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Nutritive value of edible forage from two *Leucaena leucocephala* cultivars with different growth habit and morphology

E. González-García · O. Cáceres · H. Archimède · H. Santana

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Abstract The nutritive value of edible forage from *Leucaena leucocephala* cv. Cunningham (CUNN) and cv. CNIA-250 (CNIA) was determined during the rainy (*R*) and dry (*D*) seasons of Cuba without fertilization or irrigation. Forage was supplied ad libitum and the French system of total faeces collection was used for nutritive value determination and expression by using six adult castrated *Pelibuey* wethers for each determination. There were noticeable differences in the chemical composition and nutritive value between the two cultivars which were also influenced by year season. The highest protein and energy content were found in CNIA and during the rainy season which could also explain its higher forage intake and digestibility, while CUNN expressed higher DM and nutrient yield throughout the year, mainly due to advantages in tree size and morphology (higher ramification and proportion of leaves, and acceptable branch length). Quality and nutritive value results indicated that these *Leucaena* cultivars have a suitable potential as supplements for sustainable ruminant nutrition strategies during both seasons of the year; CNIA, because of its smaller height, is strongly recommended for agrosilvopastoral small ruminant browsing systems.

Keywords Forage · *Leucaena* · Cunningham · CNIA-250 · Nutritive value · Ruminant

E. González-García (✉) · O. Cáceres · H. Santana
Estación Experimental de Pastos y Forrajes "Indio Hatuey", Central España Republicana, 44280 Matanzas, Cuba
e-mail: gonzaleg@supagro.inra.fr

E. González-García · H. Archimède
INRA-Unité de Recherches Zootechniques (URZ), Domaine de Duclos, Prise d'Eau, 97170 Petit Bourg, Guadeloupe (FWI)

Present Address:
E. González-García
UMR-Elevage des Ruminants en Régions Chaudes (ERRC) (UMR_868), INRA-Montpellier, Campus SupAgro-INRA, 2 Place Pierre VIALA, 34060 Montpellier Cedex 1, France

Introduction

During the 1970s and early 1980s, *Leucaena leucocephala* (Lam.) de Wit (*Leucaena*) was known as the 'miracle tree' because of its worldwide success as a long-lived and highly nutritious forage tree, and its great variety of other uses (Shelton and Brewbaker 1994). In Cuba, as in most tropical developing countries its main use continues to be its inclusion in the feeding and livestock production systems based on agrosilvopastoral or agroforestry approach (Cáceres et al. 1994; Delgado et al. 2001).

Garcia et al. (1996) broadly reviewed the nutritive value of leaves, fresh forage and forage productivity of *L. leucocephala* putting together data from 65 publications from 1946 to 1992. For forage, among other parameters they found average values (g/100 g DM) of 22.03 CP, 35.0 CF, 39.5 NDF, 35.1 ADF, 18.3 ash, 1.80 Ca, 0.26 P, and concluded that optimum harvesting interval should be about 8 weeks or just before the onset of flowering. During the last decades, other workers have developed a substantial number of studies evaluating the chemical composition and nutritive value of several cultivars and other shrubs and tree fodder species with various principal focuses such as experimental site, year season, method of offering to animals (fresh or dehydrated forage, leaf meal), animal species, etc. (Mtenga and Laswai 1994; El hassan et al. 2000; Barahona et al. 2003; Sandoval-Castro et al. 2005; Larbi et al. 2005; Agbede 2006; Tedonkeng Pamo et al. 2007).

However, little information is available in relation to studies which compare the variation of forage quality and the use by animals among cultivars from the same species with differences in plant structure, development and morphology which, in practice, are used as criteria by livestock keepers for different purposes at farm level.

Cunningham and CNIA-250 are two cultivars which have extreme growth habit and morphology, and at present, are locally being extended in agroforestry systems in Cuba. The objective of this work was to determine and compare, during the local rainy and dry seasons, their chemical composition and nutritive value for ruminants. We hypothesised that physiological and structural plant differences will influence edible forage nutrient composition and therefore the nutritive value which at the same time would be affected by the season.

Materials and methods

Experimental site

The experiment was conducted in the fields and facilities of the Experimental Station "Indio Hatuey", Matanzas, central Cuba (Latitude 22°48′7″N, Longitude 81°2′E; 19.01 m above sea level) with a medium soil fertility (Haplic Ferralsol, WRB 2006; or 'Ferralítico rojo hidratado' under the Cuban classification system; Hernández et al. 1999) characterised by a plain relief, a deep clay texture, good external and internal drainage, pH 6.00 (±1), 3.0% (±1) of organic matter, average N content (0.10%), low phosphorous level (≈23 ppm) and calcium predominance among the exchangeable cations; the determined chemical characteristics of soil used in the experimental site are presented in Table 1.

Table 1 Average determined chemical composition from the first 0–20 cm layer of soil (Haplic Ferralsol, WRB 2006) in the experimental site

pH	OM	Total N	P_2O_5	Other mineral content				CEC
				K	Ca	Mg	Na	
6.07	4.41	0.221	3.75	0.14	14.52	2.25	0.112	21.28

pH, soil pH determined by potassium clorurum (KCl) method; OM, soil organic matter content (%); Total N, total soil N content (%); P_2O_5, soil phosphorous P_2O_5 content (%); K, soil potassium content (cmol(+)/L); Ca, soil calcium content (cmol(+)/L); Mg, soil magnesium content (cmol(+)/L); Na, soil sodium content (cmol(+)/L); CEC, soil cation exchange capacity (capacity of a soil for ion exchange of positively charged ions between the soil and the soil solution)

Temperature in the island has little seasonal variation (average ranging from 20°C in January to 29°C in July–August, the coolest and hottest months, respectively) while the annual average precipitation is around 1,300–1,500 mm with a rainfall pattern that divides the year into two well defined distinct seasons: a rainy season (*R*) that usually starts in May and ends in October and represents approximately 80% of rains, and a dry season (*D*) that lasts the rest of the year. Hence, quantity and quality of the forage available for grazing vary according to the season and the distribution of the rainfall. Solar radiation has been estimated at 470 and 370 cal/cm^2 per day for *R* and *D* season, respectively. Evaporation ranges 8–10 mm/day from April to September and 6–8 mm/day from October to March; relative humidity is around 60–80% for *D* and *R*, respectively.

Cultivars

The two *L. leucocephala* cultivars evaluated in this study were Cunningham (CUNN) and CNIA-250 (CNIA) which were introduced in Cuba (directly through the Experimental Station "Indio Hatuey") in 1977 and 1979, respectively, as consequence of an agreement in plant genebank exchange with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia. These cultivars are mainly characterised by their different growth habit and morphology; in the in situ field evaluations (Machado and Núñez 1994a, b), CNIA have shown lower germination rates than CUNN probably because of its harder seed coat which eventually results in a longer seed dormancy; from the first month of fields establishment, marked differences in plant height have been obtained when both cultivars are compared (adult plant height: 1.65 vs. 2.00 m in CNIA and CUNN, respectively) due to a slower growth rate in CNIA (0.60 cm/day).

The cultivar CUNN shows higher level of ramification with acceptable thickness as well as higher number, length and thickness of tertiary branches and higher number and length of leaves. This favourable structure supports a higher forage yield. On the contrary, a higher number of secondary branches with lesser length has been found in CNIA.

Machado et al. (1994a, b) concluded that cultivar and climate are determinant factors in the biomass production, much more than other traits like adult plant height due to the characteristic radial growth habit in *Leucaena* spp.

Experimental design

The nutritive value of the two *L. leucocephala* cultivars grown without irrigation or fertilization, were determined for both the *R* and *D* seasons by using a 2 × 2 factorial design, which represents the two cultivars corresponding to the experimental diet and the two seasons (*R* and *D*).

Six replicates per treatment were used corresponding to the use of six adult castrated *Pelibuey* wethers (average BW = 38 ± 2.1 kg) per treatment, randomly allocated in individual metabolism crates (year, $n = 24$; season -*R*, *D*-, $n = 12$). The total faecal collection and ad libitum forage supply method, adapted to tropical conditions (Garcia-Trujillo and Cáceres 1984; Xandé et al. 1985, 1989), was used. For each treatment the NV was determined for a 21 days period (14 days for adaptation and 7 days for data collection).

During the trials, the fresh forage (leaves and edible stem fractions) obtained from two previously established experimental plots (one per cultivar) with similar plant density and age, were manually pruned every morning, and a period of 60 days of regrowth was allowed for each plot according to the optimum harvesting interval of about 8 weeks reported by Garcia et al. (1996) for *Leucaena* spp. Forage (harvested branches of 30–40 cm of length) were individually offered to the wethers as a whole feed in two ad libitum meals a day (0830 and 1600 hours) by providing a daily amount exceeding the previous day's intake by at least 15–20%. Total daily amount of fresh forage offered were between 3.3 and 3.5 kg (for a potential intake of 870–900 g DM/day), taking into account the individual metabolic weights. During the data collection week, offered and refused forage were recorded daily in order to determine voluntary DM intake (VDMI).

The in vivo apparent total tract DM digestibility (DMD), the main criterion for the determination of nutritive values with the French system (Aumont et al. 1995), the OM (OMD) and CP (CPD) digestibilities, as well as the composition of digestible CP (DCP) were determined. Nitrogen values were expressed in terms of the protein truly digestible in the small intestine (PDI) also from the French feed units system (Jarrige et al. 1978) adapted to the Cuban conditions by Garcia-Trujillo and Cáceres (1984); in this system the sources of digestible protein in the small intestine are estimated by undegraded dietary protein in the rumen which is digestible in the intestine (PDIA) and the microbial true protein truly digestible in the small intestine (PDIM); each feed contributes to microbial synthesis through both the degradable N and the available energy it supplies to the rumen microorganisms (see INRA 1989); thus, each feed express two PDIM values: (1) microbial true protein synthesised from the rumen fermented organic matter (energy available in the rumen) when degraded N is not limiting (PDIME), and (2) amount of microbial protein that could be synthesised from the degraded dietary N when energy is not limiting (PDIMN) (INRA 1989; Xandé et al. 1989). This system assigns two protein values to each feed: (1) PDIN = PDIA + PDIMN and (2) PDIE = PDIA + PDIME, where PDIA and PDIMN are calculated from the CP value and PDIME is predicted from OM, CP and CF values of the feed (see INRA 1989). Thus, unlike those systems which just consider the CP and digestible CP of feedstuff, this system makes a differentiation of the protein according to the quality and takes into account the role of microbial protein synthesis in the supply of this nutrient at intestinal level.

Analytical procedures

Samples of forage (offered and refused) were individually and daily collected in duplicate during the 7 days of data collection and finally composited for each animal. In the same period, total daily faeces were weighed and a 10% representative sample per wether was retained, stored at −20°C and further composited for each animal before bringing to the laboratory for analysis.

The DM contents of forage, orts and faeces were determined by oven drying at 105°C for 24 h (AOAC 1995; ID 950.01) while ash content was determined by heating samples at 550°C for 4 h according to AOAC (1995; ID 942.05), thereafter the OM content was calculated by difference.

Dry samples were obtained for further chemical analyses by oven drying at 60°C for 24 h and were ground to pass through a 1-mm stainless steel screen (Cyclotec 1093 Sample mill, Tecator). The CP content was calculated after N determination by Kjeldahl method (AOAC 1995; ID 976.05) using a Kjeltec Auto 1030 Analyzer (Tecator, Hogänäs, Sweden). The methods of Van Soest et al. (1991) were followed to determine NDF (aNDFom) and ADF (ADFom) (sequentially) on an ash-free basis using the Ankom^{200} Fibre Analyser incubator (Ankom Technology, Macedon, NY, USA) and adding amylase and sodium sulphite solutions (AOAC 1995; ID 989.03). As using French feed units system for NV determination implies the use of crude fibre (CF) content, this parameter was measured by using the Weende method (Henneberg and Stohmann 1859; AOAC 1995; ID 978.10).

Calculation and statistical analysis

Some of the equations used in NV determination of tropical forage from the Caribbean with the French feed unit system were reported by Aumont et al. (1995). The main equations used in our experiment in applying the Cuban adapted French PDI system (Garcia-Trujillo and Cáceres 1984) were:

$$\mathrm{PDIE} = \mathrm{PDIA} + \mathrm{PDIME} \quad (1)$$

$$\mathrm{PDIN} = \mathrm{PDIA} + \mathrm{PDIMN} \quad (2)$$

$$\mathrm{PDIA} = [\mathrm{CP}\ (1 - S) \times 0.65] \times \mathrm{dr}\ (\mathrm{g/kg\ DM}) \quad (3)$$

where S, average CP solubility of local forage; 0.65, factor to express the insoluble ruminal by-pass protein; dr, average real intestinal digestibility of dietary protein of local forage (102 in France, 67 in Cuba), calculated as follows:

$$\mathrm{dr} = (\mathrm{PAI} - \mathrm{PANDI})/\mathrm{PAI} \quad (4)$$

where PAI (dietary protein arriving to the small intestine) is calculated as follows:

$$\mathrm{PAI} = [\mathrm{CP}\ (1 - S)] \times 0.65 \quad (5)$$

and PANDI (dietary protein undegradable at the small intestine) is calculated as follows:

$$\mathrm{PANDI} = \mathrm{UN} - [(0.033\ \mathrm{DOM}) - 0.009] \times \mathrm{UOM} \quad (6)$$

where UN, undigestible nitrogen, CP kg/DM; DOM, digestible organic matter, g/kg DM; UOM, undigestible organic matter, g/kg DM.

$$\mathrm{PDIME} = 135 \times 0.80 \times 0.70 \times \mathrm{kg\ DOM} = 75.6 \times \mathrm{kg\ DOM}\ (\mathrm{g/kg\ DM}) \quad (7)$$

$$\mathrm{PDIMN} = \mathrm{CP}\ [S + 0.35(1 - S)] \times 0.80 \times 0.70\ (\mathrm{g/kg\ DM}) \quad (8)$$

where factors 135, microbial protein synthesis, g/kg DOM; 0.80, proportion of true protein coming from microbial nitrogen; 0.70, intestinal microbial protein digestibility; 0.35, indicates that around 35% of insoluble CP is degraded in rumen.

Data were analysed as a 2 × 2 factorial design by using the MIXED procedure of Statistical Analysis Systems Institute (2000) software (SAS 8.1; SAS Inst. Inc., Cary, NC, USA) with a statistical model including the effect of *Leucaena* cultivar, year season and their interaction as fixed effects; the model used was:

$$Y_{ijkl} = \mu + C_i + S_j + (C \times S)_{ij} + \varepsilon_{ijkl}$$

where Y_{ijkl}, is the observation; μ, the population mean; C_i, the cultivar effect ($i = 1$–2); S_j, the season effect ($j = 1$–2); $(C \times S)_{ij}$, the cultivar × season interaction effect ($ij = 1$–4) and ε_{ijkl} is the residual error. For all traits, the experimental unit was considered the wether, as they were individually fed and was included in the model as a random effect. Significance was declared at probability levels of ≤5% and comparisons between means were tested by the LSmeans procedure.

Results

Chemical composition of edible forage

The determined chemical composition of the two *L. leucocephala* cultivars for both seasons of the year is given in Table 2. There was no effect of *S* on forage DM content and differences in this parameter were attributed to $C \times S$ interaction. Organic matter content was similar throughout the year between the studied cultivars. The CP content was affected by differences between *C* and *S* and was determined by a significant $C \times S$ interaction; the highest CP content was found in CNIA and the lowest in CUNN, both during the *D*. No significant differences were found for CF and aNDFom due to season, and effects in the cell wall components were mainly due to the cultivar (CNIA > CUNN; 191 vs. 151 and 305 vs. 242 g/kg DM for CF and aNDFom, respectively) and significant $C \times S$ interaction was also obtained with the highest contents observed in the CNIA cultivar and the lowest in CUNN, both during the *R*; although ADFom followed the same pattern, a significant effect of season was also detected ($D > R$, 242 vs. 226 g/kg DM, respectively). The ME content of the evaluated forage was highly influenced by the cultivar and the season; both forage were more rich in energy during rainy season (8.85 vs. 8.25 MJ/kg DM, *R* vs. *D*, respectively) and CNIA (8.92 MJ/kg DM) showed the highest value when compared to CUNN (8.18 MJ/kg DM). There were significant $C \times S$ interactions in composition on DCP, PDIE and PDIN.

Voluntary DM and nutrients intake

Significant $C \times S$ interactions were also found for nutrient intakes (g/kg $BW^{0.75}$) of CP, DCP, PDIE and PDIN (Table 3) but not for voluntary DM intake which was affected ($P < 0.0001$) by the cultivar and the year season. The highest VDMI were obtained during the *R* season (58.7 vs. 56.1) and in CNIA cultivar (59.0 vs. 55.9); while there was no difference between seasons in CNIA (13.65), CPI was higher in CUNN during *R* than in the rest of combinations. The

Table 2 Determined chemical composition (analyses made by duplicates), and content on digestible crude protein and metabolisable energy of edible forage from the two *Leucaena leucocephala* cultivars (cv. Cunningham and cv. CNIA-250), as affected by the season

Item	*Leucaena leucocephala* cv.				SEM	*P* value of source of variation		
	Cunningham		CNIA-250			*C*	*S*	*C* × *S*
	R	*D*	*R*	*D*				
DM content, %	28.2	25.8	29.1	32.3	0.68	<0.000	0.561	0.001
Composition (g/kg DM)								
OM	912	911	908	906	0.6	0.446	0.798	0.932
CP (*N* × 6.38)	221	190	228	234	3.0	<0.000	0.001	<0.000
CF	142	161	201	181	5.0	<0.000	0.921	0.001
aNDFom	227	257	321	289	5.9	<0.000	0.867	<0.000
ADFom	167	228	285	256	4.3	<0.000	0.001	<0.000
Ca	23	27.0	16.0	19.0	0.77	<0.000	0.001	0.526
P	2.5	2.8	2.3	2.6	0.12	0.120	0.024	1.000
ME (MJ/kg DM)	8.5	7.9	9.2	8.6	0.12	<0.000	<0.000	0.699
Digestible CP (g/kg DM)	108	171	152	146	2.2	0.001	<0.000	<0.000
PDIE (g/kg DM)	127	99	119	122	2.5	0.001	<0.000	<0.000
PDIN (g/kg DM)	138	113	136	140	1.9	<0.000	<0.000	<0.000

R rainy season, *D* dry season, *C* effect of *Leucaena* cultivar or ecotype, *S* effect of season, *C* × *S* effect of interaction between *Leucaena* cultivar or ecotype and season, *ME* metabolisable energy, *PDIE* = PDIA (dietary protein undegraded in the rumen which is digestible in the intestine) + PDIME (microbial protein that could be synthesised from the energy available in the rumen when degraded N is not limiting), *PDIN* = PDIA + PDIMN (microbial protein that could be synthesised from the degraded dietary N when energy is not limiting)

Table 3 Voluntary intake (g/kg BW$^{0.75}$) of dry matter and nutrients of edible forage coming from two *Leucaena leucocephala* cultivars (cv. Cunningham and cv. CNIA-250), as affected by the season

Item	*Leucaena leucocephala* cv.				S.E.M.	*P* value of source of variation		
	Cunningham		CNIA-250			*C*	*S*	*C* × *S*
	R	*D*	*R*	*D*				
VDMI	57.5	54.2	59.9	58.1	0.51	<0.000	<0.000	0.142
CPI	14.3	11.8	13.7	13.6	0.33	0.090	0.009	0.002
DCPI	9.80	7.20	8.22	7.26	0.290	0.016	<0.000	0.010
PDIEI	8.10	6.10	6.15	7.31	0.259	0.169	0.119	<0.000
PDINI	8.50	7.10	6.91	8.65	0.203	0.914	0.415	<0.000
MEI (kJ/kg BW)$^{0.75}$	531	464	554	500	10.3	0.010	<0.000	0.534

R rainy season, *D* dry season, *C* effect of *Leucaena* cultivar or ecotype, *S* effect of season, *C* × *S* effect of interaction between *Leucaena* cultivar or ecotype and season, *VDMI* voluntary dry matter intake, *CPI* crude protein intake, *DCPI* digestible crude protein intake, *PDIEI* intake of PDIA (dietary protein undegraded in the rumen which is digestible in the intestine) + PDIME (microbial protein that could be synthesised from the energy available in the rumen when degraded N is not limiting), *PDINI* intake of PDIA + PDIMN (microbial protein that could be synthesised from the degraded dietary N when energy is not limiting), *MEI* metabolisable energy intake

DCPI was higher in *R* (9.01) than *D* (7.23) and in CUNN (8.50) than CNIA (7.74) with the highest intake value obtained in CUNN during *R*. Although no differences were obtained between cultivars and seasons, the results on PDIEI [(intake of PDIA (dietary protein undegraded in the rumen which is digestible in the intestine) + PDIME (microbial protein that could be synthesised from the energy available in the rumen when degraded N is not limiting)] and PDINI [(intake of PDIA + PDIMN (microbial protein that could be synthesised from the degraded dietary N when energy is not limiting)] followed different patterns between cultivars; while PDIEI and PDINI were higher in *R* for CUNN, the inverse result was obtained for CNIA (*D* > *R*). No *C* × *S* interactions effects were found in the ME intake, so that the main differences for this parameter were due to individual effects of cultivars (CNIA > CUNN, 527 vs. 498 kJ/kg BW$^{0.75}$, respectively) and season (*R* > *D*, 542 vs. 482 kJ/kg BW$^{0.75}$, respectively).

Apparent total tract digestibility

The apparent total tract digestibility (g/kg DM) of the edible forage from the two *Leucaena* cultivars during the two seasons is shown in Table 4. For DM, OM and CF digestibilities, there were high significant differences ($P < 0.0001$) between cultivars and seasons. CNIA showed higher values than those found in CUNN for DM (648 vs. 547), OM (610 vs. 569) and CF (646 vs. 572), whereas for CPD no differences

Table 4 Least squares means of apparent total tract digestibility (g/kg DM) of the edible forage of two *Leucaena leucocephala* cultivars (cv. Cunningham and cv. CNIA-250), as affected by the season

Digestibility of	*Leucaena leucocephala* cv.				SEM	*P* value of source of variation		
	Cunningham		CNIA-250			*C*	*S*	*C* × *S*
	R	*D*	*R*	*D*				
DM	567	526	669	626	10.1	<0.000	0.001	0.922
OM	588	549	632	588	7.2	<0.000	<0.000	0.732
CP	651	563	661	534	8.6	0.281	<0.000	0.034
CF	519	624	672	620	5.1	<0.000	<0.000	<0.000

R rainy season, *D* dry season, *C* effect of *Leucaena* cultivar or ecotype, *S* effect of season, *C* × *S* effect of interaction between *Leucaena* cultivar or ecotype and season were obtained. With the exception of CFD (596 vs. 622), when seasons were compared, the best results corresponded to the rainy (618 vs. 576, 610 vs. 569 and 656 vs. 549 g/kg DM for DMD, OMD and CPD in *R* vs. *D*, respectively). Significant interaction ($P < 0.0001$) was found just for CFD, where the maximum value was obtained with CNIA and the minimum with CUNN, both during *R* season (Table 4).

DM and nutrients yield

The DM, CP, digestible CP and ME yields of the experimental plots of both *Leucaena* cultivars used in the present study and during the two seasons appears in the Table 5. For all variables, there were high significant effects ($P < 0.0001$) of either the $C \times S$ interactions or the *C* and *S* individual effects. As average, the best productivities were obtained with the cultivar CUNN during rainy season, while differences were lower for dry season when comparing cultivars at the same time and even higher values were obtained in CNIA for the CP and ME yields during this season. As expected, the highest DM (10.95 vs. 1.99 t/ha in *R* and *D*, respectively) and nutrient yields (2,451 vs. 423 kg/ha, 1,313 vs. 297 kg/ha and 96.04 vs. 16.50 thousands of MJ/ha, for CP, DCP and ME in *R* vs. *D*, respectively) were found during the rainy season for both cultivars. In the whole experiment, CUNN expressed better yields than CNIA (7.62 vs. 5.32 t/ha, 1,653 vs. 1,220 kg/ha, 888 vs. 722 kg/ha and 63.88 vs. 48.65 thousands of MJ/ha, for DM, CP, DCP and ME, respectively).

Discussion

Our results demonstrate that possible differences can occur in forage yield, quality, acceptance, intake and digestibility by animals among cultivars into the same plant species and between the two contrasting climatic seasons and, more importantly, these differences can be very relevant.

Effects of season

As expected, the best DM and nutrient yields were obtained during the rainy season. The positive effects of rainfall on forage yield are well documented; water is one of the essential inputs for crop production and affects crop performance not only directly but also indirectly by influencing nutrient availability, timing of cultural operations, and other factors (Reddy et al. 2003).

Yields of *Leucaena* forage are reported to vary accordingly with soil fertility, rainfall, altitude, density and cutting frequency, while leaf yield is maximised by cutting at 6–12 week intervals during the growing season (Garcia et al. 1996). Yields in extensive hedgerow plantings in the dry tropics and subtropics generally range from 2 to 6 t/ha per year while very high yields (>15 t/ha per year) have been obtained in southeast Asia and Hawaii, with plants 0.5–1.0 m apart in rows 1–3 m apart.

Edible forage yields range from 3 to 30 t DM/ha per year. Deep fertile soils receiving greater than 1,500 mm of well distributed rainfall produce the largest quantities of quality fodder. Yields in the subtropics, where temperature limitations reduce

Table 5 Seasonal dry matter and nutrients yield of two *Leucaena leucocephala* cultivars (cv. Cunningham and cv. CNIA-250) fields established under Cuban conditions

Item	*Leucaena leucocephala* cv.				SEM	*P* value of source of variation		
	Cunningham		CNIA-250			*C*	*S*	$C \times S$
	R	*D*	*R*	*D*				
DM yield (t/ha)	13.2	2.05	8.7	1.95	0.240	<0.000	<0.000	<0.000
CP yield (kg/ha)	2,917	390	1,984	456	39.9	<0.000	<0.000	<0.000
DCP yield (kg/ha)	1,425	351	1,200	244	23.10	<0.000	<0.000	0.018
ME yield (000 MJ/ha)	111.5	16.2	80.5	16.8	0.97	<0.000	<0.000	<0.000

R rainy season, *D* dry season, *C* effect of *Leucaena* cultivar or ecotype, *S* effect of season, $C \times S$ effect of interaction between *Leucaena* cultivar or ecotype and season, *CPI* crude protein yield, *DCP* digestible crude protein yield, *ME* yield 000, metabolisable energy yield, expressed in thousands of megajouls per hectare growth rates, may be only 1.5–10 t of edible fodder per ha/year (Brewbaker et al. 1985).

In general, content and composition of cell wall constituents, as well as the digestibility of DM and OM seem to be less affected by the season relative to what normally occurs in grasses and herbaceous legumes (FAO 1992).

A decline in nitrogen compounds (CP, DCP, PDIE, PDIN) concentration and metabolisable energy during the dry season when compared to the rainy season, is probably due to factors like reduced leaf to stem ratio and the higher cell wall constituent's concentration (ADF), like occurs with advanced stages of maturity. These factors also have a direct relationship with the marked difference observed in favour of *R* season for voluntary intake and nutrient digestibility.

For both seasons there was an unbalance between PDIE and PDIN contents with higher values of PDIN which indicates the presence of important rates of non protein nitrogenous compounds (NPN) and, therefore, the necessity to balance these two fractions in the diet (Garcia-Trujillo and Cáceres 1984; Xandé et al. 1985) with other local energy sources.

Effects of differences between cultivars

The contribution of genetic as opposed to non-genetic factors (environmental factors, crop management and post-harvest techniques) to fodder yields, quality and digestibility varies between crop species and among genotypes within a crop species (Reddy et al. 2003).

Measurements showed that the two investigated cultivars differed considerably in their forage yield, quality, intake and total tract digestibility. As expected, and also demonstrated by Machado et al. (1994a, b), CNIA genotype, with a smaller height, expressed lower forage production than CUNN (Table 5). This was a direct consequence of the mentioned higher level of ramification as well as higher number, length and thickness of tertiary branches and higher number and length of leaves which gives a favourable structure for a higher forage yield in CUNN when compared to CNIA and other *Leucaena* cultivars.

A very important determinant of chemical composition and digestibility of forage species is the leaf to stem ratio, which is also correlated to the level of ramification and the number and length of leaves. This is not only because of the generally higher nutritive value in leaves compared to stems, but leaves are also more acceptable to animals as they are easier to chew and more digestible. Machado et al. (1994a, b) reported the differences between CNIA and CUNN on these aspects which were already detailed.

In general, the forage composition of the two *L. leucocephala* cultivars (cv. Cunningham and cv. CNIA-250) falls within the range of values reported for woody forage species in previous evaluations of agrosilvopastoral systems under Cuban conditions (Cáceres et al. 1994; Fortes et al. 2003; González and Cáceres 2002; González et al. 2006).

Composition was characterised by a high level of CP and variable proportions of the cell wall components. The DM content ranged between 258 and 323 g/kg DM, which allow us to infer that this parameter would not limit DM intake in ruminant diets using this cultivars as supplement. The CP content of both cultivars was considered high (190–234 g/kg DM) and being substantially greater than the minimum value of 80 g/kg DM reported as minimum for tropical forage by Minson (1990) to avoid a depression in digestibility and forage intake as a consequence of insufficiency in nitrogen to meet the needs of rumen bacteria, although the content in secondary compounds, like condensed tannins, could possibly compromise nitrogen availability and its use by ruminal microorganisms.

It was noteworthy the considerable low level of CF found in CUNN forage when compared either to CNIA or improved forage grasses and other no legumes forage species under Cuban or Caribbean conditions (Xandé et al. 1985), which is in agreement with other evaluations developed in the island (Hernández et al. 1986, 1987; Cáceres and Santana 1990).

The concentration of cell wall compounds (CF, NDF, ADF and lignin) in the forage is known to be negatively correlated with their potential intake and degradability. The higher content of these constituents in CNIA (Table 2) when compared to CUNN contrasted with its higher voluntary DM and energy intake, and digestibility (Tables 3, 4). A possible explanation to this could be the higher concentration of N compounds (CP, DCP, PDI) and metabolisable energy in CNIA which could have favoured ruminal fermentation thereby enhancing voluntary intake, microbial protein synthesis and total tract digestibility, or a lower content of secondary metabolites (particularly condensed tannins).

Larbi et al. (2005) found differences in fodder yield among browse species in a study developed in West African humid tropics, and explained that these differences may reflect variations in growth habit, residual buds, leaf area index, and storage carbohydrates. Increases in fodder yield and cell wall concentrations in that study correlated with a decline in N compounds.

Garcia et al. (1996) reviewed the nutritive value and forage productivity of *Leucaena* based on some 65 publications from 1946 to 1995. Contrary to their findings (classifying *Leucaena* forage as high in fibre), the average ADF content of *Leucaena* cultivars previously (González et al. 2006) and now reported in our studies are lower than these values ranging from 341 to 361 g/kg DM; in that sense we must highlight the low CF level of both cultivars evaluated in this experiment, especially the cv. Cunningham (Table 1). While our average P content (2.5 g/kg DM) coincides with the reported median value of 2.6 g/kg DM, the average concentration of Ca in our experiments were higher than median in the 65 reviewed publications (21 vs. 18 g/kg DM). The DM value (33.2%) reported for the acid ultisol conditions in Trinidad, West Indies, were similar to those obtained in our study with CNIA and higher than those found in the CUNN for both seasons, although all values reported fall within the accepted range for considering a normal voluntary dry matter intake in ruminants when using this forage as supplement.

Voluntary DM and nutrients intake

In general, values found for VDMI and MEI are lower than those reported for grasses under similar conditions; as DM content seems to be adequate, voluntary intake was supposed to be affected by other factors like the presence of secondary compounds which also delay the adaptation period of animals to this kind of diets. Average PDIE and PDIN intake (6.91 and 7.8 g/kg $BW^{0.75}$, respectively) was considered high and surpassed wether maintenance requirements (2.5 g PDI/kg $BW^{0.75}$); similarly, energy intake (512 kJ/kg $BW^{0.75}$) was higher than those reported for maintenance requirements (450 kJ/kg $BW^{0.75}$; Theriez et al. 1987).

Apparent total tract digestibility

As commented above, for tropical forage, digestibility is depressed and forage intake drops when CP content is lower than 80 g/kg DM (Minson 1990), partly because nitrogen is insufficient to meet the needs of rumen bacteria. The CP concentration of the two cultivars evaluated as well as the levels of DCP, PDIME and PDIMN suggest that these plants could effectively provide the N supplement for ruminants fed low N grasses or crop residues. Similar results were reported by Larbi et al. (2005) evaluating the nutritive value of browse species in the West African humid tropics.

Garcia et al. (1996) exposed a total apparent digestibility of CP ranging from 647 to 780 g/kg DM which is higher than the values found out with these two cultivars (534–661 g/kg DM) with a marked negative effect of the season on CP digestibility for both forage of 14–20% (651–563 g/kg DM CUNN and 661–534 g/kg DM CNIA, for *R* and *D*, respectively).

Average total tract digestibility was considered acceptable for all nutrients during both seasons and agreed with results obtained in other fodder woody species (Benavides 1994; Benavides et al. 1992; Ramirez et al. 2000).

Conclusions

There were noticeable differences in the chemical composition and nutritive value in ruminants for the two *L. leucocephala* cultivars studied (Cunningham and CNIA-250) which were also influenced by season. The highest protein and energy content were found in CNIA-250 and rainy season which could also explain their higher forage intake and digestibility. On the contrary, Cunningham expressed (as average) higher DM and nutrient yield throughout the year, which it is related with the advantage in tree size and morphology (highest proportion of leaves in forage composition). Both cultivars are highly recommended for use in the feeding systems (grazing as a protein bank or association, or regime of cut and carry) of agrosilvopastoral and agroforestry projects for livestock production in the tropics, while the cultivar CNIA-250 may well be included in small ruminant grazing systems due to its smaller size which makes it more accessible when browsing.

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