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Intake and digestion in sheep given fresh or air-dried *Acacia cyanophylla* Lindl foliage

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Summary — The effect of air-drying of *Acacia cyanophylla* Lindl foliage (acacia) on digestion in sheep was studied in November and December 1993 at Inra-Tunisia. Two groups of animals each including two intact and two rumen-cannulated 'Queue Fine de l'Ouest' adult sheep were offered 600 g dry matter (DM) lucerne hay and fresh or air-dried acacia foliage ad libitum. Diets were offered daily in two equal meals (08.00 and 16.00 h). A digestibility trial involving all animals and a digestion trial involving only rumen-cannulated animals were conducted according to a $2 \times 2 \times 4$ and a $2 \times 2 \times 2$ cross-over design, respectively. Each experimental period lasted 25 days, with total faecal collections, rumen fluid samplings (0, 2, 4 and 8 h post feeding) and ruminal cellulolytic activity using the nylon bag technique being made over the final 10 days. The organic matter, fibre (NDF, ADF and ADL) and crude protein (CP) contents were similar in fresh and air-dried acacia (42.9 vs 44.4, 27.0 vs 25.9, 14.1 vs 12.2, 11.9 vs 11.2% of DM, respectively). Acacia foliage, either fresh or air-dried, had a high content of insoluble nitrogen (79.0 and 84.5% of total nitrogen, respectively) and nitrogen bound to ADF (15.4 and 13.8% of total nitrogen, respectively). Air-drying reduced methanol extractable condensed tannins in acacia foliage (from 5.1 to 4.3 g catechin equivalent/100 g DM). DM intake of acacia was significantly increased ($P < 0.05$) by air-drying (from 52 to 56 g DM kg^{-1} $LW^{0.75}$). Remarkably, acacia intake was changed from day to day. Peaks were observed every 4 or 5 days in all animals. Sheep seem to regulate acacia consumption in function of tannin accumulation elsewhere in the body. The diet and acacia nutrient digestibilities were not affected by air-drying. CP digestibility of acacia was in the range 23–30%. Patterns of rumen fermentation assessed by pH, ammonia nitrogen and volatile fatty acid concentration and composition were similar in fresh and air-dried acacia treatments. There was no indication of any inhibition of ruminal fermentation with either diet. Cellulolytic activity was not affected by acacia air-drying. The increased intake of acacia foliage which

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occurred without any changes of acacia nutrient digestibilities and pattern of rumen fermentation suggests that the response was mediated probably by a decrease of the astringent taste of fresh acacia due to air-drying.

***Acacia cyanophylla* Lindl / digestion / sheep**

Résumé — Ingestion et digestion chez le mouton recevant des feuilles d'*Acacia cyanophylla* Lindl fraîches ou séchées naturellement. L'effet du séchage naturel des feuilles d'*Acacia cyanophylla* Lindl (acacia) sur la digestion chez le mouton a été étudié (en novembre et décembre 1993 à l'Inra-Tunisie). Deux groupes d'animaux comprenant chacun deux moutons normaux et deux moutons munis de canules du rumen, de race Queue Fine de l'Ouest, ont reçu 600 g MS de foin de luzerne et des phyllodes d'acacia fraîches ou séchées à l'air à volonté. Les régimes ont été distribués quotidiennement en deux repas égaux (8 et 16 h). Les mesures de digestibilité ont été effectuées sur tous les animaux et les mesures des paramètres de fermentation ont été réalisées sur les animaux munis de canules du rumen selon un dispositif en *cross-over* (deux régimes × deux périodes). Chaque période expérimentale a duré 25 j, dont 15 j d'adaptation et 10 j de mesures (collecte totale des fèces, prélèvement pendant 2 j du jus de rumen (0, 2, 4 et 8 h après le repas du matin) et de l'activité cellulolytique en incubant dans le rumen des sachets nylon contenant du papier filtre pendant 0, 4, 8, 12, 24, 48, 72 et 96 h). Les teneurs des feuilles d'acacia en matière organique, glucides pariétaux (NDF, ADF et ADL) et en matières azotées totales (MAT) n'ont pas varié avec le séchage (42,9 vs 44,4; 27,0 vs 25,9; 14,1 vs 12,2; 11,9 vs 11,2 % MS, respectivement). Les proportions d'azote insoluble et d'azote lié à la lignocellulose (ADF) ont été élevées dans l'acacia frais et séché (79,0 vs 84,5 et 15,4 vs 13,8 % de l'azote total, respectivement). Le séchage a provoqué une diminution de la concentration des tanins condensés extraits dans le méthanol (de 5,1 à 4,3 g équivalent catechine par 100 g de MS). Les quantités d'acacia ingérées ont été significativement améliorées par le séchage (56 vs 52 g MS kg^{-1} $P^{0.75}$). Une évolution cyclique de l'ingestion d'acacia frais et séché a été observée dans cette étude chez tous les moutons comme si le mouton avait tendance à contrôler la consommation d'acacia en fonction du niveau de tanins accumulés dans l'organisme. La digestibilité du régime et celle de l'acacia n'ont pas été significativement modifiées avec le séchage. La digestibilité des MAT a été de 23 et 30 %, respectivement pour l'acacia frais et l'acacia séché. La fermentation ruminale évaluée par le pH, la concentration en azote ammoniacal et des acides gras volatils a été la même avec les régimes à base d'acacia frais et séché. L'activité cellulolytique n'a pas non plus été affectée par le séchage. L'augmentation de l'ingestion d'acacia associée à l'absence de variation de la digestibilité de tous les nutriments de l'acacia et de la fermentation ruminale suggèrent que cette augmentation de la consommation d'acacia pourrait être liée à une réduction du goût astringent de l'acacia frais due au séchage.

***Acacia cyanophylla* Lindl / digestion / mouton**

INTRODUCTION

Acacia cyanophylla Lindl, classified also as *Acacia saligna* (Labill) H Wendl or *Acacia glauca* Hort, is an evergreen leguminous tree extensively established in Tunisia for range land rehabilitation. It is considered as an important fodder resource for livestock feeding in arid and semi-arid regions. Acacia plantation is usually grazed heavily from November to January to utilise herbaceous growth between the rows and the acacia foliage within reach of sheep and goats. Thereafter, browsed trees are cut and branches are fed to animals in the barn. Earlier reports (Reed et al, 1990; Ben Salem and Nefzaoui, 1993; Ben Salem et al, 1994; Ben Salem et al, in press) showed that despite the relative high palatability and crude protein content, *Acacia cyanophylla* foliage had a low nutritive value due to the presence of large amounts of condensed tannins. It was reviewed elsewhere (Kumar and Vaithiyanathan, 1990; Leinmüller et al, 1991;

Reed, 1995) that condensed tannins form insoluble complexes with proteins in the gut. Field experience of several farmers and herdsmen indicates that air-dried material of woody species is more palatable than fresh material. Moreover, it was hypothesised by some authors (Dumancic and Le Houérou, 1981; Tiedeman and Johnson, 1992) that *Acacia cyanophylla* intake could be increased by air-drying. These hypotheses need to be supported by experimental data, since no direct experimental evidence exists. Because acacia generates substantial amounts of biomass which can not be consumed by the flock in a short period of time, it appears necessary to investigate whether air-drying could be used as a technique for storage and for improving the nutritive value of acacia. This paper reports results of a comparative study of digestion in sheep given fresh or air-dried *Acacia cyanophylla* Lindl foliage-based diet.

MATERIALS AND METHODS

The experiment was conducted at the Inra-Tunisia experimental station at Oueslatia, Central Tunisia (35°51′ N and 9°35′ E) between November and December 1993. Mean annual rainfall (average of 25 years) in this station was about 390 mm.

Plant material

A 50-hectare plot of *Acacia cyanophylla* Lindl (acacia) was established in 1989. Acacia plantation was used by sheep and goats as a 3-year-old stand and was thereafter cut every 2 years. Sheep and goats are usually allowed to browse acacia within reach from November to January and then trees are cut at about 20 cm stump height. Pruned branches are fed to animals in the barn.

Acacia foliage (leaves and twigs) used in this experiment corresponds to the current-year and 2-year-old material. During the course of the experiment each morning at 06.00 h branches of acacia were harvested and leaves were separated manually. Part of fresh material was immediately distributed to animals and the other part was air-dried in a shady site for 1 week before feeding to animals. Lucerne hay was purchased from the Chenchou pilot farm of the 'Office de l'Elevage et des Pâturages' (OEP). Average daily temperatures measured under shade during the experimental period were, 26.0, 19.1, and 16.0°C, respectively in October, November and December 1993. Acacia harvesting and drying started 1 week before the feeding period so that animals received daily a 7-day air-dried acacia foliage.

Animals, diets and experimental design

Four intact and four rumen-cannulated sheep ('Queue Fine de l'Ouest' breed, initial live weight 40–44 kg) were used. Two homogeneous groups each including two intact and two sheep fitted with rumen cannulae were housed in metabolism pens during the experimental period. Each group was given one of the following diets: fresh acacia foliage ad libitum + 600 g DM lucerne hay + 30 g mineral and vitamin supplement (MVS); or air-dried acacia foliage ad libitum + 600 g DM lucerne hay + 30 g MVS.

Acacia leaves and lucerne hay were fed at the same time in separate buckets. Diets were tested according to a cross-over design (two periods × two diets) for digestibility measurements on eight animals and two periods × two diets for studies of rumen function on four rumen-cannulated animals. Acacia was offered ad libitum allowing for 20% refusals, sometimes more. The quantity of lucerne hay approximately supplied maintenance requirements (40 g digestible crude protein intake/day, and 23 g digestible organic matter intake/kg $LW^{0.75}$) according to Inra (1978) recommendations. Lucerne hay consumption was 100%. The mineral and vitamin supplement (MVS) used was purchased from the market. The declared composition of MVS was: 60% calcium carbonate, 5% trace minerals, 30% salt and 5% vitamins.

Sheep were accustomed to experimental diets for 15 days (day 1 to day 15) before a 10-day measurement period (day 16 to day 25). Diets were fed in two equal meals at 08.00 and 16.00 h. Drinking water was continuously available.

Measurements

Diet digestibility was measured by total faeces collection for 10 consecutive days (day 16 to day 25). During the collection phase, daily samples of each feed, feed refusals and faeces were taken. Refusal and faecal samples representing approximately 10% of the daily refusal and faecal production were prepared. Individual urine production was daily collected into plastic vessels which contained 100 mL of a 10% H_2SO_4 solution to prevent volatilisation of ammonia nitrogen. A 10% aliquot was removed each day and stored at −10°C. At the end of the collection phase, daily samples of feed ingredients, feed refusal, faeces and urine were bulked over the 10-day collection period, thoroughly mixed and subsamples taken. Subsamples of offered feed, refusals and faeces were air-dried in a forced-air oven at 40°C for 48 h, ground to pass through a 1-mm screen and stored for subsequent analyses. Acacia digestibility was calculated by difference. The digestibility of the same lucerne hay used in this experiment was measured on sheep in a previous work (Ben Salem et al, in press).

During days 22 and 23, about 50 mL of rumen fluid were withdrawn from the rumen-cannulated sheep just before the morning meal (0 h) and at 2, 4 and 8 h post feeding. The pH was immediately measured and then rumen fluid was filtered through four layers of cheesecloth. Samples were obtained and stored at −20°C until needed, one for ammonia nitrogen analysis (10 mL rumen fluid + four drops of H_2SO_4) and one for volatile fatty acid analysis (8 mL rumen fluid + 1 mL mercuric chloride + 1 mL 5% orthophosphoric acid). Samples of unfiltered rumen fluid were obtained at the 2-h sampling time and stored at 4°C for protozoa counting (5 mL rumen fluid + 5 mL of 1:10 diluted formalin solution).

The nylon bag technique described by Ørskov et al (1980) was used to study rumen cellulolytic activity in rumen-cannulated sheep. Approximately 2 g of Whatman no 1 filter paper used as a cellulolytic source (ground through a 3-mm screen) were placed in nylon bags (50 µm pore size) measuring 9 cm by 7 cm. The bags were randomly attached to a 25-cm plastic tube which had seven holes. The tube was suspended in the rumen on a 40-cm nylon line. Bags were incubated in duplicate for 4, 8, 12, 24, 48, 72 and 96 h. After removal, bags were washed for three 5-min cycles in a mini-washing machine, and dried at 60°C for 48 h. DM disappearance was determined. Degradation rates for DM were estimated according to the model of Ørskov and McDonald (1979):

$$D(t) = a + b\,(1 - e^{-ct})$$

Where, $D(t)$ is the degradation at time t (%), a is the rapidly degradable fraction, b is the slowly degradable fraction and c is the rate of degradation of fraction b.

Laboratory analyses

Samples of feed, refusals and faeces pooled by animal across the 10-day collection phase, were analysed for organic matter (OM) and Kjeldahl crude protein (CP) by standard procedures (AOAC, 1975). They were also analysed for their content of neutral detergent fibre (NDF) and non-sequential acid detergent fibre (ADF) and acid detergent lignin (ADL) contents according to Goering and Van Soest (1970). These two components (ADF and ADL) were analysed only in feed. Nitrogen profiles of fresh and air-dried acacia were determined by analysing soluble nitrogen (McDougall, 1948), ammonia nitrogen by steam distillation (Markham, 1942) and ADF-bound nitrogen by Kjeldahl analysis of ADF (Goering and Van Soest, 1970). Acacia condensed tannins extracted in aqueous methanol (50%) were analysed by the vanillin-HCl procedure of Broadhurst and Jones (1978). Catechin (Sigma, Lot 100H0586) was used as standard. Urine samples were analysed for Kjeldahl nitrogen content. Ruminal fluid samples were thawed and centrifuged at 2500 g for 15 min. Ammonia nitrogen (NH_3-N) was determined by the Conway (1962) method and volatile fatty acid (VFA) concentration and composition were analysed by GLC according to Jouany (1982). Protozoa population was enumerated using a haemocytometer counting chamber (Malassez, Germany) with a depth of 0.1 mm as described by Warner (1962).

Statistical analyses

The eight (digestibility data) or the four (rumen fermentation data) animals and the two periods were used to give a cross-over design for comparing the two diets. Data were analysed using GLM procedure of SAS (1985).

Table I. Chemical composition of feeds (% DM).

Item	*Acacia cyanophylla Lindl foliage*		*Lucerne hay*
	Fresh	*Air-dried*	
DM (%)	49.8	86.2	84.1
OM	87.5	86.9	87.7
CP	11.9	11.2	23.8
NDF	42.9	44.4	37.1
ADF	27.0	25.9	25.9
ADL	14.1	12.2	5.1
Condensed tannins[1]	5.1	4.3	0.1

[1]Expressed as g catechin equivalent / 100 g DM.

Table II. Nitrogen profiles of *Acacia cyanophylla* Lindl foliage.

Item	*Acacia cyanophylla Lindl foliage*	
	Fresh	*Air-dried*
Total nitrogen (Nt,% of DM)	1.9 (0.13)	1.8 (0.21)
Soluble nitrogen (% of Nt)	21.0 (0.65)	15.5 (3.18)
Ammonia nitrogen (% of Nt)	3.9 (1.12)	2.4 (0.72)
N-ADF (% of Nt)	15.4 (1.55)	13.8 (1.42)

Values are means of four replicates per treatment. Standard deviation is reported between parentheses.

RESULTS

Chemical composition

The composition of the feedstuffs is presented in table I. OM, CP and NDF contents of fresh and air-dried acacia foliage were quite similar. As expected, air-drying decreased the proportion of methanol extractable condensed tannins in acacia foliage from 5.1 to 4.3% of DM. The CP content in either fresh or air-dried acacia averaged 11% of DM. Nitrogen profiles reported in table II indicate that fresh acacia is higher in soluble nitrogen and in nitrogen bound to ADF than air-dried material. Overall, nitrogen solubility of acacia is low, not exceeding 21% of the total nitrogen.

Intake and digestibility

The intake and digestibility coefficients are given in table III. Sheep consumed more air-dried acacia than fresh acacia ($P < 0.05$; 56 and 52 g DM/kg $LW^{0.75}$, respectively).

Table III. Intake and apparent digestibility of *Acacia cyanophylla* Lindl foliage and total diet.

Item	*Diets*		*SE*	*P*
	Fresh acacia	*Air-dried acacia*		
DM intake (g / day / sheep)				
Acacia	861	935	20.1	0.03
Diet	1345	1458	39.2	0.04
DM intake (g / kg $LW^{0.75}$)				
Acacia	52.6	56.5	1.19	0.04
Diet	84.1	88.2	1.32	0.04
Diet digestibility (%)				
DM	55.4	55.5	1.50	0.93
OM	58.1	58.0	1.62	0.90
CP	49.2	50.8	1.73	0.64
NDF	37.7	39.2	2.71	0.71
Acacia digestibility (%)[1]				
DM	50.3	51.1	2.53	0.95
OM	52.7	53.3	2.72	0.97
CP	23.4	30.3	4.21	0.42
NDF	33.0	32.0	1.16	0.56
Nutritive value of diets				
DOMi (g/kg $LW^{0.75}$)	44.6	47.7	1.03	0.70
DCPi (g/day)	109.5	115.7	3.10	0.61

[1]Calculated by difference; DM, OM, CP and NDF digestibility of lucerne hay were 63.2, 66.5, 68.5 and 56.3%, respectively according to Ben Salem et al (in press).

The DM intake of acacia foliage was measured since the beginning of the experiment. Figure 1a, b illustrate the individual variation of acacia intake during the course of the experiment. The DM intake of fresh as well as air-dried acacia foliage was not constant. Even after the 15-day adaptation period, acacia intake was varying from time to time. Peaks of acacia intake by sheep were noticed approximately every 4 days. Afterwards, sheep reduced their acacia consumption.

No difference ($P > 0.05$) in apparent dietary OM, CP or NDF digestibilities existed between treatments (table III). Apparent CP digestibility of acacia, calculated by difference with the assumption that there are no interactions between lucerne hay and acacia, tended to increase with air-drying. In both treatments, CP digestibility of acacia foliage was low, 23 or 30%. The feeding value of diets assessed as digestible organic matter intake (DOMi) and digestible crude protein intake (DCPi) did not differ between treatments ($P > 0.05$).

The nitrogen balances shown in table IV indicate a trend for increased N intake ($P > 0.05$) in sheep fed air-dried acacia compared with fresh acacia. Faecal and urinary N excretion were not altered by air-drying.

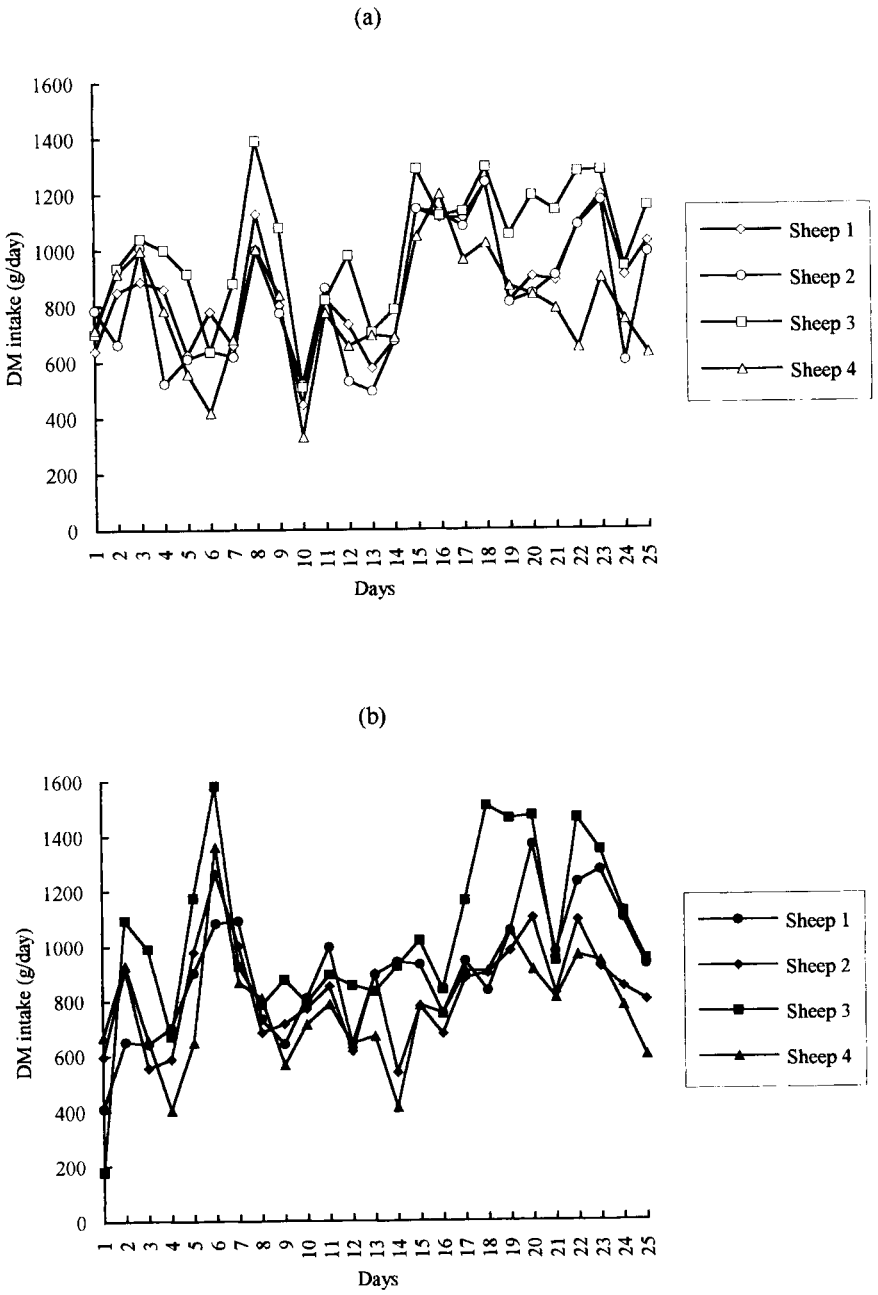

Fig 1. Daily variation of the dry matter intake of fresh **(a)** and air-dried **(b)** *Acacia cyanophylla* Lindl foliage.

Table IV. Nitrogen (N) intake and excretions in sheep fed fresh or air-dried *Acacia cyanophylla* Lindl foliage.

Item	*Diets*		*SE*	*P*
	Fresh acacia	*Air-dried acacia*		
N intake (g/day)	35.6	36.5	0.35	0.09
N excretions (g/day)				
Faeces	18.2	18.5	0.65	0.60
Urine	5.8	5.4	0.11	0.37
N-retained (g/day)	11.6	12.6	0.52	0.38

Rumen fermentation

Mean daily values for rumen pH, VFA, ammonia and protozoa are presented in table V. There was a slight decrease of the mean daily pH in the rumen of sheep fed air-dried versus fresh acacia foliage. For the post feeding sampling times, pH values were higher for fresh acacia than those for air-dried acacia (fig 2a). They fell after the morning meal. Mean daily ammonia concentrations were not affected by air-drying. Ammonia levels peaked at 2 h post feeding for all diets and then fell progressively reaching minimum values ranging from 40 to 60 mg NH_3-N L^{-1} rumen liquor (fig 2b). Air-drying resulted in a non-significant increase of total VFA concentrations. Sheep fed air-dried acacia exhibited over the day a slightly higher total VFA, acetate, propionate and butyrate concentration compared with those fed fresh acacia (fig 2c, d, e, f). Air-drying caused a significant decrease of protozoa number in the rumen fluid at the 2-h sampling time ($P < 0.05$).

Table V. Mean rumen VFA, NH_3-N, protozoa and pH in sheep given fresh or air-dried acacia foliage.

Item	*Diets*		*SE*	*P*
	Fresh acacia	*Air-dried acacia*		
pH	6.76	6.67	0.04	0.37
NH_3-N (mg/100 mL)	6.3	6.5	0.48	0.70
Total VFA (mmol/L)	67.7	77.4	4.76	0.23
Acetate (molar/100 mol)	74.6	75.7	3.49	0.17
Propionate (molar/100 mol)	17.1	16.9	0.94	0.30
Butyrate (molar/100 mol)	8.2	7.9	0.57	0.93
Acetate/propionate	4.5	4.9	0.14	0.28
Protozoa ($\times 10^5$ /mL)	4.5	2.8	0.36	0.04

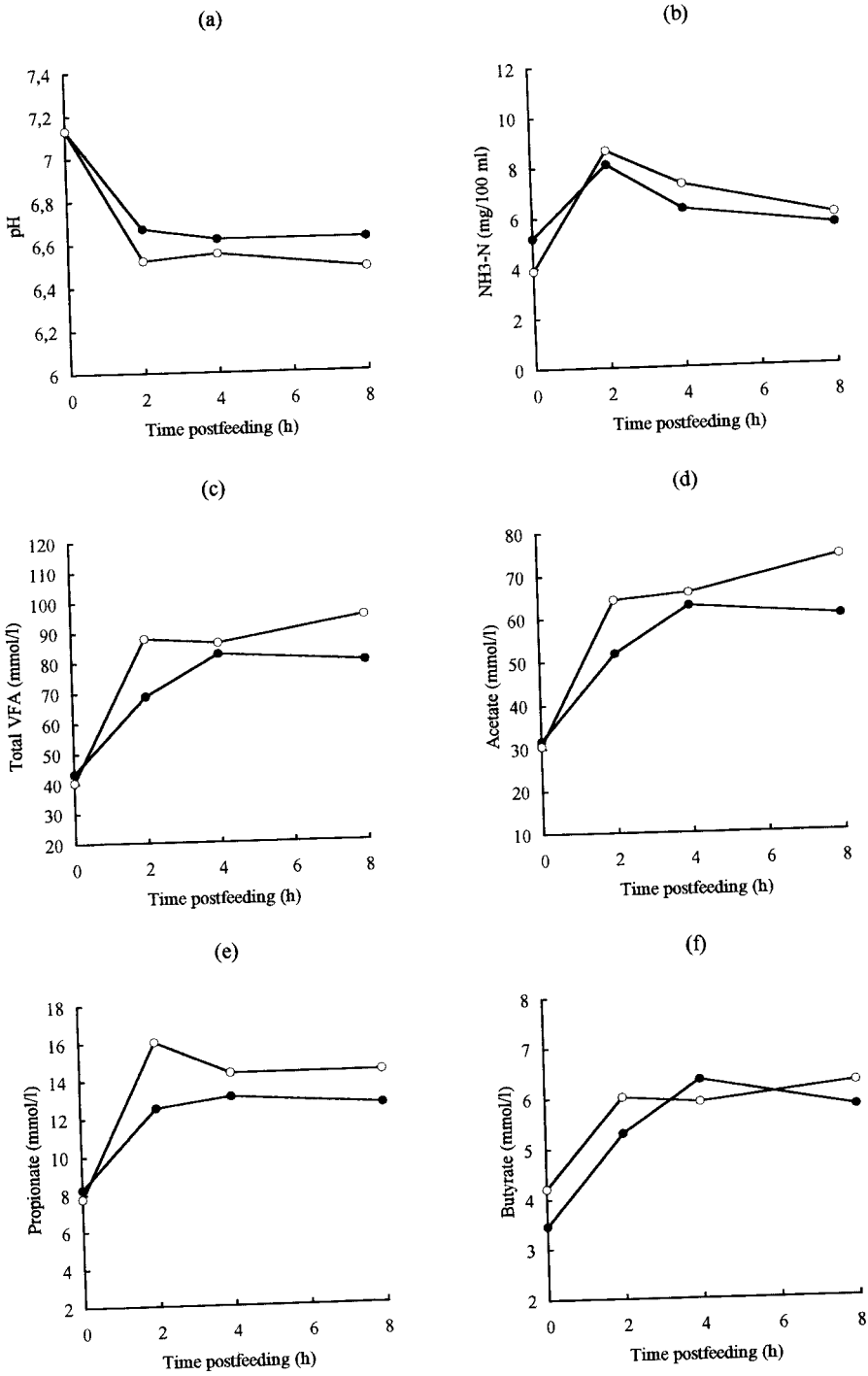

Fig 2. Diurnal variation of pH (**a**), NH_3-N (**b**), total VFA (**c**), acetate (**d**), propionate (**e**) and butyrate (**f**) concentrations in the rumen fluid of sheep given fresh (●) or air-dried (○) *Acacia cyanophylla* Lindl foliage.

Cellulolytic activity

Data reported in table VI suggested that air-drying had no effect on rumen cellulolytic activity. DM disappearance rates for filter paper calculated at each incubation time did not differ between treatments. DM degradation parameters were not affected by acacia air-drying ($P > 0.05$). The potential degradability defined as the sum of *a* and *b* fractions and the effective degradability calculated at the hypothetical outflow rates of 3 and 6%/h, tended to be increased by air-drying, but without significance.

DISCUSSION

There is little data dealing with the effect of drying on the nutritive value of woody species. *Acacia cyanophylla* Lindl foliage used in this study was fed to sheep either fresh or air-dried. The drying process lasted a week in the autumn and early winter of 1993. The air temperature in that period ranged between 10 and 25°C. Proximal analysis of acacia foliage revealed no significant effect of air-drying on ash, crude protein and fibre contents. The DM content of fresh acacia was somewhat high (~ 50%) when compared to values found earlier by Ben Salem et al (1996). These authors studied the seasonal change of the nutritive value of several shrubs and fodder trees and found that for *Acacia cyanophylla* Lindl the DM content of samples harvested monthly over a year ranged between 30 and 40%. The difference could be explained by inter-annual

Table VI. Cellulolytic activity in the rumen of sheep given fresh or air-dried acacia foliage: percentages of filter paper disappearance at different times of incubation and degradation parameters.

Item	*Diets*		*SE*	*P*
	Fresh acacia	*Air-dried acacia*		
Incubation time				
4 h	21.2	19.2	1.00	0.29
8 h	23.5	21.9	0.79	0.30
12 h	25.5	23.6	0.85	0.23
24 h	35.5	32.5	0.75	0.11
48 h	50.1	48.8	0.93	0.37
72 h	53.4	53.9	1.12	0.78
96 h	57.0	58.2	0.50	0.80
DM degradation parameters of filter paper				
a (%)	14.8	13.6	0.86	0.31
b (%)	47.3	50.9	0.71	0.07
c (% / h)	2.53	2.18	0.63	0.06
Potential degradability (%)[1]	62.1	64.5	1.27	0.38
$EDeg_3$ (%)[2]	34.9	37.0	1.04	0.31
$EDeg_6$ (%)[2]	27.1	29.3	0.99	0.26

[1] Potential degradability = a + b.
[2] $EDeg_3$ and $EDeg_6$: effective degradability calculated with an outflow rate of respectively 3 and 6% per h.

differences. Air-dried acacia foliage exhibited a lower level of condensed tannins compared with the fresh acacia. However, such a level (CT, 4.5 g catechin equivalent/100 g DM) was found to decrease diet organic matter, crude protein and fibre apparent digestibility and rumen fermentation by sheep fed on limited amounts of lucerne hay and air-dried *Acacia cyanophylla* foliage (Ben Salem et al, in press). The same finding was reported by Terrill et al (1989, 1990) and Grillet and Villeneuve (1994). The latter authors analysed crude protein and condensed tannin contents in fresh, frieze-dried, air-dried and oven-dried samples of some shrubs and fodder trees. Results obtained in this study indicated that, compared with fresh samples, air-drying had no effect on CP content but decreased the condensed tannin levels. The size of decrease ranged between 7 and 65%. The same trend was observed in the current study. Methanol extractable condensed tannin content of acacia foliage was reduced by 17% as a consequence of air-drying. According to McLeod (1974), tannins are located in the vacuoles of living plant cells. Drying of plant material causes shrinking of vacuoles and thus favours contact between tannins and proteins. The decrease of tannins in dried woody species may be explained by one or more of the following processes (Goldstein and Swain, 1963): complexion between tannins and proteins, polymerisation, and oxidation.

Intake and digestibility

The common opinion about the positive effect of air-drying on intake of tannin-rich woody species by sheep seems to be justified in this study. DM intake of acacia foliage was improved in animals given air-dried material. Such a trend is in agreement with results reported by Le Houérou (1987). Terrill et al (1989) compared the nutritive value of a tannin-rich whole crop of *Sericea lespedeza* offered to sheep in a fresh or field-dried condition. Field-dried sericea was found to be better consumed than fresh material. Since air-drying reduced extractable condensed tannins, the increase of DM intake may be a consequence of a decrease of astringent taste. Astringency is defined as the sensation caused by the formation of complexes between tannins and salivary glycoproteins. It was concluded elsewhere (Bate-Smith, 1973) that high levels of tannins reduce the palatability and intake of woody species as a result of astringency in the mouth of animals. In our study, air-drying might increase salivation in sheep and thus increase the palatability of acacia foliage. Further experiments are needed to verify this hypothesis. The positive effect of air-drying on *Acacia cyanophylla* intake observed in our study does not agree with the review of Meuret (1989) who reported an increased dry matter voluntary intake of fresh material as compared to dried material of numerous woody species. Indeed, such a review did not allow for a comparison of fresh and dried plant material within a species. Moreover, various studies indicated that goats behave differently from sheep with regard to the use of woody species. Therefore, the conclusions drawn by Meuret using goats may not apply for sheep. Further experiments are needed to investigate the effect of air-drying on the nutritive value of a wide range of woody species fed to different animal species.

There was a periodic pattern of daily feed intake. As noted in *Results*, DM intake of acacia foliage fed as either fresh or air-dried material was in a continuous change from day to day. This observation is illustrated in figure 1a, b. Even after the 15-day adaptation period, acacia intake was fluctuating from time to time. Peaks of acacia intake occurred every 4 days, in between which acacia intake was reduced by 30 to 60%. The same phenomenon was observed for longer periods (up to 60 days) in previous experiments conducted in our laboratory

(Ben Salem et al, unpublished data). This phenomenon cannot be explained by the observation made in this paper. Recently, Nitsan et al (1996) noted that meals and breaks between meals of goats fed high-tannin foliage were cyclic. They hypothesised that the cyclic feeding behaviour could be associated with the development of food aversion due to interaction of tannins with the rumen epithelium. In our case, it can be hypothesised that sheep have a tendency to regulate acacia consumption according to the level of tannin accumulation somewhere in the body. Maybe there was an absorption of acacia tannins, with accumulation, to which sheep reacted by limiting their acacia consumption until these secondary compounds were excreted or metabolised. It was suggested by McLeod (1974) that high levels of tannins in the diet can cause gastritis and changes in the intestinal mucous membranes, enabling condensed and hydrolysable tannins to be absorbed. Goodchild (1989) found that 75 and 88% of the tannins of *Leucaena leucocephala* and *Acacia aneura* CT were absorbed post-ruminally by sheep. Recently, Perez-Maldonado (1994) studied the metabolism of CT in the digestive tract of sheep and goats fed *Desmodium intortum* and *Calliandra calothyrsus*. He found that 10–20% of dietary CT were degraded in the rumen and approximately 70–80% of the tannins were absorbed/degraded during passage to the faeces. However, contrasting results were reported by Terrill et al (1994). These authors concluded that little of ^{14}C-labelled CT-carbon was absorbed from the small intestine of sheep fed on *Lotus pedunculatus* and that a substantial part of condensed tannins released during protein digestion in the small intestine may not be detectable by normal CT analytical methods. In view of these controversial results and the few available data on absorption of tannins, further works have to be done to study the fate of tannins present in various species, particularly *Acacia cyanophylla* tannins, through the gastrointestinal tract of ruminants. The rumen fill may be another criteria to explain the cyclic acacia intake. Mechanisms involved in the regulation of food intake are well documented for the case of conventional forages (Dulphy and Demarquilly, 1994; Faverdin et al, 1995), but no information on the regulation of woody species intake is available. The average intakes (mean of four sheep) of fresh or dried acacia were cyclic over the 25-day experimental period. The magnitude of variations was more pronounced with fresh than with dried acacia. Chewing activity may be reduced in sheep fed fresh acacia due to astringency, resulting in a low transit rate of acacia particles. Mastication plays an important role in intake regulation, since particles can leave the rumen only if they are smaller than approximately 1 mm (Dulphy and Demarquilly, 1994). We are not aware of any published data dealing with daily variation of intake of tannin-rich species by ruminants. For better understanding of the striking phenomenon observed in this study, it would be worthwhile to investigate the feeding behaviour of animals fed on acacia and the fate of acacia tannins in the digestive tract and their possible absorption.

Air-drying had no effect on diet and acacia digestibilities. CP digestibility of air-dried acacia foliage tended to increase, but without significance. The nutrient digestibility of acacia was low in both treatments. The absence of effect of air-drying on acacia digestibility is not consistent with results obtained by Terrill et al (1989). These authors found a significant increase of nitrogen digestibility of field-dried *Sericea lespedeza* compared with the fresh material fed to sheep. Total nitrogen loss (faeces and urine) was higher with fresh than with field-dried sericea. In contrast, in our study faecal and urinary nitrogen excretion were the same in both treatments.

Rumen fermentation

Patterns of diurnal variation were similar in both diets. Fermentation parameters (pH, VFA and ammonia nitrogen) did not suggest any inhibition of ruminal activity. Ammonia concentrations in rumen liquor at no time fell substantially below 50 mg L^{-1}, which is the level generally assumed to be the minimum concentration necessary to sustain maximum microbial growth (Satter and Slyter, 1974). The slight increase of VFA concentration at all sampling times in sheep given air-dried acacia may be the consequence of the increase of digestible organic matter intake. Data on the effect of condensed tannins on protozoa population are scanty. Chiquette et al (1989) found higher protozoa counts in the rumen fluid of sheep given a high-tannin strain of birdsfoot trefoil (*Lotus corniculatus* L) as compared to those receiving a low-tannin strain. These findings are consistent with our results. Fresh acacia treatment, which exhibited the highest tannin concentrations, resulted in higher protozoa counts as compared with the air-dried acacia treatment. The absence of effect of air-drying on in sacco degradation of a cellulolytic substrate (filter paper) is consistent with the absence of variation of NDF digestibility and VFA concentrations in the rumen fluid. The decrease of condensed tannin concentration by air-drying seems to be insufficient to allow an improvement of diet and acacia nutrient digestibilities and ruminal fermentation. The drying conditions used in this study may, however, not be the same as those applied by Terrill et al (1989), therefore. Care should be taken when interpreting results. Investigations are needed to study the effect of drying conditions on the nutritive value of acacia (sun-cured versus shade-drying of acacia, drying temperature and duration, etc).

In conclusion, air-drying was found to improve acacia intake without significant changes of its digestibility and digestion in the rumen of sheep. In situations where acacia biomass is abundant and exceeds livestock requirements, air-drying may be considered as a technique for acacia storage. Other drying conditions (sun-curing, etc) may allow a larger improvement of acacia nutritive value, and will be the subject of future research.

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