 65.74% in Treatment 3 (DENT) to 70.04% in Treatment 4 (ENENT 75). There were significant differences ($p<0.05$) in NFE values across dietary treatment. The range of NFE values in this study was slightly higher than the 64.71% reported by Isah *et al.* (2011). The high NFE made it possible for EC leaves to be properly ensiled as a sole feedstuff. However, ensiling EC leaves with feedstuffs high in readily fermentable carbohydrates such as cassava peels will enhance its fermentation quality **(**Olorunnisomo and Fayomi, 2012; Ekanem *et al.*, 2017)**.**

Table 2 shows the fibre fractions of fresh and treated EC leaves. There were significant differences ($p<0.05$) across the dietary treatments in all the fibre fractions assessed. Higher neutral detergent fibre (NDF) values (56.64 – 57.92%) which were significantly different ($p<0.05$) from each other were obtained. The highest NDF value was obtained for ensiled EC leaves (Treatment 2). The range of values for NDF reported in this study is within the range of

51.4 – 63.94 % reported for fresh and dried EC leaves (Koenig *et al.,* 2007; Galindo *et al.,* 2014; Aderinboye *et al.,* 2016). Similarly, the range of values (37.14 – 39.87%) for acid detergent fibre (ADF) obtained in this study agreed with values of 31.90 and 42.99% by Aderinboye *et al.* (2016) and Galindo *et al.* (2014) for fresh and 3-day sundried EC leaves respectively. High lignin contents (13.30 – 14.96%) were also obtained.

Table 2: Fibre fractions (%) of fresh and treated *Enterolobium cyclocarpum* leaves

Parameters	FENT	ENENT	DENT	ENENT 75	ENENT 50	ENENT 25	SEM
NDF	57.86^{b}	57.92^{a}	56.64^{f}	57.73^{c}	57.59^{e}	57.65^{d}	0.10
ADF	39.37^{d}	39.87^{a}	37.14^{e}	39.58^{b}	39.47^{c}	39.56^{b}	0.22
ADL	14.83^{b}	14.96^{a}	13.30^{f}	14.25^{c}	14.18^{e}	14.21^{d}	0.13
Hemicellulose	18.49^{b}	18.05^{f}	19.50^{a}	18.15^{c}	18.12^{d}	18.10^{e}	0.12
Cellulose	24.54^{d}	24.91^{c}	23.85^{e}	25.33^{a}	25.29^{b}	25.34^{a}	0.13

$^{a-f}$ Means on the same row with different superscripts are significantly different ($p<0.05$); FENT = 100% Fresh *Enterolobium cyclocarpum* leaves; ENENT = 100% Ensiled *Enterolobium cyclocarpum* leaves; DENT = 100% Sundried *Enterolobium cyclocarpum* leaves; ENENT 75 = 75% Ensiled + 25% Sundried *Enterolobium cyclocarpum* leaves; ENENT 50 = 50% Ensiled + 50% Sundried *Enterolobium cyclocarpum* leaves; ENENT 25 = 25% Ensiled + 75% Sundried *Enterolobium cyclocarpum* leaves; SEM = Standard error of mean. NDF = Neutral detergent fibre ADF = Acid detergent fibre. ADL = Acid detergent lignin.

The anti-nutritional factors present in fresh and treated EC leaves are as shown in Table 3. The fresh EC leaves were quite high in oxalic acid (450.21 mg/100g). Tannin was also present in higher concentrations (74.41 – 158.11 mg/100g) in both fresh and treated EC leaves. Saponin, phytate and HCN occurred in relatively low proportions in the fresh EC leaves. Apart from the contents of oxalate, there were significant differences ($p<0.05$) in the anti-nutrients composition of fresh and treated EC leaves. The preservation of EC leaves either as silage, hay and silage-hay combinations drastically reduced the amounts of oxalic acid to the range of 234.10 – 315.14mg/100g. Sun drying reduced the amount of oxalate quite lower (288.13mg/100g) in EC leaves compared to ensiling (315.14 mg/100g). However, the lowest concentration of oxalate (234.10mg/100g) was recorded for d 5 with the 50:50 silage/hay EC leaf combinations. On the other hand, the concentration of tannin, saponin, phytate and HCN varied with the differently treated EC leaves and treated leaves combinations. Ensiling significantly ($p<0.05$) reduced the concentration of tannin, phytate and HCN compared to sun drying. Conversely, sun drying reduced the concentration of saponin compared to ensiling. Results obtained in this study showed that the different treatment methods reduced/affected the concentrations of the secondary plant metabolites but do not completely eliminate them. This is in line with the findings of Heckendon *et al.* (2006) who reported that despite the conditions experienced during the drying of the leaves of the sainfoin browse plants to hay, the hay still contained significant bioactive properties similar to those in the fresh leaves. Similarly, Stewart (2018) also reported significant concentrations of condensed tannins in some non-popular browse leaves hays when she determined the effect of tannin-containing legume hays on enteric methane emissions and nitrogen partitioning in beef cattle. Higher concentrations of tannins are desirable in ruminant nutrition because of their reported beneficial effect such as tannin-protein binding with increased protein flow into the duodenum, partitioning more nitrogen

excretion to feaces rather than urine and reducing methanogenesis (Carulla *et al.*, 2005; Mueller-Harvey, 2006; Maamouri *et al.*, 2011; Aguerre *et al.*, 2015; Stewart, 2018).

Table 3: Anti-nutritional factors (mg/100g) of fresh and treated *Enterolobium cyclocarpum* leaves

Parameters	FENT	ENENT	DENT	ENENT 75	ENENT 50	ENENT 25	SEM
Tannin	93.40^{c}	74.41^{e}	75.97^{d}	158.11^{a}	74.59^{e}	130.73^{b}	7.81
Saponin	3.92^{c}	4.30^{b}	3.18^{f}	3.80^{d}	4.49^{a}	3.64^{e}	0.10
Oxalate	450.21^{d}	315.14^{c}	288.13^{bc}	276.12^{abc}	234.10^{a}	253.30^{ab}	17.76
Phytate	3.60^{e}	2.51^{f}	3.96^{d}	89.90^{a}	81.48^{b}	80.84^{c}	9.81
HCN	6.10^{e}	4.50^{f}	11.70^{c}	15.90^{b}	10.27^{d}	19.96^{a}	1.29

$^{a-d}$ Means on the same row with different superscripts are significantly different ($p<0.05$); FENT = 100% Fresh *Enterolobium cyclocarpum* leaves; ENENT = 100% Ensiled *Enterolobium cyclocarpum* leaves; DENT = 100% Sundried *Enterolobium cyclocarpum* leaves; ENENT 75 = 75% Ensiled + 25% Sundried *Enterolobium cyclocarpum* leaves; ENENT 50 = 50% Ensiled + 50% Sundried *Enterolobium cyclocarpum* leaves; ENENT 25 = 25% Ensiled + 75% Sundried *Enterolobium cyclocarpum* leaves; SEM = Standard error of mean. HCN = Hydrocyanide.

Table 4 shows the mineral composition of fresh, ensiled, sundried and combinations of ensiled and sundried EC leaves. The EC leaves were quite high in the macro mineral compositions. The mineral contents in EC leaves obtained in this study were within the range needed for adequate physiological growth, reproduction and milk production of West African dwarf sheep and goats. The calcium: phosphorus ratio was within the recommended 1:1 level. Most of the macro mineral contents obtained in this study were within the range of values reported by Babayemi (2006) and Galindo *et al.* (2014). The slight variations in the concentrations of some macro minerals obtained in this study compared to that reported by Babayemi (2006) and Galindo *et al.* (2014) for fresh and dried EC leaves respectively may be due to soil type, climatic conditions and method of analyses.

Table 4: Mineral composition (%) of fresh and treated *Enterolobium cyclocarpum* leaves

Parameters	FENT	ENENT	DENT	ENENT 75	ENENT 50	ENENT 25	SEM
Calcium	0.24^{bc}	0.26^{a}	0.23^{cd}	0.25^{ab}	0.22^{d}	0.22^{d}	0.00
Phosphorus	0.33^{ab}	0.34^{a}	0.32^{bc}	0.33^{ab}	0.32^{bc}	0.31^{c}	0.00
Potassium	0.63^{bc}	0.65^{a}	0.63^{bc}	0.64^{ab}	0.62^{c}	0.59^{d}	0.01
Magnesium	0.28^{a}	0.29^{a}	0.26^{b}	0.28^{a}	0.25^{bc}	0.24^{c}	0.01
Sodium	0.17^{bc}	0.19^{a}	0.16^{c}	0.18^{ab}	0.16^{c}	0.13^{d}	0.01

$^{a-d}$ Means on the same row with different superscripts are significantly different ($p<0.05$); FENT = 100% Fresh *Enterolobium cyclocarpum* leaves; ENENT = 100% Ensiled *Enterolobium cyclocarpum* leaves; DENT = 100% Sundried *Enterolobium cyclocarpum* leaves; ENENT 75 = 75% Ensiled + 25% Sundried *Enterolobium cyclocarpum* leaves; ENENT 50 = 50% Ensiled + 50% Sundried *Enterolobium cyclocarpum* leaves; ENENT 25 = 25% Ensiled + 75% Sundried *Enterolobium cyclocarpum* leaves; SEM = Standard error of mean.

The vitamin contents of fresh and treated EC leaves are shown in Table 5. There were significant differences ($p<0.05$) in the concentration of vitamin A, C, D and E of the EC leaves. Concentration of vitamin A was highest in the sundried EC leaves while vitamin D was highest in the ensiled leaves. Concentrations of vitamin C was generally higher in the preserved leaves (Treatment 2 - 6), with highest value obtained in Treatment 4 (ensiled 75: hay 25%).

Table 5: Vitamin contents (mg/100g) of fresh and treated *Enterolobium cyclocarpum* leaves

Parameters	FENT	ENENT	DENT	ENENT 75	ENENT 50	ENENT 25	SEM
Vitamin A	1.44^{e}	1.02^{f}	2.39^{a}	1.82^{c}	2.09^{b}	1.61^{d}	0.11
Vitamin C	308.79^{f}	489.40^{d}	613.40^{c}	657.60^{a}	626.33^{b}	444.21^{e}	29.74
Vitamin D	57.96^{c}	58.85^{a}	55.67^{d}	58.72^{b}	55.48^{e}	53.96^{f}	0.45
Vitamin E	22.18^{a}	17.33^{c}	13.10^{e}	11.28^{f}	13.78^{d}	20.10^{b}	0.95

$^{a-f}$ Means on the same row with different superscripts are significantly different ($p<0.05$); FENT = 100% Fresh *Enterolobium cyclocarpum* leaves; ENENT = 100% Ensiled *Enterolobium cyclocarpum* leaves; DENT = 100% Sundried *Enterolobium cyclocarpum* leaves; ENENT 75 = 75% Ensiled + 25% Sundried *Enterolobium cyclocarpum* leaves; ENENT 50 = 50% Ensiled + 50% Sundried *Enterolobium cyclocarpum* leaves; ENENT 25 = 25% Ensiled + 75% Sundried *Enterolobium cyclocarpum* leaves; SEM = Standard error of mean.

Conclusion

Ensiling and sun drying affected the proximate, fibre fractions, minerals and vitamins composition of EC leaves. However, the CP contents in the fresh and preserved EC leaves were higher than the minimum protein requirements for ruminant animals. Ensiling and sun drying reduced the contents of anti-nutritional factors in EC leaves but do not completely eliminate them. Ensiling reduced the concentrations of condensed tannins, phytate and HCN in EC leaves compared to sun drying. On the other hand, sun drying reduced the concentration of saponin in EC leaves. Concentrations of vitamins and minerals in both the fresh and treated leaves were within range for normal physiological functions of farm animals.

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