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Chemical composition, secondary metabolites and nutritive value of elephant-ear tree (*Enterolobium cyclocarpum* (Jacq.) Griseb): A review

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Abstract

Enterolobium cyclocarpum is naturally found in the tropical region and it is a fast growing tree. It is a browse plant that is available all year round. The leaves, seeds, pods and fruits of Enterolobium cyclocarpum are rich in chemical composition such as protein and in secondary metabolites. The secondary metabolites or anti-nutritional factors have both beneficial and detrimental effects. The chemical composition, anti-nutritional factors and nutritive value of Enterolobium cyclocarpum leaves, pods, seeds and fruits were examined in this review. Enterolobium cyclocarpum is rich in: crude protein (10.40 in seeds to 22.50 in leaves), crude fibre (3.10 in leaves to 63.50 in seeds), ether extract (2.21 to 11.00 in leaves), ash (4.40 – 11.80), nitrogen free extract (51.40 – 70.04), neutral detergent fibre (51.4 – 63.94) and acid detergent fibre (31.90 – 42.99).The variations in values could be attributed to soil type, climatic conditions, stage of growth and methods of analyses. The leaves, pods seeds, and fruits of Enterolobium cyclocarpum are rich in the macro minerals (calcium, phosphorus, magnesium and potassium and sodium), micro minerals (zinc, manganese, copper and iron) and vitamins (vitamins A, C, D and E) and some are present within the range needed for normal physiological functions of ruminant animals. Secondary metabolites present in Enterolobium cyclocarpum in varying quantities are tannins, saponins, oxalate, phytate, hydrocyanic acid, trypsin inhibitors and alkaloids. Enterolobium cyclocarpum have been identified as the highest poisonous plants, with the fruits being the most toxic that can cause photosensitization. Preservation methods such as toasting, ensiling and sun drying drastically reduced these to beneficial and tolerable levels. These metabolites such as saponins have been reported to reduce the numbers of protozoa in the short run (12 – 14 days) and also favour moderate methane production. Acceptability of Enterolobium cyclocarpum by ruminants is dependent on types of forages offered and previous experience while low to moderate digestibility have been reported in vitro and in vivo. Depending on processing or preservation methods and levels of inclusion in the diets, Enterolobium cyclocarpum have no deleterious effect on growth performance and carcass characteristics of ruminant animals.

Keywords: browse plants, *Enterolobium cyclocarpum*, nutrients composition, bioactive compounds and defaunation

Composition chimique, métabolites secondaires et valeur nutritive de l'arbre d'éléphant-ear (Enterolobiumcyclocarpum (Jacq.) Griseb) : une revue

Résumé

Enterolobium cyclocarpum se trouve naturellement dans la région tropicale et c'est un arbre à croissance rapide. C'est une plante à brouter disponible toute l'année. Les feuilles, les *graines, les gousses et les fruits d'Enterolobium cyclocarpum sont riches en composition chimique comme les protéines et en métabolites secondaires. Les métabolites secondaires ou facteurs anti-nutritionnels ont à la fois des effets bénéfiques et néfastes. La composition chimique, les facteurs anti-nutritionnels et la valeur nutritive des feuilles, des gousses, des graines et des fruits d'Enterolobium cyclocarpum ont été examinés dans cette revue. Enterolobium cyclocarpum est riche en : protéines brutes (10,40 dans les graines à 22,50 dans les feuilles), fibres brutes (3,10 dans les feuilles à 63,50 dans les graines), extrait d'éther (2,21 à 11,00 dans les feuilles), cendres (4,40 - 11,80), extrait sans azote (51.40 – 70.04), fibre au détergent neutre (51.4 – 63.94) et fibre au détergent acide (31.90 – 42.99). Les variations de valeurs peuvent être attribuées au type de sol, aux conditions climatiques, au stade de croissance et aux méthodes d'analyse. Les feuilles, les graines de gousses et les fruits d'Enterolobium cyclocarpum sont riches en macro-minéraux (calcium, phosphore, magnésium et potassium et sodium), en micro-minéraux (zinc, manganèse, cuivre et fer) et en vitamines (vitamines A, C, D et E) et certains sont présents dans la plage nécessaire aux fonctions physiologiques normales des ruminants. Les métabolites secondaires présents dans Enterolobium cyclocarpum en quantités variables sont les tanins, les saponines, l'oxalate, le phytate, l'acide cyanhydrique, les inhibiteurs de la trypsine et les alcaloïdes. Enterolobium cyclocarpum a été identifié comme la plante la plus toxique, les fruits étant les plus toxiques pouvant provoquer une photosensibilisation. Les méthodes de conservation telles que le grillage, l'ensilage et le séchage au soleil les ont considérablement réduits à des niveaux bénéfiques et tolérables. Il a été rapporté que ces métabolites tels que les saponines réduisaient le nombre de protozoaires à court terme (12 à 14 jours) et favorisaient également une production modérée de méthane. L'acceptabilité d'Enterolobium cyclocarpum par les ruminants dépend des types de fourrages offerts et de l'expérience antérieure, tandis qu'une digestibilité faible à modérée a été signalée in vitro et in vivo. Selon les méthodes de transformation ou de conservation et les niveaux d'inclusion dans les régimes alimentaires, Enterolobium cyclocarpum n'a aucun effet délétère sur les performances de croissance et les caractéristiques de la carcasse des ruminants.*

Mots clés: plantes à brouter, Enterolobiumcyclocarpum, composition en nutriments, composés bioactifs et défaunation.

Introduction

Browse plants are less expensive but have high nutritive value. They are available all year round. They contain both primary and secondary metabolites (Galindo *et al.,* 2014). The primary metabolites are directly involved with growth and development while the secondary metabolites have beneficial and detrimental effects on the plants and on animals consuming those (Crozier *et al*., 2006). These less beneficial secondary metabolites are bioactive compounds/anti-nutritional factors (ANFs) which confer a mechanism of chemical defense against microorganisms, insects and grazing ruminants. Plant bioactive compounds include a variety of plant secondary metabolites such as saponins, tannins, mimosine, coumarin, oxalate, phytate and hydrocyanic acid (HCN) (Galindo *et al*., 2014).These compounds have the advantage of being "natural" compounds, which may or may not be readily accepted by livestock. Some of these ANFs affect the activities of microbes in the rumen, increasing bacterial proteins and overall nutrients flow and digestibility to the duodenum for subsequent absorption by the ruminant (Koenig *et al.,* 2007; Isah *et al.,* 2011; Idowu *et al.,* 2013). Some of these ANFs have defaunation qualities while some have bactericidal or bacteriostatic properties (Galindo *et al.,* 2014;Isah *et al.,* 2011). These plant bioactive compounds possess antimicrobial activity which can be used as alternative additives to reduce methanogen population in the rumen (Kamra *et al.,* 2012). Herbal extracted products have a prominent effect on rumen microbiota either directly changing the methanogens or indirectly affecting protozoa (Karri *et al.,* 2015).

Enterolobium cyclocarpum (EC)**, commonly known as **guanacaste**, **carocaro**, or **elephant-ear tree**, is a species of flowering tree in the pea family, Fabaceae, that is native to tropical regions of America, from central Mexico south to northern Brazil (Roraima) and Venezuela.* 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). *Enterolobium cyclocarpum* is easy to establish and it is a fast and luxuriantly growing tree (Babayemi, 2006). The aim of this paper therefore was to review the chemical composition, anti-nutritional factors and nutritive potentials of ***Enterolobium cyclocarpum leaves.

Common names

Enterolobium cyclocarpum is known by the following local names: Mexican walnut, enterolobium, elephant ear tree, carocaro, ear fruit, ear pod tree (due to the semicircular shape of the seed pods which resembles human or monkey ear), guanacaste, pitchwood, monkey soap, Devil's ear and mulatto ear in English (Orwa*et al.*, 2009; Sheffield's, 2017; Wikipedia, 2018). The generic name *enterolobium* comes from two Greek words: *entero*, meaning "intestines' and *lobium*, meaning "lobe." Thus enterolobium refers to all species in this genus that have seedpods resembling curled intestines. The specific name *cyclocarpum* is also derived from two Greek words: *cyclo,* which means "circle," and *carpus*, which means "fruit." The species name for this tree is also in reference to the curled seedpods produced by this species (Andreu *et al.*, 2015). The synonyms of *Enterolobium cyclocarpum* are *Albizia longipes* Britton &Killip, *Enterolobium cyclocarpa* (Jacq.) Griseb.,*Feuilleea cyclocarpa* (Jacq.) Kuntze, *Inga cyclocarpa* (Jacq.)Willd.,*Mimosa cyclocarpa* Jacq., *Mimosa parota* Sessé & Moc., *Pithecellobium cyclocarpum* (Jacq.) Mart., *Prosopis dubia*Kunth (Feedipedia, 2017).

Chemical composition

Babayemi (2006) assessed the anti-nutritional factors, nutritive value and *in vitro* gas production of leaf, seed, pod and whole fruit of *Enterolobium cyclocarpum*. The DM contents reported for the leaf, seed, pod and whole fruit of *Enterolobium cyclocarpum* were 39.08, 87.34, 83.23 and 82.39% respectively. He reported a crude protein of 18.60, 21.70, 10.40 and 15.70% for leaf, seed, pod and whole fruit respectively. He also reported crude fibre values of 48.20, 63.50, 39.80 and 46.1% for leaf, seed, pod and whole fruit respectively. The ether extract values reported by Babayemi (2006) for the leaf, seed, pod and whole fruit of *Enterolobium cyclocarpum* were 11.00, 10.00, 11.20 and 10.70 respectively. Ash values reported by the same author were 4.90, 4.20, 4.60 and 4.90 for leaf, seed, pod and whole fruit respectively. Koenig *et al.* (2007) reported DM, OM, CP, NDF and ADF of 932, 918, 231, 589 and 486 g/kg DM respectively for dried *Enterolobium cyclocarpum* leaves. **Isah *et al.* (20**11) reported the following proximate composition for fresh *Enterolobium cyclocarpum* leaves: DM, CP, CF, EE, ash and NFE of 32.15, 17.07, 8.16, 2.21, 7.85 and 64.71 % respectively.

The leaf, seed, pod and whole fruit of

Enterolobium cyclocarpum are generally high in the macro minerals (calcium, phosphorus, magnesium and potassium), except sodium which was low (0.05% in seed to 0.13% in leaf). Calcium contents in *Enterolobium cyclocarpum* as reported by Babayemi (2006) ranged between 0.65% in seed and 0.95% in leaf. Phosphorus content ranged from 0.28% in seed to 0.54% in pod, magnesium content ranged from 0.31% in whole fruit to 0.39% in pod, while potassium content ranged from 0.88% in whole fruit to 1.68% in leaf. The calcium, phosphorus, magnesium and potassium contents were within the range needed for adequate physiological growth, reproduction and milk production of West African dwarf sheep and goats. The calcium: phosphorus ratio is also within the recommended 2:1 or 1:1 level. However, lower contents of the micro minerals zinc (41.37 ppm in whole fruit and 57.13 ppm in leaf), manganese (71.13 ppm in pod and 113.17 ppm in leaf) and copper (10.09 ppm in seed and 19.15 ppm in leaf) were reported in literature (Babayemi, 2006). The iron contents (203.15 ppm in seed and 219.7 ppm in pod) of *Enterolobium cyclocarpum* reported by Babayemi (2006) is within the range needed for normal physiological function (growth, reproduction and milk production) of small ruminants.

Aderinboye *et al.* (2016) reported the following chemical composition for *Enterolobium cyclocarpum* leaves: DM of 344 g/kg as fed basis, CP of 182 g/kg DM, NDF of 514 g/kg DM, ADF of 319 g/kg DM and ADL of 86 g/kg DM. The chemical composition (%) of 3 days sundried *Enterolobium cyclocarpum* leaves as reported by Galindo *et al.* (2014) were CP 15.59, NDF 63.94, ADF 42.99, ash 11.80, Ca, 0.97 and P 0.20.

Ekanem *et al*. (2020a) assessed the effect of preservation methods on the chemical composition of *Enterolobium* cyclocarpum leaves. They reported the following range of chemical composition values for fresh, ensiled, dried and silage: hay combinations (%): DM (34.93 – 93.35), CP (14.70 – 22.05), CF (3.10 – 5.12), EE (3.18 – 4.71), ash (4.40 – 7.91), NFE (65.74 – 70.04), NDF (56.64 – 57.92), ADF (37.14–39.87), ADL (13.30 – 14.96), hemicellulose (18.05 – 19.50), cellulose (23.85 – 25.33), calcium (0.22 – 0.26), phosphorus (0.31 – 0.34), potassium (0.59 – 0.65), magnesium (0.24 – 0.29) and sodium (0.13 – 0.19). The vitamin contents (mg/100g) they reported were: vitamin A (1.02 – 2.39), vitamin C (308.79 – 657.60), vitamin D (53.96 – 58.85) and vitamin E (11.28 – 22.18). They concluded that preservation improved chemical composition.

Anti-nutritional and toxicological properties

Torres *et al.* (2012) surveyed plants considered to be poisonous to cattle in eastern Colombia. They reported that nineteen plants were reported to be toxic by more than two respondents, *with Enterolobium cyclocarpum* in the family Fabaceae being the highest identified poisonous plants, recording a frequency of toxicity of 29.I %. They further reported that it is the fruit of *Enterolobium cyclocarpum* that is most toxic, causing photosensitization. Photosensitization is an abnormal reaction of the skin to sunlight due to the presence of a photodynamic agent in the dermis. Photosensitization is divided into two categories – primary and secondary (hepatogenous) photosensitization. Primary photosensitization occurs due to the ingestion of lush green plants (e.g. St. John's Wort or clover – *Hypericum perforatum*, *Amni majus* – Bishop's weed, *Cymoteris watsonni* – Spring parsley, *Fagopyrum esculentum* - Buckwheat) containing photodynamic agents. Secondary photosensitization occurs due to liver or bile duct damage, most often as a result of ingestion of hepatotoxic plants (e.g. *Senecio jacobea, Lantana camara, Lapinus angustifolius*, *Agave lechiguilla* – Agave, *Brassica species* – Rape, *Trifolium hybridum* – Alsike clover) and blue-green algae. In secondary photosensitization, the normal conjugation and excretion of phylloerythrin which is a breakdown product of chlorophyll is prevented. The phylloerythrin will thus accumulates in the blood and body tissues such as the skin, leading to the absorption and release of ultra-violet light, with its accompanied phototoxic reaction, resulting in sunburn-like lesions on hairless regions of the skin (WikiVet, 2012; Penn Veterinary Medicine, 2018). Other symptoms of intoxication as a result of consuming poisonous plants as reported by Torres *et al.* (2012) are sudden death, bone fractures, prostration, bloating, nervous signs and muscular weakness. Babayemi (2006) reported moderate saponin contents of 6.00 mm in the leaf of *Enterolobium cyclocarpum*, compared to the seed, pod and whole fruit with values of 1.00, 2.50 and 1.5 mm respectively. He reported that no hydrolysable or condensed tannin was found in the leaf, seed and whole fruit. Proll *et al.* (1998) reported that the seeds of *Enterolobium cyclocarpum* also contain high amounts of trypsin inhibitors and alkaloids. Isah *et al.* (2011) reported these values (%) of anti-nutritional factors in fresh *Enterolobium cyclocarpum* leaves: 0.076 tannin, 0.305 saponin, 0.679 oxalate, 0.496 phytate and 0.021 hydrocyanic acid (HCN). In an experiment to evaluate the effect of 12 tropical plants (*Samanea saman, Albizia lebbeck, Azadirachta indica, Tithonia diversifolia* pm 23, *Cordia alba, Leucaena leucocephala, Pithecelo biumdulce, Moringa oleifera, Gliricidia sepium, Guazuma ulmifolia, Tithonia diversifolia* pm 10 and *Enterolobium cyclocarpum)* foliage on the control of methane production and *in vitro* ruminal protozoa population, Galindo *et al.* (2014) screened for the qualitative test of phytochemical metabolites in them. They reported significant presence (+++) of tannins in *A. indica*, *L. leucocephala* and *Enterolobium cyclocarpum* and moderate amounts (++) of this metabolite in *S. saman*, *G.ulmifolia*, *M. oleifera*, as well as in *Tithonia diversifolia* pm 23 and *Tithonia diversifolia* pm 10. Moderate amounts (++) of saponin were reported in *A. lebbeck*, *L. leucocephala*, *G. sepium*, *T. diversifolia* pm.10 and *Enterolobium cyclocarpum*. Low presence (+) of saponin were detected in other browse foliage assessed (Galindo *et al.*, 2014). Babayemi (2006) also reported medium presence of saponin in *Enterolobium cyclocarpum*.

Ekanem *et al*. (2020a) assessed the effect of preservation methods on the chemical composition of *Enterolobium cyclocarpum* leaves and reported the following range of values (mg/100g) for anti-nutritional factors in fresh and preserved leaves: tannins (74.41 – 158.11), saponins (3.18 – 4.49), oxalate (234.10 – 450.21), phytate (2.51 – 89.90) and hydro cyanic acids (4.50 – 19.96). Anti-nutritional factors were significantly reduced in preserved leaves.

In vitro* gas production potentials of *Enterolobium cyclocarpum

The contents of the net gas volume (ml), metabolizable energy (MJ/kg DM), organic matter digestibility (%) and short chain fatty acids (µmol) in *Enterolobium cyclocarpum* as reported by Babayemi (2006) ranged from 31.35 - 73.0, 7.66 - 13.55, 51.42 - 89.82 and 0.69 - 1.68 respectively. These parameters were highest in the seed and lowest in the leaf. Koenig *et al.* (2007) also reported a reduced ruminal organic matter digestibility, total tract organic matter, N and fibre digestion when the leaves of *E. cyclocarpum* was fed to sheep. The sheep (wethers) were maintained either fauna free (FF), inoculated with total mixed fauna (TF) or *Entodiniumcaudatum* as a single-species monofauna (EN). The reduced organic matter digestibility was pronounced in the TF and EN inoculated wethers.

Aderinboye *et al.* (2016) evaluated the *in vitro* gas production and dry matter degradation of four browse plants using cattle, sheep and goats inocula. The four browse species used were *Moringa oleifera*, *Millettia griffoniana*, *Enterolobium cyclocarpum* and *Gmelina arborea*. Irrespective of source of inocula, total gas production and *in vitro* dry matter digestibility was highest for *Moringa oleifera*, followed by *Enterolobium cyclocarpum*, *Gmelina arborea* and *Millettia griffoniana*. They reported that higher gas volume among browse species corresponded to a higher CP, higher contents of fermentable nutrients, lower cell wall contents and concentrations of anti-nutritional factors (Njidda and Nasiru, 2010).

Defaunating/anti-protozoal and methane reduction potentials of ruminants fed Enterolobium cyclocarpum

Enterolobium cyclocarpum has medium concentration of the anti-nutritional factor saponin (Babayemi, 2006). One of the mechanisms of action of saponin is their antiprotozoal activities. Koenig *et al.* (2007) assessed the effect of dietary *Enterolobium cyclocarpum* on microbial protein flow and nutrient digestibility in sheep maintained fauna-free (FF), with total mixed fauna (TF) or with *Entodinium caudatum* (EN) monofauna. They reported that in period 2 of the experiments when the wethers were fed *E. cyclocarpum*, protozoal numbers were reduced between 31 and 88% 2 h after feeding for the third to twelfth day of supplementation and by an average of 25 % in samples collected over the 24 h feeding cycle. They also reported that supplementation of the diet with *E. cyclocarpum* and the consequent protozoal reduction in TF and EN sheep improved the flow of non-ammonia N and bacterial N to the small intestine and the efficiency of microbial synthesis. Other authors have also reported a reduction in ruminal ciliate protozoa numbers in sheep fed *Enterolobium cyclocarpum*. However, they also reported that the anti-protozoal effect was short-lived, lasting for 12 – 14 days only and being most effective in animals that were not previously exposed to the anti-protozoal diets (Navas-Camacho *et al.*, 1993; Ivan *et al.*, 2004). CABI (2013) and Feedipedia (2017) reported that Elephant's ear leaf favour moderate methane production. Galindo *et al.* (2014) evaluated the effect of 12 tropical plants (*Samanea saman, Albizia lebbeck, Azadirachta indica, Tithonia diversifolia* pm 23, *Cordia alba, Leucaena leucocephala, Pithecelo biumdulce, Moringa oleifera, Gliricidia sepium, Guazuma ulmifolia, Tithonia diversifolia* pm 10 and *Enterolobium cyclocarpum)* foliage on the control of methane production and *in vitro* ruminal protozoa population. They reported that browse plants that were capable of reducing methane production (4.30 – 16.38 µL. g/DM) in the rumen in a large amount were *T. diversifolia* pm 23, *A. indica*, *L. leucocephala*, *A. lebbeck*, *S. saman*, *P. dulce* and *C. alba. Browse plants that were reported to have moderate (20.03 – 47.15*µL. g/DM) *methane reduction potentials were G. sepium*, *M. oleifera*; *G. ulmifolia* and *T. diversifolia* pm 10. However, compared to the control grass (*Cynodon nlemfuensis 65.15* µL. g/DM*), the methane reduction potential of Enterolobium cyclocarpum* (64.71 µL. g/DM) was similar to the control, though with different characteristics. They said that the explanation of this aspect was not properly clarified and as such further studies are required. This is worthy of note because all browse plants in that study including *Enterolobium cyclocarpum* reduced protozoa population (Galindo *et al.,* 2014).

Effect of feeding Enterolobium cyclocarpum on acceptability, digestibility and rumen bacteria

In a preference study conducted by Ekanem *et al.* (2020b), WAD bucks accepted the fresh *Enterolobium cyclocarpum* leaves most because of their previous experience in consuming fresh forages. They also observed that the WAD bucks preferred the ensiled forages to hay probably due to reduced contents of anti-nutritional factors. Mota *et al.* (2005) reported that EC have low *in vitro* rumen degradability and posited that they were potential source of rumen undegradable protein. They also reported moderate digestibility of intestinal N, possibly due to the presence of saponins in the leaves. *Arigbede et al. (2012) reported in vitro* OM and CP degradability of above 60%. In a digestibility study by Idowu *et al.* (2013) to evaluate the performance of WAD rams to graded levels (0, 10, 20, and 30%) of toasted *Enterolobium cyclocarpum* seed meal concentrate diets, they reported that rams fed concentrate diet with 10 % toasted *Enterolobium cyclocarpum* seed meal recorded the highest nutrient retention values of DM (83.91 g/d), CF (78.26 g/d), EE (93.90 g/d), CP (88.10 g/d), ash (87.45 g/d) and N balance (87.76 g/d). Isah *et al.* (2011) fed tropical browse species and crop by-products to West African dwarf goats for 84 days to determine the effect of anti-nutritional factors present in these feedstuffs on the rumen bacteria and performance of the WAD goats. The feeding stuffs they used were cassava peels, palm kernel cake, maize offal, *Gmelina arborea*, *Enterolobium cyclocarpum* and *Albizia saman*. They reported an increase in rumen bacteria count for WAD goats fed maize offal from $13x10^6$cfu/ml to $17x10^6$cfu/ml. All other experimental ingredients reduced rumen bacterial count after feeding. For goats fed cassava peels, the rumen bacteria count before feeding was $7x10^6$cfu/ml; this reduced to $5x10^6$cfu/ml. Rumen bacterial counts of goats fed palm kernel cake reduced from $12x10^6$cfu/ml to $5x10^6$cfu/ml, while rumen bacteria counts of WAD goats fed *Gmelina arborea* reduced from $11x10^6$cfu/ml to $10x10^6$cfu/ml. Similarly, rumen bacteria counts of goats fed *Enterolobium cyclocarpum* reduced from $6x10^6$cfu/ml to $4x10^6$cfu/ml and those of goats fed *Albizia saman* reduced from $13x10^6$cfu/ml to $6x10^6$cfu/ml.

Effect of feeding Enterolobium cyclocarpum on growth performance and carcass characteristics of ruminant animals

Isah *et al.* (2011) fed a basal diet of *Panicum maximum* to WAD goats for 84 days. They supplemented the basal diet with 500g each of either crop by-products (cassava peels, palm kernel cake, maize offal) or browse plants (*Gmelina arborea*, *Enterolobium cyclocarpum*, *Albizia saman*) to assess the effects of anti-nutrients in these feed stuffs on animal performance. Goats supplemented with *Enterolobium cyclocarpum* recorded the highest feed intake for both the supplemental feed (109.43 g/d) and in total dry matter intake (274.29 g/d). The least intake of supplemental feed (88.86 g/d) and for total dry matter intake (195.72 g/d) was by goats fed the maize offal as supplements. While the lowest average daily weight gain (24.29 g/d) was recorded by goats supplemented with palm kernel cake, however, WAD goats supplemented with *Enterolobium cyclocarpum* recorded the highest average daily weight gain of 39.05 g/d. Thus, the feeding of browse plants at 500 g/d had no deleterious effect on animal performance.

Idowu*et al.* (2013) fed graded levels (0, 10, 20, and 30%) of toasted *Enterolobium cyclocarpum* seeds to WAD rams to assess their growth performance and nutrient digestion. Rams fed diet 2 (10% toasted *Enterolobium cyclocarpum* seed meal diet) had the highest daily weight gain of 58.93 g/d compared to diet 1 (57.72 g/d), diet 3 (56.55 g/d) and diet 4 (47.62 g/d). Similarly, diet 2 (10% inclusion level) recorded the least and best feed conversion ratio (FCR) of 8.61 g/d compared to diets 1, 3 and 4 with FCR of 10.65, 10.53 and 12.07 g/d respectively.

Conclusion

Enterolobium cyclocarpum leaves, pods, seeds and fruits are rich in nutrients (proximate composition, fibre fractions, vitamins and minerals) in both the fresh and preserved forms and most in quantities within range for normal physiological functions of farm animals. Secondary bioactive substances present in *Enterolobium cyclocarpum*are reduced during processing/preservation to beneficial levels readily acceptable and digestible by ruminant animals. Feeding of *Enterolobium cyclocarpum* favoured defaunation, reduce methane production and have no deleterious effect on growth and carcass characteristics.

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