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Original Research Article

Influence of drying technique on chemical composition and ruminal degradability of subtropical *Cajanus cajan* L.

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ABSTRACT

The experiment investigated the influence of forage drying methods on the dry-matter digestibility of foliage from *Cajanus cajan* varieties (ICEAP 00557, ICEAP 01514 and CIMMYT100/01). These leaves were harvested at week 20 of growth and either oven- or shade-dried and analysed for chemical components and rumen degradability. Three rumen fistulated lactating Holstein cows (430 ± 18 kg live weight) were used to evaluate ruminal degradation kinetics using *in vitro* and *in sacco* procedures. Samples were incubated for 0, 4, 8, 12, 24, 30 and 48 h *in vitro* (IV Daisy^{II}) procedure. In the *in sacco* procedure, samples were incubated for 0, 4, 8, 12, 24, 30 and 48 h in the rumen of cows. Dry matter disappearance (DMD) data for both measures were fitted to the equation $Y = a + b\,(1 - e^{-ct})$, where *b* is the slowly degradable fraction and *c* is the degradation rate constant, to approximate rumen degradability characteristics of varieties. Shade dried leaves contained higher crude protein (CP) ($P < 0.05$) than oven dried leaves. Oven drying method increased ($P < 0.05$) neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) content of varieties. However, shade drying method gave the higher concentration of NDIN and ADIN. Drying technique had no effect ($P > 0.05$) on ash, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) of varieties. Drying method did not affect ($P > 0.05$) calcium (Ca) and phosphorus (P) concentration in the forage dry matter. Drying method had no effect ($P > 0.05$) on *b* and *c* of all varieties during *in vitro* procedure. However, shade-drying method increased ($P < 0.05$) *b* and *c* of all varieties during *in sacco* procedure. It was concluded that shade-drying, in contrast to oven-drying, would be the most suitable method as it improves the nutritive value of the forage for ruminants.

1. Introduction

Fodder production in southern Africa is classified by large amounts of foliage production towards the end of the 4- to 5-month-long rainy season. Up to 8 to15 t/ha forage dry matter yield can be accomplished. At the point when left uncut, this foliage biomass will be lost amid the long dry season because of leaf fall, frost harm or disintegration. This is especially true in South Africa, where frosts are prevalent in the June–July period (Dzowela et al., 1995). Thusly, at the pinnacle of the dry season, most trees become deciduous due to climatic stress. Forage conservation systems are essential and include cutting and drying before leaf drop sets in (Dzowela et al., 1995). When cut, the fodder is dried, generally by spreading the material on a solid floor until it can be easily pulverized by hand, more often after 2 to 3 days. At this stage, the material is still green in colour, but drying for longer periods brings about a brown coloration which is linked with loss of value (Dzowela et al., 1995). Alternatively, drying could be done using an artificial heat source such as a temperature-regulated oven. Both drying strategies preserve the forage for utilisation in winter

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(Dzowela et al., 1995). Nevertheless, drying temperatures and techniques are imperative factors in forage assessment since they influence the forage nutritional value (Ramsumair et al., 2014). Depending on heat levels, drying results in loss of water-soluble sugars attributed towards decomposition and respiration (Deinum and Maassen, 1994) and Maillard reaction (Van Soest, 1982). These solubles are inadequately soluble in acid and neutral detergents (Van Soest, 1982) and their formation results in increased heat input during the drying period. Drying lessens the moisture content in the feed thereby inhibiting microbial and enzymatic reactions allowing feed to be preserved (McDonald et al., 2002).

Various drying procedures are accessible, although some of these cause nutrient losses (Papachristou and Nastis, 1994). Drying forages at temperatures beneath 30 °C results in enzymatic degradation of sugars and subsequent losses of carbon and dry matter. Such losses are in respect to the water content of forages and result from continued enzymatic respiration during the drying process (Collins and Coblentz, 2007). Dry matter losses at higher temperatures are a result of degradation and volatilization of cellular constituents. Some of the commonly used drying methods alter some chemical constituents of legumes. Other reports by Burrit et al. (1988) and Papachristou and Nastis (1994) showed that oven drying increases the NDF and lignin concentrations and depresses the *in vitro* dry matter digestion (IVDMD). The nitrogen solubility could also be influenced by the drying technique, thus lowering the nutritive value of fodder (Van Soest, 1982). However, data is required on the impacts of drying forages derived from woody species in smallholder farming systems. The present study was undertaken to evaluate the nutritive value of different varieties of Pigeon pea forage when offered to ruminants as supplementary feed in the dry season in South Africa.

2. Materials and methods

2.1. Source of forages

Legume forages were cut at 20 weeks of growth from the University of Fort Hare research farm. Tree leaves from 3 individual tree varieties were dried using the 2 different drying methods: oven 60 °C and shade-drying 30 °C. Five experimental replicates per variety were each allocated to 1 of the 2 drying methods. Oven drying was done in a forced-air ventilated Imperial V Laboratory oven (Labline Instruments Inc., IL, USA) at 60 °C for 48 h. Shade-drying was done under the protection of a greenhouse at 30 °C for 3 days until the leaves became crisp. This was achieved by protecting tree leaves from direct exposure to the sun using cardboard shields. Leaves were dried to achieve a constant weight, after which dry samples were ground to pass through a 1-mm sieve using a Wiley mill (Glen Creston Ltd, Middlesex, UK) and stored in brown bags at room temperature.

2.2. Animals, feed samples and rumen fluid collection

Ruminal liquor was obtained from the rumen of three 3-year-old mid-lactating Holstein cows. These cows received a total mixed ration according to production and stage of lactation with *ad libitum* fresh water. A rumen fluid sample was collected 3 h post-morning meal in thermos flasks and taken instantly to the laboratory where it was strained through 2 layers of cheesecloth and kept at 39 °C under a CO_2 environment. Dried feed samples were used for chemical analyses and dry matter disappearance. All experimental measures were permitted by the Council of Animal Research Ethics Committee (University of Fort Hare) and the study was referenced: MUP151SBUT01.

2.3. Measurements

2.3.1. Chemical analyses

Dried samples were assessed for CP using the Kjeldahl procedure (Fujihara et al., 2001). Neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) were all determined according to Goering and van Soest (1970). Total ash, Ca and P were determined by the methods of A.O.A.C (1990).

2.3.2. In vitro ruminal degradability

In vitro rumen degradability was performed in Daisy[II] Incubator (ANKOM Technology Corp., Fairport, NY, USA). Dried samples were weighed into nylon bags (5 cm × 10 cm; 40 μm pore size) (Agri-Environment Solutions, Midrand, South Africa). Each sample (in 5 replicates) was incubated in one jar (33 bags/jar), and bags were removed at defined times of incubation and weighed. All procedures related to ruminal fluid mixing and straining, preparation of the buffer solution, and manipulation at initiation and during incubations were performed under constant flushing of CO_2. Bags containing 0.5 g sample were heat-sealed, and incubated (0, 4, 8, 12, 24, 30 and 48 h) in ruminal fluid combined with a buffer solution (1:4, vol/vol). After incubation, jars were drained and bags rinsed thoroughly with tap water followed by an extraction with a neutral detergent solution (Goering and van Soest, 1970) for 1 h at 100 °C, in Ankom[220] Fiber Analyzer (ANKOM Technology Corporation, Fairport, NY, USA). These bags with residues were again rinsed gently in cold water, dried in a forced-air oven for 48 h at 60 °C and weighed. To estimate *in vitro* degradation parameters, data of DM disappearance over time at different incubation times were fitted to the following model (Orskov and McDonald, 1979):

$$Y(t) = a + b\left(1 - e^{-ct}\right),\ t \geq 0 \tag{1a}$$

where *Y(t)* = dry matter disappearance (%) at time *t* hours, *a* = soluble or rapidly degradable fraction (the zero time intercept), *b* = insoluble or slowly degradable fraction (asymptote of the exponential), *c* = fractional rate constant of degradation of *b* (1/h), *t* = incubation time (0, 4, 8, 12, 24, 30, 48 h) and *e* = base for natural logarithm.

Effective degradabilities (ED) for DM and OM were estimated according to Orskov and McDonald (1979):

$$ED = a + [bc/(k + c)] \tag{2a}$$

where ED = effective degradability, and *a*, *b* and *c* are the constants as described in Eq. (1a), and *k* = rumen outflow at 3 ruminal passage rates (0.02, 0.05, and 0.08 per hour).

2.3.3. In sacco ruminal degradability

In sacco rumen degradability was determined for each browse variety according to Orskov and McDonald (1979). Dried forage samples were weighed into 5 cm × 10 cm nylon bags (5 g/bag) (40 μm pore size), which was anchored with a 30-cm length of braided fishing line. All samples were prepared in 5 replicates. These bags were incubated for 0, 4, 8, 12, 24, 30 and 48 h in the rumen of 3 female Holstein cows. Nylon bags were removed from the rumen simultaneously as suggested by Vanzant et al. (1998) in order to reduce the error. Upon removal from the rumen, bags were washed in running tap water until the water became clear. Zero time disappearances were obtained by washing unincubated bags in a similar fashion. Bags were dried in an oven at 60 °C for 48 h and weighed to determine the dry weight of the incubation residues. *In sacco* dry matter disappearance (DMD) was estimated as described by Osuji et al. (1993). To estimate *in sacco* degradation parameters data of DMD at different incubation, times was fitted to the following model (Orskov and McDonald, 1979):

$$Y(t) = a + b\left(1 - e^{-ct}\right),\ t \geq 0 \quad (1b)$$

where $Y(t)$ = dry matter disappearance (%) at time t hours, a = soluble or rapidly degradable fraction, b = insoluble or slowly degradable fraction, c = fractional rate constant of degradation of b (1/h), t = incubation time (0, 4, 8, 12, 24, 30, 48 h) and e = base for natural logarithm.

Effective degradabilities for DM were estimated according to Orskov and McDonald (1979):

$$ED = a + [bc/(k + c)] \quad (2b)$$

where ED = effective degradability, and a, b and c are the constants as described in Eq. (1b), and k = rumen at 3 ruminal passage rates (0.02, 0.05, and 0.08 per hour).

2.4. Statistical analysis

Chemical composition data were analysed in a randomized complete block design with 5 replications arranged in a 2 × 3 factorial using software package of SAS Institute Inc., (2003), version 9.1.3. *In vitro* and *in sacco* degradability data were analysed using the NEWAY computer programme for estimation of degradation constants (Osuji et al., 1993). The analysis of variance was carried out on the chemical constituencies and on DM disappearance coefficients a, b, c, $a + b$ and P of ICEAP 00557, ICEAP 01514 and CIMMYT 100/01 using the SAS program General Linear Model Procedure (SAS Institute Inc, 2003). Differences between treatment means were assessed by Least Significant Difference. The following model was used:

$$Y_{ijkl} = \mu + T_i + V_j + D_k + (VDT)_{ijk} + E_{ijkl} \quad (3)$$

where Y_{ijkl} = observation of the dependent variable; μ = fixed effect of population mean for the variable; T_i = effect of incubation time h (0, 4, 8, 12, 24, 30, 48); V_j = effect of variety (j = 3; ICEAP 00557, ICEAP 01514 and CIMMYT 100/01); D_k = effect of drying method (k = Oven-drying and shade-drying); VDT_{ijk} = effect of interaction among variety at level j, drying method at level k and incubation time at level l; E_{ijk} = the random error associated with observation *ijkl*.

3. Results

3.1. Chemical composition

Results of the proximate analyses of 3 varieties of *Cajanus cajan* forage dried with either shade or oven are shown in Table 1. Variety ICEAP 01514 showed a higher (P < 0.05) CP than ICEAP 00557 (24.19%). All *C. cajan* varieties had a higher (P < 0.05) CP content when shade-dried than when oven-dried. However, the CP content of all the 3 varieties did not differ (P > 0.05) when oven-dried. The interactive effect of varieties and drying methods were significant (P < 0.05) on CP, NDIN and ADIN content of the browse varieties. Oven-dried ICEAP 01514 had a lower NDIN (2.16%) and ADIN (1.87%) content than other oven-and shade-dried varieties. Differences in chemical constituents that occurred in oven-drying method contributed to the observed V × D interaction in Table 1. However, the browse varieties, method of drying and the interaction of variety and drying method had no effect (>0.05) on the ash, NDF, ADF and ADL content of *C. Cajan* varieties.

3.2. In vitro ruminal degradability

The mean *in vitro* rumen degradation constants a, b, c and $a + b$ for dry matter (DM) of the 3 *C. cajan* varieties are given in Table 2. There was a difference (P < 0.05) in the rapidly degradable fraction of all the 3 varieties but the drying method had no effect (P > 0.05). Variety CIMMYT 100/01 (9.75%) had a higher mean dry matter disappearance value than ICEAP 00557 (10.72%) and ICEAP 01514 (9.08%). Slowly degradable fractions of all varieties were not different (P > 0.05) on drying methods. The degradation rate constant of the slowly degradable fraction was not different (P > 0.05) for the three *C. cajan* varieties. There was no difference (P > 0.05) in the mean potentially degradable fraction across all *C. cajan* varieties. Fig. 1 shows that the maximum extent of *in vitro* DM disappearance was higher for variety ICEAP 00557 followed by ICEAP 01514 and least for CIMMYT 100/01 on drying methods. The effective *in vitro* degradabilities of the varieties were different (P < 0.01) at a rumen fractional outflow rate of 2% and 5% per hour. Variety ICEAP 00557 (33.95% DM) and ICEAP 01514 (33.80% DM) had the higher effective degradability than CIMMYT 100/01 (33.09% DM) at rumen outflow rate of 2%. Similarly, variety ICEAP 00557 (31.62% DM) and ICEAP 01514 (31.43% DM) had a higher effective degradability than CIMMYT 100/01 (30.34% DM) at rumen outflow rate of 5%. The effective degradabilities of these varieties were different (P < 0.05) at a rumen outflow rate of 8% per hour. Variety ICEAP 00557 (29.79% DM) and ICEAP 01514 (29.51% DM) had a higher effective degradability than CIMMYT 100/01 (28.17% DM) at rumen outflow rate of 8% (Table 2). Shade-dried varieties had a (P < 0.05) higher effective degradability than oven-dried materials, 36.97% vs. 30.31% DM at k = 2% per hour, 34.18% vs. 28.08% DM at k = 5% per hour and 31.98% vs. 26.32% DM at k = 8% per hour, respectively.

3.3. In sacco ruminal degradability

The mean *in sacco* rumen degradation constants a, b, c and $a + b$ for dry matter (DM) of the three *C. cajan* varieties are given in Table 3. Variety ICEAP 01514 (6.47%) and CIMMYT 100/01 (5.97%) had higher mean dry matter disappearance values than ICEAP 00557 (5.44%). Similarly, there were differences (P < 0.05) in the slowly degradable fraction of all the 3 varieties but the drying method had no significant effect. Variety CIMMYT 100/01 (41.32%) and ICEAP 01514 (36.73%) had higher mean dry matter disappearance value than ICEAP 00557 (35.56%). Degradation rate constants of the slowly degradable fraction were different (P < 0.05) across the three *C. cajan* varieties, but were not affected by the drying method. There was a difference (P > 0.05) in the mean potentially degradable fraction across all *C. cajan* varieties. From Fig. 2, the maximum extent of *in sacco* DM disappearance was higher for variety CIMMYT 100/01 followed by ICEAP 01514 and least for ICEAP 00557 on drying methods. The effective *in sacco* degradability of the varieties was different (P < 0.05) at a rumen fractional outflow rate of 2% and 5% per hour. Variety ICEAP 01514 (42.00% DM) and CIMMYT 100/01 (41.76% DM) had a higher effective degradability than ICEAP 00557 (37.88% DM) at a rumen outflow rate of 2%. Variety ICEAP 01514 (36.56% DM) and CIMMYT 100/01 (35.83% DM) had a higher effective degradability than ICEAP 00557

Table 1
Proximate composition (DM basis) of either oven- or shade-dried *Cajanus cajan* varieties grown in the subtropics.

Item	Drying method	CP, %	NDF, %	ADF, %	ADL, %	NDIN, %	ADIN, %	Ash, %	Ca, %	P, %
ICEAP 00557[1]	Oven-dried	24.03^{b}	51.34^{a}	46.42^{a}	23.34^{a}	2.35^{a}	2.03^{a}	9.05^{a}	1.27^{a}	0.26^{b}
	Shade-dried	24.35^{b}	49.26^{a}	46.05^{a}	22.66^{a}	2.48^{a}	2.28^{a}	8.42^{a}	1.21^{a}	0.25^{b}
ICEAP 01514[2]	Oven-dried	24.46^{b}	50.06^{a}	45.42^{a}	18.04^{a}	2.16^{b}	1.87^{b}	8.93^{a}	1.23^{a}	0.27^{b}
	Shade-dried	25.67^{a}	49.38^{a}	44.43^{a}	21.42^{a}	2.36^{a}	2.11^{a}	9.01^{a}	1.29^{a}	0.30^{a}
CIMMYT 100/01[3]	Oven-dried	23.52^{b}	52.49^{a}	46.17^{a}	19.52^{a}	2.43^{a}	2.04^{a}	9.48^{a}	1.40^{a}	0.27^{b}
	Shade-dried	24.57^{b}	51.17^{a}	46.54^{a}	19.13^{a}	2.33^{a}	2.02^{a}	9.12^{a}	1.35^{a}	0.28^{a}
SEM	V	0.26	0.83	0.84	1.29	0.06	0.06	0.32	0.06	0.01
	D	0.21	0.68	0.74	1.05	0.05	0.05	0.26	0.05	0.01
	V × D	0.37	1.17	1.18	1.83	0.08	0.08	0.45	0.09	0.01
Significance	V	*	NS	NS	NS	NS	NS	NS	NS	*
	D	NS	NS	NS	NS	NS	NS	NS	NS	NS
	V × D	*	NS	NS	NS	*	**	NS	NS	*

NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; NDIN = neutral detergent insoluble nitrogen; ADIN = acid detergent insoluble nitrogen; SEM = standard error of the mean; V = variety; D = drying method.
[a–d] Means within the same column having different superscripts were significantly different ($P < 0.05$). Significance level: ** = significant at $P < 0.01$; * = significant at $P < 0.05$; NS = not significant at $P > 0.05$.
[1] Chitedze 1.
[2] Chitedze 2.
[3] Cimmyt 3.

Table 2
In vitro dry matter degradability parameters (%) of either oven- or shade-dried *Cajanus cajan* varieties grown in the subtropics.

Item	Drying method	Degradability coefficients				Effective degradability		
		a	*b*	*a* + *b*	*c*	*p*(*k* = 0.02)	*p*(*k* = 0.05)	*p*(*k* = 0.08)
ICEAP 00557	Oven-dried	8.78^{a}	24.03^{a}	32.81^{a}	0.22^{a}	30.79^{b}	28.32^{b}	26.35^{c}
	Shade-dried	10.72^{as}	28.21^{a}	38.93^{a}	1.27^{a}	37.10^{a}	34.92^{a}	33.22^{a}
ICEAP 01514	Oven-dried	6.91^{b}	31.77^{a}	38.67^{a}	0.26^{a}	29.79^{b}	28.09^{c}	26.65^{c}
	Shade-dried	11.25^{a}	29.09^{a}	40.34^{a}	0.22^{a}	37.81^{a}	34.77^{a}	32.37^{a}
CIMMYT 100/01	Oven-dried	9.88^{a}	22.29^{a}	32.17^{a}	0.23^{a}	30.18^{b}	27.82^{c}	25.97^{c}
	Shade-dried	7.12^{b}	31.48^{a}	38.60^{a}	0.24^{a}	36.00^{a}	32.86^{a}	30.36^{b}
SEM	V	0.61	2.72	2.42	0.30	0.82	0.49	0.42
	D	0.49	2.22	1.97	0.24	0.67	0.39	0.34
	V × D	0.86	3.85	3.42	0.42	1.16	0.69	0.59
Significance	V	NS	NS	NS	NS	NS	NS	*
	D	NS	NS	NS	NS	NS	NS	NS
	V × D	*	NS	NS	NS	*	**	*

a = soluble fraction; *b* = slowly degradable fraction; *a* + *b* = potentially degradable fraction; *c* = degradation rate constant; *p* = effective degradability; *k* = ruminal passage rate; SEM = standard error of the mean; V = variety; D = drying method.
[a–d] Means within the same column having different superscripts were significantly different ($P < 0.05$); Significance level: ** = significant at $P < 0.01$; * = significant at $P < 0.05$; NS = not significant at $P > 0.05$.

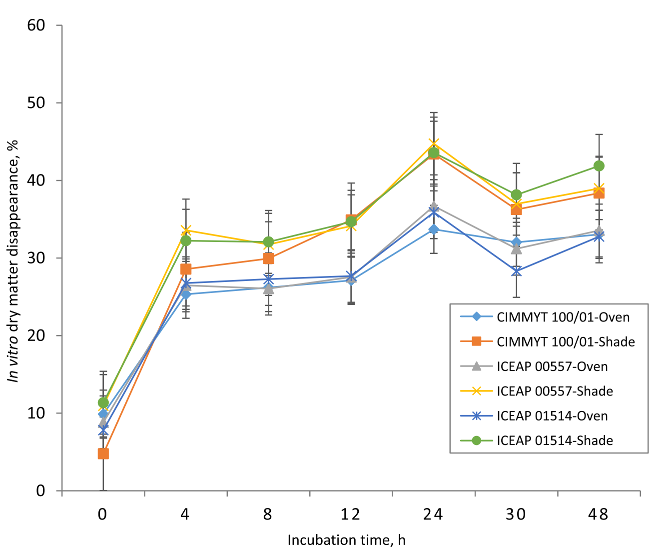

Fig. 1. *In vitro* dry matter disappearance (%) of either oven- or shade-dried *Cajanus cajan* varieties grown in the subtropics.

(34.13% DM) at rumen outflow rate of 5%. Similarly, the effective degradability of these varieties were different ($P < 0.05$) at a rumen outflow rate of 8% per hour. Variety ICEAP 01514 (33.05% DM) and CIMMYT 100/01 (31.62% DM) had a higher effective degradability followed by ICEAP 00557 (31.17% DM) at rumen outflow rate of 8% (Table 3). Shade-dried varieties had a ($P < 0.05$) higher effective degradability than oven-dried materials, 43.28% vs. 37.81% DM at $k = 2\%$ per hour, 37.98% vs. 32.02% DM at $k = 5\%$ per hour and 34.39% vs. 29.50% DM at $k = 8\%$ per hour, respectively.

4. Discussion

4.1. Chemical composition

According to the quality standard defined by Garcia et al. (2003) and Rivera and Parish (2010), the CP value of the assessed varieties fall within very good quality standards. High content of NDF decreases feed intake, but the NDF average of 50.62% observed in this study falls within the good standard of 47% to 53% (Garcia et al., 2003). In the present studied *C. cajan* varieties, the higher lignin and NDF contents were recorded by the varieties ICEAP 00557 and CIMMYT 100/01. Akin to this study, Cheva-Isarakul (1992) also reported 61% NDF value. The range of ash content of *C. cajan* (8.5% to

Table 3
In sacco dry matter degradability parameters (%) of either oven- or shade-dried *Cajanus cajan* varieties grown in the subtropics.

Item	Drying method	Degradability coefficients				Effective degradability		
		a	*b*	*a* + *b*	*c*	*p*(*k* = 0.02)	*p*(*k* = 0.05)	*p*(*k* = 0.08)
ICEAP 00557	Oven-dried	4.15[b]	32.53[b]	36.68[b]	0.25[a]	34.01[b]	30.78[b]	28.21[b]
	Shade-dried	6.72[a]	38.59[a]	45.31[a]	0.19[a]	41.74[a]	37.47[a]	34.13[a]
ICEAP 01514	Oven-dried	5.11[b]	33.66[b]	38.77[b]	0.23[a]	40.69[a]	34.72[a]	30.50[b]
	Shade-dried	7.82[a]	39.79[a]	47.60[a]	0.17[a]	43.31[a]	38.39[a]	35.60[a]
CIMMYT 100/01	Oven-dried	4.84[b]	38.51[a]	43.36[a]	0.15[a]	38.72[a]	33.56[a]	29.79[b]
	Shade-dried	7.10[a]	44.13[a]	51.24[a]	0.12[b]	44.79[a]	38.09[a]	33.44[a]
SEM	V	0.49	2.09	2.04	0.02	1.77	1.26	0.93
	D	0.39	1.71	1.66	0.02	1.45	1.03	0.76
	V × D	0.69	2.96	2.88	0.03	2.50	1.79	1.32
Significance	V	NS	NS	NS	*	NS	NS	NS
	D	NS	NS	NS	NS	NS	NS	NS
	V × D	*	*	*	*	*	*	*

a = soluble fraction; *b* = slowly degradable fraction; *a* + *b* = potentially degradable fraction; *c* = degradation rate constant; *p* = effective degradability; *k* = ruminal passage rate; SEM = standard error of the mean; V = variety; D = drying method.
[a–d] Means within the same column having different superscripts were significantly different ($P < 0.05$); Significance level: ** = significant at $P < 0.01$; * = significant at $P < 0.05$; NS = not significant at $P > 0.05$.

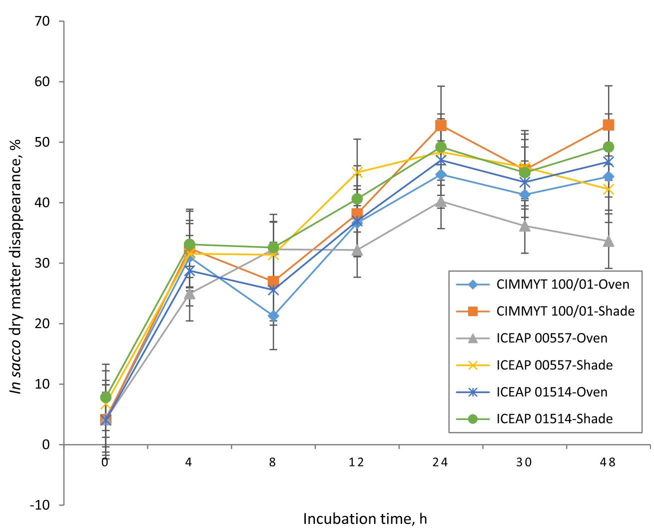

Fig. 2. *In sacco* dry matter disappearance (%) of either oven- or shade-dried *Cajanus cajan* varieties grown in the subtropics.

9.5%) obtained in this study was higher than the 5.8% outlined by Dzowela et al. (1995). However, it is also essential to account that not merely the browse variety, the sampling site, climatic conditions, soil and management conditions and stage at harvest also affects the nutrient acquisition (Adjolohoun et al., 2013). The higher fibre and lignin components produced by oven drying method in this study is consistent with the results obtained by other researchers (Goering and van Soest, 1970; Burrit et al., 1988; Nastis and Malechek, 1988; Papachristou and Nastis, 1994), which is thought to be due to the formation of artefact lignin. The ADF and NDF contents of oven-dried *C. cajan* varieties obtained in this study is within the range 50% to 60%, respectively as reported by Dzowela et al. (1995). The differences in chemical constituents between oven-dried and shade-dried samples are primarily attributed to the formation of insoluble polymers, non-enzymatic browning effect or Maillard reaction (Van Soest, 1982). Maillard reaction is a heat-induced chemical reaction between protein (amino acids) and sugars (Ramsumair et al., 2014). However, these differences may simply be due to loss of organic matter (Acosta-Gonzalez and Kothman, 1978). This explanation is consistent with the study by Mayhuddin et al. (1988) mainly with respect to *Ficus macrophylla*. Sun-air drying exposes the material to ultra-violet radiation, which reacts with forage constituents to increase ADF and NDF. This was observed in the study in both *Acacia angustissima* and *F. macrophylla*, which had exceedingly high range of ADF (50.6% to 55.0%), NDF (58.7% to 61.8%) and lignin (14.3% to 19.3%) when sun-air dried.

4.2. In vitro ruminal degradability

Parameters *a*, *b*, and *p* of IVDMD were consistent with the range of values reported for legumes (Hoffman et al., 1993; Marichal et al., 2010), grasses (Van Vuuren et al., 1992), high dry matter forages (Varga and Hoover, 1983), and by-products (DePeters et al., 1997; Pereira and Gonzalez, 2004; Varga and Hoover, 1983). Exceptions were the high DMD kinetics in variety CIMMYT 100/01, which could have resulted from their high DM disappearance in early hours (i.e., 4 h) of incubation. Forages may differ critically in brittleness, and thus the distribution in size, and composition of particles passing a screen might vary (Lindberg and Knutsson, 1981).

4.3. In sacco ruminal degradability

The least soluble fraction (*b*) of leaves documented in variety CIMMYT 100/01 could be linked to the loss of finer particles from the bags in this treatment. The lower values of *a* in the present study compared to the *a* values assessed for 20 multipurpose trees and shrub species studied by Ngodigha and Anyanwu (2009) is attributed to the variation of the plant varieties. Higher level of soluble fraction results in more efficient rumen fermentation. The differences in soluble fraction could be ascribed to the proportion of soluble carbohydrates to structural carbohydrates. Soluble carbohydrates ferment faster than structural carbohydrates (Van Soest, 1982). The *in sacco* effective degradability decreased with oven-drying method in the three browse varieties. The changes in effective degradability with high drying temperature relate to the changes in the proportions of potentially degradable DM and increase in NDF content of the fodder. This is in agreement with these reports by Balde et al. (1993) and Hadjipanayiotou et al. (1996). Variety ICEAP 01514 maintained higher effective degradability, with CIMMYT 100/01 being intermediate and ICEAP 00557 was the least. These differences could have been caused by the browse variety variation in fibre content. Forages with low fibre content have been found to have higher effective degradabilities than those with high fibre content (Llamas-Lamas and Combs, 1990). In this study, the *in sacco* dry matter disappearance lower in variety ICEAP 00557 as compared to ICEAP 01514 and CIMMYT 100/01. The latter result might have been associated with the differences in cell wall structure and in components between those of the three *C. Cajanus* varieties.

5. Conclusion

The 3 subtropical forage pigeon pea varieties showed a great variation in chemical composition and ruminal degradability. Variety ICEAP 00557 yielded high ruminal degradability when shade-dried. Variety ICEAP 00557 was therefore of high practical feeding value to ruminants. Shade-dried varieties had higher effective degradabilities than oven-dried materials during IV Daisy[II] and *in sacco* procedures. Therefore, air-drying in the shade is the best technique that can be employed in forage preparation for laboratory purposes based on its ability to improve degradability of forages. However, this method can lengthen the drying periods.

Conflicts of interest

The authors have no competing interests to declare.

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