Original Research Article

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

Lindokuhle S. Buthelezi a,*, John F. Mupangwa a, Voster Muchenje a, Florence V. Nherera-Chokuda b

a University of Fort Hare, Department of Livestock and Pasture Science, Private Bag X1314, Alice 5700, South Africa
b Agricultural Research Council, Animal Production Institute, Private Bag X2, Irene 0062, South Africa

ARTICLE INFO

Article history:
Received 23 November 2017
Received in revised form 9 March 2018
Accepted 12 March 2018
Available online 24 March 2018

Keywords:
Forages
In vitro
In sacco
Degradation
Drying methods

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) 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.

© 2019, Chinese Association of Animal Science and Veterinary Medicine. Production and hosting by Elsevier B.V. on behalf of KeAi Communications Co., Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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 to 15 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.
(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 small-holder 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 tree leaves (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 small-holder 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 tree leaves (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 small-holder 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.
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):

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

(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):

\[ ED = a + |bc/(k + c)| \]  

(2b)

where \( ED \) = effective degradability, and \( a, b, c \) and \( k \) 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 constituents and on DM disappearance coefficients \( a, b, c, a + b \) and \( P \) of IICEAP 00557, IICEAP 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:

\[ Y_{ijkl} = \mu + T_i + V_j + D_k + (VDT)_{ijk} + E_{ijkl} \]  

(3)

where \( Y_{ijkl} \) = observation of the dependent variable; \( \mu \) = 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 \( j = 3 \); IICEAP 00557, IICEAP 01514 and CIMMYT 100/01; \( D_k \) = effect of drying method \( (k = \text{Oven-drying and shade-drying}) \); \( VDT_{ijk} \) = effect of interaction among variety at level \( j \), drying method at level \( k \) and incubation time at level \( l \); \( E_{ijkl} \) = the random error associated with observation \( ijk \).

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 IICEAP 01514 showed a higher \((P < 0.05)\) CP than IICEAP 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 IICEAP 01514 had a lower NDIN (21.6%) 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 \( V \times D \) 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 shown 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 IICEAP 00557 (10.72%) and IICEAP 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 IICEAP 00557 followed by IICEAP 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 IICEAP 00557 (33.95% DM) and IICEAP 01514 (33.80% DM) had the higher effective degradability than CIMMYT 100/01 (33.09% DM) at rumen outflow rate of 2%. Similarly, variety IICEAP 00557 (31.62% DM) and IICEAP 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 IICEAP 00557 (29.79% DM) and IICEAP 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 IICEAP 01514 (6.47%) and CIMMYT 100/01 (5.97%) had higher mean dry matter disappearance values than IICEAP 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 IICEAP 01514 (36.73%) had higher mean dry matter disappearance value than IICEAP 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 IICEAP 01514 and least for IICEAP 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 IICEAP 01514 (42.00% DM) and CIMMYT 100/01 (41.76% DM) had a higher effective degradability than IICEAP 00557 (37.88% DM) at a rumen outflow rate of 2%. Variety IICEAP 01514 (36.56% DM) and CIMMYT 100/01 (35.83% DM) had a higher effective degradability than IICEAP 00557.
rate; SEM \( \equiv \) NS

denitrogen; SEM \( \equiv \) NS \( \equiv \) NS

Cajanus cajan varieties grown in the subtropics.

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

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   | Oven-dried    | 24.03b | 51.34a | 46.42a | 23.34a | 2.35a   | 2.03a   | 9.05a | 1.27b | 0.26b |
|               | Shade-dried   | 24.35b | 49.26a | 46.05a | 22.66a | 2.48a   | 2.28a   | 8.42a | 1.21a | 0.25b |
| ICEAP 01514   | Oven-dried    | 24.46b | 50.06a | 45.42a | 18.04a | 2.16b   | 1.87b   | 8.93a | 1.23a | 0.27b |
|               | Shade-dried   | 25.67a | 49.38a | 44.43a | 21.42a | 2.38a   | 2.11a   | 9.01a | 1.29a | 0.30a |
| CIMMYT 100/01 | Oven-dried    | 23.52b | 52.49a | 46.17a | 19.52a | 2.43a   | 2.04a   | 9.48a | 1.40a | 0.27b |
|               | Shade-dried   | 24.57b | 51.17a | 45.64a | 19.13a | 2.33a   | 2.02a   | 9.12a | 1.35a | 0.28a |
| Shade-dried   | 24.03a        | 51.34a | 46.42a | 23.34a | 2.35a   | 2.03a   | 9.05a   | 1.27b | 0.26b |
| 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 |
| D × V         |               | 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    | NS   |
|               | D             | NS     | NS     | NS     | NS     | NS      | NS      | NS    | NS    | NS   |
| D × V         |               | *      | NS     | NS     | NS     | *       | **      | NS    | NS    | NS   |

DN D = 0.21 0.68 0.74 1.05 0.05 0.05 0.26 0.05 0.01

D * NS NS NS * ** NS NS NS *

DN D = 0.37 1.17 1.18 1.83 0.08 0.08 0.45 0.09 0.01

D * NS NS NS * ** NS NS NS *

DN D = 0.86 3.85 3.42 0.42 1.16 0.69 0.59 0.09 0.01

D * NS 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 | Degradation coefficients | Effective degradability |
|---------------|---------------|--------------------------|-------------------------|
|               |               | a b a + b c p(k = 0.02) p(k = 0.05) p(k = 0.08) |
| ICEAP 00557   | Oven-dried    | 8.78a 24.03a 32.81a 0.22a 30.79b 28.32a 26.35c |
|               | Shade-dried   | 10.72a 28.21a 38.93a 1.27a 37.10a 34.92a 33.22a |
| ICEAP 01514   | Oven-dried    | 6.91a 31.77a 38.67a 0.26a 29.79b 28.09a 26.65a |
|               | Shade-dried   | 11.25a 29.09a 40.34a 0.22a 37.81a 34.77a 32.37a |
| CIMMYT 100/01 | Oven-dried    | 9.88a 22.29a 32.17a 0.21a 30.18a 27.82a 25.97a |
|               | Shade-dried   | 7.12b 31.48a 38.60a 0.24a 36.00a 32.86a 30.36b |
| Shade-dried   | 7.12b         | 31.48a | 38.60a | 0.24a | 36.00a | 32.86a | 30.36b |
| SEM           | V             | 0.61   | 2.72   | 3.42   | 0.42   | 1.16   | 0.69   | 0.59  |
|               | D             | 0.49   | 2.22   | 1.97   | 0.24   | 0.67   | 0.39   | 0.34  |
| D × V         |               | 0.86   | 3.85   | 3.42   | 0.42   | 1.16   | 0.69   | 0.59  |
| Significance  | V             | *      | NS     | NS     | NS     | NS     | *      | NS    |
|               | D             | NS     | NS     | NS     | NS     | NS     | *      | NS    |
| D × V         |               | *      | NS     | 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 \( P > 0.05 \).

(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, 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
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

### Table 3

| 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<sup>a</sup> | 32.53<sup>b</sup> | 36.68<sup>b</sup> | 0.25<sup>a</sup> | 34.01<sup>b</sup> | 30.78<sup>b</sup> | 28.21<sup>b</sup> |
| ICEAP 01514 | Oven-dried | 5.11<sup>b</sup> | 33.66<sup>b</sup> | 38.77<sup>b</sup> | 0.23<sup>b</sup> | 40.69<sup>b</sup> | 34.72<sup>*</sup> | 30.50<sup>**</sup> |
| CIMMYT 100/01 | Oven-dried | 4.84<sup>b</sup> | 38.51<sup>a</sup> | 43.36<sup>a</sup> | 0.15<sup>a</sup> | 38.72<sup>a</sup> | 33.56<sup>a</sup> | 29.79<sup>a</sup> |
| 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 |

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.

<sup>a-d</sup> 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.
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 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.

Acknowledgements

Authors would like to thank the National Research Foundation of South Africa - Research and Technology Fund Grant 98715 for financial support.

References

A.O.A.C. Official methods of analysis. 15th ed. Washington, DC, USA: Association of official Analytical Chemists; 1990.

Acosta-Gonzalez RA, Kothman MM. Chemical composition of oesophageal-fistulated forage samples as influenced by drying method and salivary leaching. J Anim Sci 1978;47:691–8.

Adjolohou S, Dahouda M, Adanedjan C, Toleba S, Kindomihou V, Sinsin B. Evaluation of biomass production and nutritive value of nine Panicum maximum ecotypes in Central region of Benin. Afr J Agric Res 2013;8:1661–8.

Burrit EA, Pfister JA, Malecheck JC. Effect of drying method on the nutritive composition of oesophageal fistula forage samples: influence of maturity. J Range Manag 1988;41:346–9.

Cheva-Iaarakul B. Pigeon pea as a ruminant feed. Asian Australas J Anim Sci 1992;5(3):549–58.

Collins M, Cobentz WK. Postharvest physiology. In: Barnes RF, Nelson CJ, Moore KJ, Collins M, editors. Forages: The Science of Grassland Agriculture. 6th ed., vol. II; 2007, p. 583–90.

DePeters E, Fadel J, Arosemena A. Digestion kinetics of neutral fiber and chemical composition within some selected by-product feedstuffs. Anim Feed Sci Technol 1997;67:127–40.

Dzowela BH, Hove I, Mafongoya PL. Effect of drying method on chemical composition and in vitro digestibility of multi-purpose tree and shrub fodders. Trop Grassl 1995;29:263–9.

Fujihara S, Kasuga A, Aoyagi Y. Nitrogen-to-Protein conversion factors for common vegetables in Japan. J Food Sci 2001;66(3):412–5.

Garcia A, Thiez N, Kalscheur K, Tjardes K. Interpreting hay and haulage analysis. Rev 4002, ExEx, Dairy Science. USDA: South Dakota State University; 2003.

Goering HK, VanSoest PJ. Forage fibre analysis: apparatus, reagents, procedures and some applications. Agriculture handbook No. 379. Washington, DC, USA: USDA-ARS; 1970.

Hoffman PS, Sievert J, Shaver R, Welch D, Combs DK. In situ dry matter, protein, and fiber digestion of perennial forages. J Dairy Sci 1993;76:2632–43.

Lindberg JE, Koutsson PG. Effect of bag pore size on the loss of particulate matter and on the degradation of cell wall fibre. Agric Environ 1981;6:171–82.

Llamas-Lamas G, Combs DK. Effect of alfalfa maturity on fiber utilisation by high producing cows. J Dairy Sci 1990;73:1089.

Marichal deJ M, Carriquiry M, Astigarraga L, Trujillo AT. N fractionation, degradability, intestinal digestibility, and adequacy for ruminal microbial activity of cultivated legumes. Livest Res Rural Dev 2010;22(23). Retrieved February 9, 2016 from, http://www.lrrd.org/lrrd22/2/lrrd220223.htm.

Mayhuddin P, Little DA, Lowry JB. Drying treatment drastically affects feed evaluation and feed quality with certain tropical forage species. Anim Feed Sci Technol 1988;22:69–78.

McDonald P, Edwards RA, Greenhalgh JFD, Morgan CA. Animal nutrition. 7th ed. London: Prentice Hall; 2002 [United States].

Nastis AS, Malechek JC. Estimating digestibility of oak browse diets for goats by in vitro techniques. J Range Manag 1988;41:255–8.

Orskov ER, McDonald I. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J Agric Sci 1979:92:499–503.

Osiji PO, Nashiai IV, Khalili H. Feed evaluation. In: ILCA manual 5. 1993. ILCA, Addis Ababa, Ethiopia. 40.

Papachristou TG, Nastis AS. Changes in chemical composition and in vitro digestibility of oesophageal fistula and hand plucked forage samples due to drying method and stage of maturity. Anim Feed Sci Technol 1994;46:87–95.

Pereira JC, Gonzalez J. Rumen degradability of dehydrated beet pulp and dehydrated citrus pulp. Anim Res 2004;53:99–110.

Ramusumar A, Mlambo V, Laloo CHO. Effect of drying method on the chemical composition of leaves from four tropical tree species. Trop Agric 2014;91:179–85.

Rivera JD, Parish JA. Interpreting forage and feed analysis reports. Mississippi: Mississippi State University Extension Service; 2010.

SAS Institute Inc. In: Proceedings of the twenty-eighth annual SAS® users group international conference. Cary, NC: SAS Institute Inc. 2003.

Van Soest PJ. Analytical systems for evaluation of feeds. In: van Soest PJ, editor. Nutritional ecology of the ruminant. Corvallis, Oregon, USA: O & B Books; 1982, p. 75–94.

Van Vuuren AM, Kriel-Kramer F, van der Lee RA, Corbijn H. Protein digestion and intestinal amino acids in dairy cows fed fresh Lolium perenne with different nitrogen contents. J Dairy Sci 1992;75:2215–22.

vanZante ES, Coehran RC, Tigemeyer EC. Standardization of in situ techniques for ruminant feedstuff evaluation. J Anim Sci 1998;76:2717–29.

Varga GA, Hoover WH. Rate and extent of neutral detergent fiber digestion in feedstuffs in situ. J Dairy Sci 1983;66:2109–16.