Research Note

Chemical composition and nutritive value of leaves and stems of tropical weed *Chromolaena odorata*

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Abstract

Chromolaena odorata (Siam weed) has been classified as a weed plant in West Africa. Data from *C. odorata* foliage after 4, 6, 8, 10 and 12 weeks of regrowth showed that the leaf fraction had a crude protein content above 194 g kg^{-1} dry matter (DM) and an average leaf to stem ratio of 2·1:1. Chemical analysis of the leaf fraction of an 8-week-old regrowth indicated a high crude protein content (258 g kg^{-1} DM) and a high degradable nitrogen content (60·7 g N kg^{-1} digestible organic matter), but low neutral-detergent fibre (331 g kg^{-1} DM), acid-detergent lignin (53·1 g kg^{-1} DM), total extractable phenolic (37·1 g kg^{-1} DM), extractable tannin (0·72 absorbance at 550 nm) and extractable condensed tannin (1·4 g kg^{-1} DM) contents. *In sacco* degradability analysis of the 8-week-old regrowth leaf sample showed a high 48 h organic matter (935 g kg^{-1} DM) and crude protein (953 g kg^{-1} DM) degradability. The leaf sample had an organic matter degradability of 670 g kg^{-1} DM as estimated by cumulative gas production *in vitro* after 24 h incubation. There was little or no phenolic-related antinutritive factors in *C. odorata*. Additionally, leaf samples had no effect on rumen protozoa activity estimated as the rate of [^{14}C]leucine *Selenomonas ruminantum* bacterial protein breakdown. Data from this study suggest that *C. odorata* leaves are of high nutritive value and might have the potential to be used as a protein supplement to ruminants. There is need for further investigation to test whether *C. odorata* leaves may have any deleterious effect on the host animal.

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Introduction

Siam weed (*Chromolaena odorata*), formerly known as *Eupatorium odoratum,* has been classified as a noxious weed. This is because it is difficult to control by either curative or preventive measures (Baxter, 1995) and has spread widely through most open cultivated fields of West Africa and other tropical areas. *C. odorata* is a perennial shrub which can grow to a height of up to 5 m. Its stems intermingle during growth and eventually sag to the ground, smothering other vegetation. It has simple pinnate leaves arranged oppositely on the branches of the plant. Previous study showed that *C. odorata* plant foliage has been used as a fallow crop or green manure to improve soil fertility because of its high biomass production (15 tonne DM ha^{-1}) (Oyen, 1995) after 2–4 years fallow and the high degradability of its foliage (Baxter, 1995). Preliminary findings (P. Mensa, personal communication) showed an accumulation rate of soil organic carbon of 29·2 g kg^{-1} $year^{-1}$ within 4 years of fallow under *C. odorata*.

Various studies have focused on measures to control *C. odorata* as a weed or its use as an organic fertilizer (Marutani and Muniappan, 1991; Biller *et al*., 1994; Roder *et al*., 1995). Such studies have also indicated the high biomass production and protein content of *C. odorata*. It is therefore important that further studies are carried out to assess its nutritive value and potential use as a ruminant feed supplement.

In its natural state, i.e. fresh green material, animals tend to refuse *C. odorata* forage when grazing it, which may be related to its strong smell. This work was undertaken to assess the chemical composition and degradability characteristics of the dried leaves of *C. odorata*.

Materials and methods

One hectare of pasture of the Teaching and Research Farm of University of Cape Coast, Ghana (latitude 5°15′N and longitude 1°23′W), which was infested with *Chromolaena odorata* plants, was cut to a height of 10 cm

in December 1995 and 250 *C. odorata* plants were tagged for the study. The regrowth of *C. odorata* foliage was cut at 4, 6, 8, 10 and 12 weeks of age and used to study the effect of cutting regime on nitrogen content of the foliage parts. Fifty plants were harvested at 15 cm above ground level at each growth stage. Leaves were separated by cutting them off from the stems and both fractions were bulked and oven-dried at 50°C for 48 h. Dried leaf and stem samples were milled to pass through a 1-mm sieve for chemical analysis. Based on the preliminary results, leaf samples from an 8-week-old *C. odorata* regrowth were harvested from fifty plants in September of the following year and used for further *in sacco* and *in vitro* degradability studies.

Chemical analysis

The dry-matter (DM), fat and ash contents of the original leaf and stem samples were determined according to AOAC (1984). Neutral-detergent fibre (NDF) and acid-detergent lignin (ADL) were analysed according to Goering and van Soest (1970). Total nitrogen (N) content of original leaf and stem samples, NDF residues and *in sacco* undegraded residues were analysed by an automated method (Davidson *et al.*, 1970). Crude protein (CP) content was then calculated by multiplying N content by a factor of 6·25. The total phenolic content in the leaf sample was extracted in 70% acetone solution (Mueller-Harvey and Dhanoa, 1991). Total extractable phenolic (TEPH) content of the supernatant was determined by the Folin Ciocalteau method (Julkunen-Titto, 1985), using tannic acid as a standard. Total extractable tannins (TETA) were analysed by the Watterson and Butler (1983) procedure and extractable condensed tannins (TCTA) by the vanillin-HCL assay, using catechin as a standard (Broadhurst and Jones, 1978). The amino acid profile of the 8-week-old leaf sample was determined according to Moore (1963), Lucas and Sotelo (1980) and Brown (1998).

The digestible organic matter (DOM) in leaf samples was estimated using the following equation (Menke and Steingass, 1988):

$$\mathrm{DOM} = 24{\cdot}59 + 0{\cdot}7984\mathrm{GP} + 0{\cdot}0496\mathrm{CP}$$

where GP is gas production (ml 200 mg^{-1} DM after 24 h) and CP is crude protein content (g kg^{-1} DM). Degradable nitrogen (dN) was estimated by *in sacco* technique after 48 h incubation. Data were then expressed as the dN/DOM (g kg^{-1} DOM) ratio.

In sacco dry matter and protein degradability analysis

The *in sacco* degradability analysis on the 8-week-old leaf samples was carried out according to Mehrez and Ørskov (1977). About 3 g of samples of the *C. odorata* leaf was transferred into nylon bags and incubated in triplicate in the rumens of three fistulated Finn Dorset × Suffolk wethers. The wethers were fed at maintenance level twice daily on a high-quality grass hay diet. The nylon bags were withdrawn after 8, 16, 24, 48, 72 and 96 h of incubation, thoroughly washed with cold water for 20 min and dried at 60°C for 48 h. Three nylon bags with leaf samples of *C. odorata* were soaked in water at 39°C for 1 h, washed and dried. The dried and washed residues for each incubation time were bulked and further ground through a 1-mm sieve for N determination. Data for the *in sacco* dry matter and protein degradability were fitted by the exponential equation by following: $P = a + b\,(1 - e^{ct})$ (Ørskov and McDonald, 1979), where a, b and c are constants, and P is the degradability at time t.

In vitro gas production

Rumen fluid was collected before feeding in the morning from the same three animals used for the *in sacco* technique. The rumen fluid was transferred to prewarmed flasks, strained through three layers of gauze and mixed with buffer/mineral solution (artificial saliva) in a 1:2 ratio according to Menke and Steingass (1988). *C. odorata* leaf samples (200 mg) harvested after 8 weeks of regrowth were incubated in triplicate in 30 ml rumen liquor/artificial saliva mixture in 100-ml glass syringes at 39°C. Gas production after 3, 6, 12, 24, 48, 72 and 96 h incubation was recorded and data fitted by the exponential equation as previously described.

Eight-week-old regrowth leaf samples were also incubated in the presence of an equivalent weight (200 mg) of polyethylene glycol 4000 (PEG-4000), as described by Makkar *et al.* (1995), to assess the effect of phenolic-related inhibitory compounds on gas production *in vitro*.

The effect of *C. odorata* leaves on the activity of rumen protozoa was estimated according to the procedure described by Wallace and McPherson (1987), in which the rate of ^{14}C-labelled leucine *Selenomonas ruminantum* bacterial protein degradation (%DPM h^{-1}) in strained rumen fluid with *C. odorata* was taken as an index of protozoan activity.

Results and discussion

The leaf to stem ratio and crude protein content of the leaves and stems of *C. odorata* are shown in Table 1. There was an average leaf to stem ratio of 2·1:1 on a weight basis (ranging from 1·5:1 to 2·9:1). The minimum value of 1·5:1 (60% leaves) was higher than the values of 40–50% reported for tropical leguminous forages (Becker, 1992). Highest crude protein content

Table 1 Leaf to stem ratio and crude protein content of *Chromolaena odorata* forage after regrowth periods of up to 12 weeks.

Regrowth period (weeks)	Leaf/stem ratio	Plant fraction	Crude protein (g kg^{-1} DM)
4	2·9:1	Leaf	213
		Stem	108
6	2·4:1	Leaf	203
		Stem	126
8	2·1:1	Leaf	234
		Stem	136
10	1·6:1	Leaf	205
		Stem	94
12	1·5:1	Leaf	209
		Stem	76

was obtained in 8-week-old regrowth and thereafter declined at a rate of 0·89 g kg^{-1} DM d^{-1} and 3·2 g kg^{-1} DM d^{-1} for leaf and stem respectively. The average ratio of crude protein in stems to that in leaves was 0·49. Becker (1992) observed, for most tropical leguminous forages, similar values for crude protein content in leaves (130–170 g kg^{-1} DM), rate of protein decline (0·86 g kg^{-1} DM d^{-1}) and ratio of protein in stems to that in leaves (0·49). The observed reduction in total nitrogen content of *C. odorata* stem with increasing age at cutting is related to, or a consequence of, the development of, or increase in, fibre content of the stems with age.

The chemical composition of the 8-week-old leaf sample of *C. odorata* is presented in Table 2. The high crude protein (258 g kg^{-1} DM), degradable nitrogen (60·7 g N kg^{-1} DOM) and low NDF contents of *C. odorata* leaf indicate similar characteristics to other forage protein supplements. Its protein fraction is highly degradable (Table 3) and therefore may be suitable as a protein supplement to low protein feeds, such as crop residues and low protein grasses. This is an important characteristic of *C. odorata*, which in turn could be the most economical and environmentally friendly way of controlling 'the weed'. In most West African and other tropical countries, where *C. odorata* has colonized open cultivated farmlands, lack of protein feeds limit the production from ruminant livestock. This is particularly important in dry seasons when crop residues form the main feed for the animals. The high protein, low NDF and low extractable phenolic (tannins and condensed tannins) contents are similar to those values reported for other leaves from West African browse plants fed to small ruminants (Rittner and Reed, 1992). From the amino acid profile (Table 2), about 565 g kg^{-1} of the total protein consists of amino acid.

Table 2 Chemical composition of leaf samples of *Chromolaena odorata* after an 8-week regrowth.

Component	Content (g kg^{-1} DM)
Dry matter (air-dried sample)	834
Crude protein	258
Ash	109
Fat	57·4
Neutral-detergent fibre	331
Acid-detergent lignin	53·1
Total extractable phenolics	37·1
Total extractable tannins (HCl-butanol method)	0·72*
Extractable condensed tannins (vanillin-HCl method)	1·40
Degradable nitrogen (g N kg^{-1} DOM)	60·7
Individual amino acid	(g kg^{-1} protein)
Aspartic acid	52·2
Threonine	30·5
Serine	29·1
Glutamic acid	68·2
Glycine	33·3
Alanine	37·4
Valine	36·2
Isoleucine	30·1
Leucine	50·4
Tyrosine	25·0
Phenylalanine	34·1
Lysine	31·4
Histidine	12·2
Arginine	34·2
Proline	35·3
Cysteine	11·4
Methionine	14·3

*Absorbance at 550 nm.

Table 3 Parameters of the exponential equation of Ørskov and McDonald (1979) for the *in vitro* gas production and for the *in sacco* dry matter and protein degradability of leaf samples from an 8-week regrowth of *Chromolaena odorata*.

	Degradability characteristics			
Assay	a	b	a + b	c
In vitro gas production		ml		% h^{-1}
C. odorata only	−3·61	42·3	38·7	5·35
C. odorata + PEG	−3·76	42·9	39·1	5·45
In sacco degradability of:		g kg^{-1} DM		% h^{-1}
Dry matter	376	535	911	22·7
Protein	289	658	947	24·1

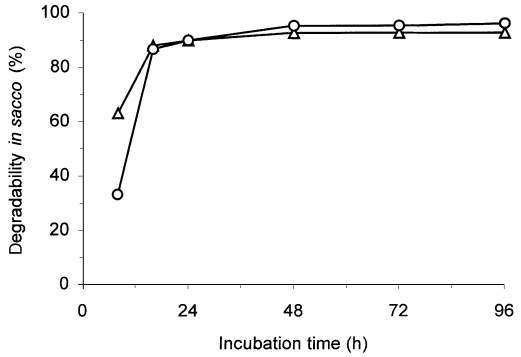

Figure 1 Dry-matter (triangles) and protein (circles) *in sacco* degradability of leaf samples from an 8-week regrowth of *Chromolaena odorata.*

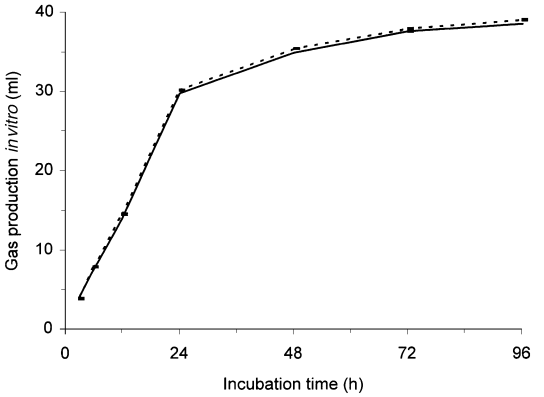

Figure 2 Gas production *in vitro* of leaf samples from an 8-week regrowth of *Chromolaena odorata* incubated with (dashed line) or without (solid line) polyethylene glycol 4000 (PEG-4000).

In sacco dry matter and protein degradability data are shown in Figure 1 and Table 3. The 24-h DM and protein degradabilities were high (above 900 g kg^{-1} DM). The *in sacco* technique overestimated the organic matter disappearance at 24 h incubation (≈81%) compared with the *in vitro* method (≈50%). The difference might have been due to the presence of significant amounts of soluble material that was not fermented (Dewhurst *et al.*, 1995). The 48-h values (Figure 1) were higher than values previously reported for other well-known West African browse leaves such as *Thespesia populnea*, *Ficus exasperata*, *Sesbania sesban*, *Cajanus cajan* and introduced *Gliricidia sepium* (Dwowela *et al.*, 1995), which are being routinely fed to ruminant livestock. Additionally, the high protein degradability data obtained from *C. odorata* indicates that its amino acid profile may not be relevant when used to feed ruminants, as most of the plant protein will be converted in the rumen into microbial protein. However, this is an important parameter for determining its nutritive value when monogastric feeding is considered.

The cumulative gas production data of *C. odorata* incubated with or without PEG-4000 are presented in Figure 2 and Table 3. Cumulative gas production was unaffected by the addition of PEG-4000 (from –2·5% to 5·4%). This suggests a very low level of PEG-4000-related inhibitory phenolics in *C. odorata* leaf sample.

The rate of ^{14}C-labelled leucine *Selenomonas ruminantum* bacterial protein breakdown (% h^{-1}) in strained rumen fluid with *C. odorata* extract assayed was 8·7% h^{-1} (s.e. 0·9), which was not significantly different ($P < 0·05$) from the control sample (10·6% h^{-1}; s.e. 0·08). This indicates that *C. odorata* leaf substrate does not affect the activity of rumen protozoa.

Previous studies on the toxicity of *C. odorata* showed that it contains nitrate nitrogen, which was significantly higher ($P < 0·05$) in yellow than in green leaves (589 and 71·6 p.p.m. respectively) (Marutani and Muniappan, 1991). Another report showed that *C. odorata* contains N-oxides of five pyrrolizidine alkaloids, i.e. 7- and 9-angeloyletronecine, intermedine, rinderine and 3-acetylrinderine (Biller *et al.*, 1994). It was found that higher concentrations of the alkaloids occur in the roots of *C. odorata* (1·03 μmol g^{-1} DM) and in its mature flower heads (2·44 μmol g^{-1} DM), whereas leaves (<0·002 μmol g^{-1} DM for leaf blade and 0·11 μmol g^{-1} DM of leaf petiole) and stems (0·08 μmol g^{-1} DM) were almost devoid of alkaloids and no alkaloids were found in nectar.

Irobi (1997) assayed the antibacterial activity of the ethanol extract from *C. odorata* leaves on *Bacillus*, *Staphylococcus*, *Escherichia* and *Streptococcus* bacterial strains and found a small concentration (0·13–8·0 mg ml^{-1}) of inhibitory compounds. This antibacterial activity was further reduced when pH of the medium was increased from acidic to neutral. The high *in vitro* gas production with *C. odorata* leaves in the present study suggests a negligible content of inhibitory compounds, for example N-oxides, in its leaves. The current observation might also be related to the loss of the microbial inhibitory effect of the active compounds in the rumen liquor due to its high pH of 6–7, as previously reported by Irobi (1997).

Conclusion

C. odorata leaves evaluated in this study can be compared to high-quality leguminous forages currently used as protein foodstuffs in the tropics. The *in vitro* gas production and protozoa activity data suggest that antimicrobial compounds might be absent or found in negligible amounts in *C. odorata* leaves. The reluctance

of livestock to consume *C. odorata* is, as demonstrated by the current study, not related to its energy or protein value and must be for other reasons. There is a need for further studies on methods of preservation such as drying, wilting or ensiling, which may alter its acceptability and induce higher intake. Additionally, the combination of *C. odorata* with other foodstuffs that can mask its strong odour should be studied in order to establish optimum levels of inclusion to maximize feed intake. Much would be gained if this high-yielding and aggressive plant could be utilized as an animal feed, as opposed to attempting to control its population by mechanical and chemical methods of weed control.

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