In-vitro assessment of the nutritive value of vegetable wastes as feed supplement for ruminants

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Abstract

The need to optimize livestock production to meet the growing demand for animal products has necessitated the efficient use of available resources, including crop wastes to enhance livestock productivity. Fifteen vegetable waste samples were analyzed to determine their nutritive value as ruminant feed. The chemical composition was determined using standard methods, and a 24-hour in-vitro fermentation was done to determine the dry matter degradability (DMD), short chain fatty acid (SCFA), and enteric methane (CH_4) emission of each sample. Talinum triangulare leaf had the highest ($p<0.05$) crude protein value (31.50%) and Cucumis sativa had the lowest value (11.51%). A significant difference ($p<0.05$) was observed among the values of the proximate composition of the samples. Cucumis sativa had the highest CH_4 percentage (36.75%) while the lowest CH_4 percentage (10.00%) was observed in Cochorus olitorius stem. There was no significant difference ($p<0.05$) observed among the DMD values of the samples. The value of SCFA was highest for Daucus carota (0.33) and lowest for Talinum triangulare stem (0.07). The results of the proximate composition, CH_4 percentage, and dry matter degradability of the samples observed in this study revealed that they could be further investigated through in-vivo trials to establish their suitability as alternative feedstuffs in ruminant diets.

Keywords: Ruminants; Methane; Vegetable wastes; *In-vitro*.

Evaluation in-vitro de la valeur nutritive des déchets végétaux comme complément alimentaire pour les ruminants.

Résumé

La nécessité d'optimiser la production animale pour répondre à la demande croissante de produits animaux a nécessité l'utilisation efficace des ressources disponibles, y compris les déchets de récolte pour améliorer la productivité de l'élevage. Quinze échantillons de déchets végétaux ont été analysés pour déterminer leur valeur nutritive en tant qu'aliments pour ruminants. La composition chimique a été déterminée à l'aide de méthodes standard et une fermentation in vitro de 24 heures a été effectuée pour déterminer la dégradabilité de la matière sèche (DMS), les émissions d'acides gras à chaîne courte (AGCC) et de méthane entérique (CH_4) de chaque échantillon. La feuille de Talinum triangulare avait la valeur de protéines brutes la plus élevée ($p < 0,05$) (31,50 %) et Cucumis sativa avait la valeur la plus faible (11,51 %). Une différence significative ($p<0,05$) a été observée entre les valeurs de la composition approximative des échantillons. Cucumis sativa avait le pourcentage de CH_4 le plus élevé (36,75%) tandis que le pourcentage de CH_4 le plus bas (10,00%) a été observé dans la tige de Cochorus olitorius. Aucune différence significative ($p < 0,05$) n'a été observée entre les valeurs DMS des échantillons. La valeur de AGCC était la plus élevée pour Daucus carota (0,33) et la plus faible pour la tige de Talinum triangulare (0,07). Les résultats de la composition approximative, du pourcentage de CH_4 et de la dégradabilité de la matière sèche des échantillons observés dans cette étude ont révélé *qu'ils pourraient être étudiés plus avant par des essais in vivo pour établir leur pertinence comme aliments alternatifs dans l'alimentation des ruminants.*

Mots-clés : Ruminants ; Méthane; Déchets végétaux; In vitro.

Introduction

The demand for animal products has increased significantly within the last decade and there is an expectation for it to rise further with the growing human population. With the recurring crisis of animal feed shortage, climate change and biodiversity loss in sub-Saharan Africa, there is a need to explore alternative feed sources to meet the nutritional needs of livestock. The demand for meat and milk for human consumption is ever-increasing in developing countries where feed deficits are prominent, creating a wide gap. There is need to continuously investigate alternative feed resources for animals, especially ruminants, to fill this gap (Wadhwa and Bakshi, 2013) reduce the competition between animal feed and human food ingredients (Ndamitso *et al*., 2010) improve animal performance (Lamidi and Ologbose, 2014) and enhance food security. The availability of ruminants feed all year round is a major production constraint in sub-Saharan Africa. Therefore, non-conventional feed resources such as vegetable wastes could be explored for supplementing ruminant diets.

Vegetable wastes include whole or parts of vegetables that are 'leftovers' from human consumption, damages from transportation stress, wastes generated from packing, distribution, and sales, and those discarded for not having visual appeal by human consumers. According to Bakshi *et al*. (2016), the production of fresh vegetables increased by 40 million tons between 2003-2013, and the anticipation that this figure will continue to increase in the future, guarantees the availability of vegetable wastes as potential sources of animal feed.

Studies have shown the possibility of using food wastes, crop residues, agro-industrial by-products, and other non-conventional feed resources as alternative sources of ruminant feed during off-season periods to augment the nutrients obtained from grazing in different locations, and this study aims to assess the nutritive value of vegetable wastes from two major vegetable market locations in Ibadan, Oyo State, as viable sources of ruminants feed, while also determining their impact on the environment through their methane emission capabilities.

Materials and Methods

The analyses were carried out in the Department of Animal Science laboratory, University of Ibadan, Oyo State.

Sample collection and preparation:

A total of fifteen vegetable waste samples were used for this study. They were collected from two major markets in Ibadan, Oyo State, during the wet season, in the month of May. The samples collected were *Amaranthus spinosus* (leaf), *Talinum triangulare* (leaf), *Telferia occidentalis* (leaf), *Cochorus olitorius* (leaf), *Brassica oleracea, Latuca sativa, Pisum sativum, Allium fistulosum, Daucus carota, Capsicum annuum* and *Cucumis sativa*. In addition, the stems of *Amaranthus spinosus*, *Talinum triangulare*, *Telferia occidentalis*, and *Cochorus olitorius* were collected and analyzed. The sample locations were chosen based on the availability of vegetable wastes during the period of this study. Samples were dried, milled, and kept in air-tight containers before investigations were carried out. All analyses were done in replicates.

Table 1. Vegetables collected from markets in Ibadan

Scientific Name	Common Name
Telferia occidentalis	Pumpkin
Brassica oleracea	Cabbage
Talinum triangulare	Water leaf
Allium fistulosum	Spring onions

Cochorus olitorius	Jute mallow
Daucus carota	Carrot
Amaranthus spinosus	Spiny amaranth
Latuca sativa	Lettuce
Pisum sativum	Green peas
Capsicum annuum	Green pepper
Cucumis sativa	Cucumber

Proximate analysis:

The moisture content, crude protein, crude fibre, ash, and ether extract content of the samples were determined using the AOAC (1995) procedure, and the crude protein was calculated as the nitrogen content multiplied by 6.25 (CP= N x 6.25).

***In-vitro* fermentation procedure:**

A sensitive weighing balance was used to weigh 0.100g (100mg) of each sample into small incubation bags which were properly sealed to prevent leakage. The bags were placed in plastic syringes. Each bag and syringe was properly labeled. Rumen liquor was collected from goats kept in confinement, fed Guinea grass (*Panicum maximum*) and water *ad-libitum*. The liquor was collected using the method described by Babayemi and Bamikole (2006). The rumen liquor was then filtered and maintained under anaerobic conditions by continuous flushing with CO_2. The buffer solution was prepared using the following reagents: $Na_2HPO_4.12H_2O$, KH_2PO_4, $MgCl_2.6H_2O$, NH_4HCO_3, $NaHCO_3$, and NaOH. The buffer solution was mixed with the rumen liquor. 15ml of the inoculum was then introduced into each of the syringes containing the small bags. Silicon tubes were placed on each syringe, and the tubes were clipped. The syringes were placed inside an incubator and were incubated at a temperature of 39˚C. The incubation period was as reported by Menke and Steingass (1988). Blanks containing only the inoculum were incubated and used as control. Gas production rates were recorded at 3, 6, 9, 12, 15, 18, 21 and 24 hours of incubation (i.e., at 3hrs interval). At the end of 24hrs, the last reading was taken, and the fermentation process was terminated. Methane (CH_4) production was determined by manually injecting 2ml of 1M NaOH into the incubated syringes through the silicon tube using a 5ml syringe. The incubated syringes were then agitated properly after the injection of NaOH to absorb the CO_2 within each syringe and CH_4 readings were then taken and recorded. The incubation bags were then oven-dried to constant weight to determine the dry matter degradability.

Statistical analysis:

Data collected were analyzed using ANOVA in a completely randomized design, following the procedure of SAS (2004). Separation of means was done using Duncan New Multiple Range Test for multiple means and least significant difference (LSD) for pair mean comparison in the same SAS (2004) software.

Results and Discussion

Proximate composition:

The proximate composition of the vegetable waste samples is presented in Table 2. The dry matter content was highest ($p<0.05$) in *Cochorus olitorius* stem (48.22%) while the lowest value was observed in *Cucumis sativa* (16.22%). *Capsicum annuum* had the highest ($p<0.05$) crude fibre value (29.60%) and *Talinum triangulare* leaf had the lowest value (10.73%). A significant difference was observed among the values of the crude protein, ash and organic matter content of the vegetable waste samples.

The results of the dry matter content of the vegetable waste samples reported in Table 2 were within the range reported by Garcia *et al*. (2005) and Esteban *et al*. (2007) who stated that biodegradable wastes have high moisture, and low dry matter content of 20-40%. The values of dry matter obtained in this study were 16.22-48.22%. The dry matter content of *Talinum triangulare* leaf (19.55%) and *Talinum triangulare* stem (20.11%) were similar to the value (20.85%) reported by Olomu (2011) for both samples. The high moisture content of the vegetable wastes can be attributed to their succulent nature, and according to Bakshi *et al*. (2016) this is a major constraint in using these products as livestock feed. This constraint arises from the problems associated with transportation and storage of these products.

The crude protein values presented in Table 2 range from 11.51-31.50%, with most of the samples having high values between 20-31%, which agreed with the report of Bakshi *et al*. (2016) who stated that vegetable wastes and by-products are good sources of both crude protein and energy, especially for ruminant animals. All the samples yielded crude protein values higher than the 7 % CP recommended as being minimum requirement for ruminants in the tropics (Minson, 1982). The crude protein value of *Latuca sativa* (24.06%) was similar to the value (28.2%) reported by Tobias *et al*. (2010). *Brassica oleracea* and *Telferia occidentalis* stem had crude protein values of 28.14% and 23.63% respectively, which corresponds to the value (29.57%) reported by Olomu (2011) for *Brassica oleracea* and 21.50% for *Telferia occidentalis* stem.

The ash content of the samples represents the inorganic mineral elements in the forms of oxide, chloride, or sulphate. The values obtained in this study ranged from 9.74-33.02% which were relatively high, and this can be attributed to the presence of sand in the samples at the time of collection. The ash content of *Daucus carota* (9.74%) obtained in this study was in line with the values (10.73% and 8.2%) reported by Ishraga *et al*. (2016) and Bakshi *et al*. (2016) respectively. The ash contents of *Telferia occidentalis* leaf (13.95%) and *Telferia occidentalis* stem (17.42%) obtained in this study, correspond with the value 14.10% reported by Olomu (2011) for both samples. Also, the ash content of *Cochorus olitorius* leaf (18.73%) and *Cochorus olitorius* stem (11.71%) agreed with the value 14.70% reported for both samples by Olomu (2011). The ash content of *Cucumis sativa* (13.16%) obtained in this study was similar with the value (11.3%) reported by Bakshi *et al*. (2016). The ash value of *Brassica oleracea* (16.18%) was in accordance with values 15.8% and 13.9% reported by Bakshi *et al*. (2016) and Olomu (2011) respectively. The organic matter contents of these samples also correspond with the given literature for the ash values because the organic matter content is the reverse of the ash content.

The ether extract content, also known as crude fat, comprises of all substances that are soluble in ether. Although ether extract contains lipids which provide energy, it will also include other fat-soluble substances such as chlorophyll and fat-soluble vitamins (Ishraga *et al*., 2016). The ether extract content of *Brassica oleracea* (9.47%) obtained in this study was slightly higher than the values (5.10% and 6.97%) reported by Tobias *et al*. (2010) and Olomu (2011) respectively. *Cochorus olitorius* leaf and *Cochorus olitorius* stem gave ether extract values of 10.57% and 12.43% respectively, thus slightly higher than the values (6.61%) reported by Olomu (2011).

Crude fibre is the chemical component of the feed that determines its rate of digestion. It consists of the soluble fibres (pectins, gums and mucilages) and insoluble fibres (cellulose, hemicellulose, and lignin) present in the samples, and it is negatively correlated with dry matter intake (Schroeder, n.d.). As the crude fibre in plants increases, animals will consume less. Crude fibre increases with the advancing maturity of forages, and it is inversely related to plant's digestibility (McDonald *et al*., 1995, Gillespie, 1998). The crude fibre values obtained in this study were relatively high, ranging from 10.73%-29.60%. This is beneficial to the animals because with fibre, there is a feeling of fullness. Also, since the insoluble fibres absorb water, they help in the elimination of intestinal wastes and thus help to correct constipation. The soluble fibres on the other hand bind bile acids and cholesterol, and help to carry these out of the body, thus reducing their blood levels (Olomu, 2011). The crude fibre value of *Daucus carota* obtained in this study was similar to the value (15.4%) reported by Ishraga *et al*. (2016). The crude fibre values of *Talinum triangulare* leaf (10.73%) and *Telferia occidentalis* leaf (13.17%) obtained in this study were similar to the values 10.30% and 12.60% reported by Olomu (2011) for both samples respectively. Also, the crude fibre values of *Brassica oleracea* (15.97%) and *Cochorus olitorius* leaf (13.93%) were slightly higher than the values (10.43% and 8.82%) reported by Olomu (2011) respectively.

The nitrogen free extract content represents the highly digestible carbohydrates present in the samples. Thus, the values obtained in this study ranged from 13.45%-48.89%, which agreed with the report of Bakshi *et al*. (2016) who stated that vegetable wastes and by-products are good sources of both crude protein and energy, especially for ruminant animals. The nitrogen free extract value for *Daucus carota* (48.89%) obtained in this study was similar to the value (49.53%) reported by Ishraga *et al*. (2016). The values of *Cochorus olitorius* leaf (39.11%) and *Cochorus olitorius* stem (34.91%) were similar to the value (39.70%) reported by Olomu (2011) for both samples. *Brassica oleracea* yielded a value of 30.24% slightly lower than the value (39.15%) presented by Olomu (2011). There are many factors affecting the chemical composition of feed stuffs such as stage of growth, maturity, species or variety, drying method, environment, and soil type (Von Keyserligk *et al*. 1996, Agbagla-Dolmini *et al*., 2001, Promkot and Wanapat, 2004). These factors may partially explain differences in the chemical composition among the studied waste products.

Table 2: Proximate composition of the vegetable waste samples

Sample	MC	DM	CP	Ash	OM	EE	CF	NFE
Telferia occidentalis (leaf)	56.78^{f}	43.22^{a}	29.02^{ab}	13.95^{hi}	86.04^{abcd}	10.57^{cd}	13.17^{a}	17.96^{ab}
*Brassica olerace*a	72.89^{bcd}	27.11^{cde}	28.14^{abc}	16.18^{gh}	83.82^{bcd}	9.47^{cd}	15.97^{a}	30.24^{ab}
Telferia occidentalis (stem)	69.99^{d}	30.00^{c}	23.63^{bcde}	17.42^{g}	83.57^{bcd}	12.43^{bc}	22.13^{a}	24.38^{ab}
Talinum triangulare (stem)	79.89^{abc}	20.11^{def}	26.39^{abcd}	23.14^{de}	76.86^{ef}	8.57^{d}	25.90^{a}	16.01^{ab}
Allium fistulosum	57.63^{f}	42.55^{a}	21.87^{cdef}	28.16^{bc}	68.86^{g}	12.80^{abc}	22.27^{a}	14.90^{ab}
Cochorus olitorius (leaf)	66.78^{de}	33.22^{bc}	17.06^{fg}	18.73^{fg}	81.27^{cde}	11.17^{bcd}	13.93^{a}	39.11^{ab}
Daucus carota	70.78^{cd}	29.22^{cd}	16.77^{fg}	9.74^{j}	90.26^{a}	11.27^{bcd}	13.33^{a}	48.89^{a}
Cochorus olitorius (stem)	51.78^{f}	48.22^{a}	16.48^{fg}	11.71^{ij}	88.29^{ab}	11.77^{bcd}	25.13^{a}	34.91^{ab}
Amaranthus spinosus (leaf)	59.00^{ef}	40.99^{ab}	18.52^{ef}	23.70^{de}	76.30^{ef}	10.87^{cd}	14.3^{3a}	32.58^{ab}
Latuca sativa	75.11^{abcd}	24.89^{cdef}	24.06^{bcde}	33.02^{a}	66.97^{g}	12.27^{bc}	17.20^{a}	13.45^{b}
Pisum sativum	72.00^{bcd}	27.99^{cde}	28.72^{ab}	19.22^{fg}	80.78^{de}	9.73^{cd}	19.80^{a}	22.53^{ab}
Capsicum annuum	72.78^{bcd}	27.22^{cde}	20.12^{def}	21.34^{ef}	77.06^{ef}	10.63^{cd}	29.60^{a}	18.30^{ab}
Cucumis sativa	83.78^{a}	16.22^{f}	11.51^{g}	13.16^{hi}	86.84^{abc}	14.57^{ab}	19.47^{a}	41.29^{ab}
Amaranthus spinosus (stem)	74.73^{abcd}	25.27^{cdef}	21.58^{def}	28.65^{b}	71.34^{fg}	19.97^{abc}	18.60^{a}	18.20^{ab}
Talinum triangulare (leaf)	80.45^{ab}	19.55^{ef}	31.50^{a}	25.24^{cd}	74.76^{f}	15.80^{a}	10.73^{a}	16.73^{ab}
SEM	0.36	0.36	0.22	0.26	0.27	0.07	0.21	0.43

^{abcdefghij} = Means on the same column with the same letter are not significantly different ($p<0.05$).
MC= Moisture content, DM= Dry matter, CP= Crude protein, OM= Organic matter, EE= Ether extract, CF= Crude fibre, NFE= Nitrogen free extract, SEM= Standard error of the mean difference.

Gas volumes at different hours of incubation:
The total gas volumes at different hours of incubation during the *in-vitro* fermentation study is presented in Table 3. The highest gas volume ($p<0.05$) was observed in *Daucus carota,* followed by *Cucumis sativa,* each having 15.00mls and 13.67mls respectively of gas at 24 hours of incubation. The lowest gas volume on the other hand was observed in *Talinum triangulare* stem, followed by *Latuca sativa***,** each having a gas volume of 3.33mls and 4.33mls respectively at 24 hours of incubation. There were significant differences among the values of

the samples at 15, 18, 21, and 24 hours of incubation.

The vegetable waste samples used in this *in-vitro* fermentation study showed a slow rate of gas production, especially for the first four hours of fermentation. This shows a slow degradability of the samples, meaning that it involves less wastage. The samples produced low methane gas, as the highest methane percentage value (36.75%) obtained in this study was observed in *Cucumis sativa*, while most of the samples had values less than 30%. This can be attributed to the presence of saponin in the samples, as it has been established to reduce bacteria population in the rumen (Teferedegne, 2000), thereby reducing the amount of methane gas production (Babayemi *et al*., 2004). The production of methane as a byproduct of enteric fermentation in the rumen is a source of energy loss from ruminants' production system. Thus, reducing enteric methane production may also lead to production benefits.

There are many factors that determine the amount of gas produced during fermentation, depending on the nature and level of fibre, the presence of secondary metabolites (Babayemi *et al*., 2004) and potency of the rumen liquor for incubation. It is possible to attain potential gas production in a feedstuff if the donor i.e., animal that produced the rumen liquor used for incubation got the required nutrient (Babayemi, 2007). Generally, gas production is a function and mirror of degradable carbohydrates and therefore, the amount depends on the nature of the carbohydrate (Demeyer and Van Nevel, 1975, Blummel and Becker, 1997).

Table 3: Volume of gas production at different hours of incubation

Sample	3	6	9	12	15	18	21	24
Telferia occidentalis (leaf)	0.33^{b}	2.33^{bc}	3.67^{bcd}	5.33^{cd}	6.00^{cdef}	6.67^{cde}	7.00^{cdef}	8.00^{cdef}
Brassica oleracea	0.67^{b}	3.67^{b}	5.33^{b}	7.67^{bc}	10.33^{abc}	11.33^{abc}	12.00^{abc}	12.67^{abc}
Telferia occidentalis (stem)	0.00^{b}	0.67^{c}	1.67^{cd}	2.67^{de}	4.33^{efg}	5.33^{def}	5.67^{ef}	7.00^{def}
Talinum triangulare (stem)	0.00^{b}	0.67^{c}	0.67^{d}	0.67^{e}	0.67^{g}	1.00^{f}	1.00^{g}	3.33^{f}
Allium fistulosum	1.33^{b}	3.00^{bc}	5.00^{bc}	6.67^{cd}	9.00^{bcd}	11.33^{abc}	11.67^{abcd}	12.67^{abc}
Cochorus olitorius (leaf)	1.00^{b}	3.33^{b}	5.00^{bc}	7.00^{c}	8.00^{cde}	9.00^{bcd}	9.33^{bcde}	10.00^{bcd}
Daucus carota	4.00^{a}	8.00^{a}	10.67^{a}	12.67^{a}	14.00^{a}	14.67^{a}	14.67^{a}	15.00^{a}
Cochorus olitorius (stem)	0.67^{b}	1.33^{bc}	4.00^{bcd}	5.00^{cd}	6.00^{cdef}	6.67^{cde}	6.67^{def}	7.00^{def}
Amaranthus spinosus (leaf)	0.67^{b}	2.33^{bc}	3.33^{bcd}	4.67^{cd}	6.00^{cdef}	7.33^{cde}	7.33^{cdef}	8.33^{cde}
Latuca sativa	0.00^{b}	1.33^{bc}	1.67^{cd}	2.67^{de}	3.33^{fg}	3.67^{ef}	4.00^{fg}	4.33^{ef}
Pisum sativum	0.67^{b}	2.67^{bc}	4.33^{bc}	4.67^{cd}	7.67^{cdef}	8.33^{cde}	9.33^{bcde}	10.33^{abcd}
Capsicum annuum	1.00^{b}	2.67^{bc}	3.67^{bcd}	4.33^{cde}	5.00^{def}	6.00^{de}	6.33^{ef}	7.33^{def}
Cucumis sativa	3.67^{a}	6.33^{a}	8.67^{a}	11.00^{ab}	12.33^{ab}	13.33^{ab}	13.33^{ab}	13.67^{ab}
Amaranthus spinosus (stem)	0.00^{b}	2.00^{bc}	2.00^{bcd}	3.67^{cde}	5.33^{def}	6.33^{de}	7.00^{cdef}	7.33^{def}
Talinum triangulare (leaf)	0.33^{b}	1.67^{bc}	4.33^{bc}	5.67^{cd}	7.67^{cdef}	8.67^{cd}	9.00^{bcdef}	9.33^{bcd}
SEM	0.05	0.08	0.10	0.12	0.13	0.14	0.14	0.13

^{abcdefg} = Means on the same column with the same letter are not significantly different ($p<0.05$).

SEM= Standard error of the mean difference

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Post-fermentation parameters:

The post-fermentation parameters of the vegetable waste samples are presented in Table 4. There was no significant difference ($p<0.05$) in the CH_4 volume, CH_4 percentage, and dry matter degradability of the samples. Babayemi and Bamikole (2006) reported that methane production in the rumen has a negative correlation with utilization of feeds in ruminant livestock. There was significant difference among the short chain fatty acid values of the vegetable waste samples observed. The highest short chain fatty acids value ($p<0.05$) was observed in *Daucus carota* (0.33) while the lowest was recorded in *Talinum triangulare* stem (0.07). Low SCFA for *Talinum triangulare* stem

(0.07) was due to the lower gas production which was evident in the first 24 hours of incubation. High SCFA in *Daucus carota* (0.33) compared to *Talinum triangulare* stem (0.07) suggests a potential to make energy available to the ruminants. (Blummel and Orskov, 1994) suggested that gas production from different classes of feeds incubated *in-vitro* in buffered rumen fluid was closely related to the production of SCFA which was based on carbohydrate fermentation.

Table 4: Post *in-vitro* parameters for the vegetable waste samples used for the *in-vitro* study

Sample	CH_4(ml)	CH_4(%)	DMD	SCFA
Telferia occidentalis (leaf)	2.67^{a}	28.15^{a}	22.00^{a}	0.17^{cdef}
Brassica oleracea	2.67^{a}	20.51^{a}	27.67^{a}	0.28^{abc}
Telferia occidentalis (stem)	1.67^{a}	25.38^{a}	17.33^{a}	0.14^{def}
Talinum triangulare (stem)	1.00^{a}	30.56^{a}	28.33^{a}	0.07^{f}
Allium fistulosum	3.00^{a}	19.94^{a}	20.67^{a}	0.28^{abc}
Cochorus olitorius (leaf)	2.33^{a}	21.11^{a}	21.67^{a}	0.22^{bcd}
Daucus carota	2.67^{a}	16.61^{a}	28.33^{a}	0.33^{a}
Cochorus olitorius (stem)	1.00^{a}	10.00^{a}	19.33^{a}	0.15^{def}
Amaranthus spinosus (leaf)	2.00^{a}	26.67^{a}	19.67^{a}	0.18^{cde}
Latuca sativa	1.67^{a}	27.62^{a}	20.67^{a}	0.09^{ef}
Pisum sativum	2.00^{a}	18.18^{a}	22.33^{a}	0.22^{abcd}
Capsicum annuum	2.33^{a}	31.48^{a}	16.67^{a}	0.16^{def}
Cucumis sativa	5.00^{a}	36.75^{a}	33.00^{a}	0.29^{ab}
Amaranthus spinosus (stem)	2.33^{a}	26.67^{a}	19.67^{a}	0.16^{def}
Talinum triangulare (leaf)	2.00^{a}	19.09^{a}	24.67^{a}	0.20^{bcd}
SEM	0.03	0.26	0.18	0.00

^{abcdef} = Means on the same column with the same letter are not significantly different ($p<0.05$).
CH_4=Methane, DMD= Dry matter degradability, SCFA= Short-chain fatty acids, SEM= Standard error of the mean difference.

Conclusion

Vegetable wastes are potential sources of crude protein and other nutrients for livestock, most especially ruminants. Their inclusion in animal feed can economize the production of livestock, especially during periods of feed deficit as they can be obtained at no cost, and this could help to reduce the amount of biodegradable municipal waste going to landfills. It is recommended that *in-vivo* feeding trials should be conducted to determine the palatability of the samples used in this study and substantiate their suitability as feed supplements in livestock feed.

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