Journal of Agricultural Science, Cambridge (1999), **133**, 235–240. *Printed in the United Kingdom*

Comparison of fresh and dried *Digitaria decumbens* grass intake and digestion by Black-belly rams

H. ARCHIMÈDE[1]*, C. PONCET[2], M. BOVAL[1], F. NIPEAU[1], L. PHILIBERT[1], A. XANDÉ[1] AND G. AUMONT[1]

[1] *Institut National de la Recherche Agronomique, INRA, Unité de Recherches Zootechniques, Prise d'eau, 97170 Petit-bourg, Guadeloupe, French West Indies*

[2] *Institut National de la Recherche Agronomique, INRA, Station de Recherches sur la Nutrition des Herbivores, Centre de Clermont-Ferrand-Theix, Theix, 63122 Saint-Genes-Champanelle (France)*

(*Revised MS received 1 April 1999*)

SUMMARY

The intake and digestion of fresh and dried *Digitaria decumbens* grass by rams was compared using a 2×2 factorial design. The experiment took place in Guadeloupe (French West Indies) in 1996. Eight rams (mean liveweight: $45{\cdot}7 \pm 3{\cdot}1$ kg) were maintained in metabolism cages. *Digitaria decumbens* grass was cut daily and distributed to four of them, the other four were fed the following day with the equivalent forage which had meanwhile been dried for 20 h at 60 °C. Chemical composition (g/kg of dry matter (DM)) of the two diets based on neutral detergent fibre (NDF, 713, S.E. 18), acid detergent fibre (ADF, 361, S.E. 13) and crude protein (CP, 90, S.E. 4) was similar. The DM intake (61·0 and 53·2 g/$W^{0{\cdot}75}$, S.E. 2·0, $P < 0{\cdot}05$), the NDF (0·753 and 0·727, S.E. 0·004, $P < 0{\cdot}011$) and CP (0·588 and 0·544, S.E. 0·014, $P < 0{\cdot}09$) total tract digestibility of fresh and dried herbage were different. Nylon bag estimates of effective DM degradability and fractional degradation rates (per h) in the rumen were 0·436, 0·414 (S.E. 0·005, $P < 0{\cdot}004$) and 0·048, 0·038 (S.E. 0·002, $P < 0{\cdot}02$) for fresh and dried grass, respectively. Rumen digestibility of organic matter and NDF were 0·516, 0·541 (S.E. 0·021) and 0·763, 0·692 (S.E. 0·019), respectively. The rumen turnover rates of particles (per h) were 0·024 and 0·015 (S.E. 0·001, $P < 0{\cdot}05$) for fresh and dried forage respectively. The efficiency of microbial protein synthesis (g microbial nitrogen/kg organic matter apparently degraded in the rumen) was similar with the two diets: 33·5 and 33·0 (S.E. 3·3, $P < 0{\cdot}9$) for fresh and dried forage respectively. In conclusion, fresh *Digitaria decumbens* was nutritionally superior to dried. This is probably due to a faster degradation rate and a lower rumen retention time of the fresh forage.

INTRODUCTION

Fresh forage is the main and often the sole diet of ruminants in the humid tropics. The chemical composition, intake and total tract digestibility of tropical forage grasses have already been studied. Most of these results were obtained with dried forage for practical reasons (Minson 1990). In contrast, in our laboratory, the nutritive values of tropical forages were determined using fresh forage (Aumont *et al.* 1995). For both intake and digestion, there is evidence in several studies of significant differences between dried and fresh temperate forages. Large differences were recorded for digestion measurements (Demarquilly 1970; Vérité & Journet 1970; Beever *et al.* 1971, 1976).

* To whom all correspondence should be addressed. Email: archi@ontilles.inra.fr

Voluntary intake is one of the main factors affecting the nutritive value of tropical forages. Poppi *et al.* (1981*a*, *b*) showed the importance of rumen turnover, fill and digestion rate in determining voluntary intake of *Digitaria decumbens*. These studies, however, were made with dried forages whose relevance in assessing its nutritive value seems questionable. The current trial therefore compared dried and fresh *Digitaria decumbens* in relation to voluntary intake and digestion.

MATERIALS AND METHODS

Location

The research was carried out at the animal experimental station of the National Agricultural Research Institute of the French West Indies, Guadeloupe (latitude 16° 16′ N, longitude 61° 30′ W). Average temperatures ranged from 21–25 °C to

27–31 °C. The mean rainfall on the experimental site is 3000 mm a year.

Experimental design, animals, diets and feeding

The experiment was conducted using a 2×2 factorial design. The experimental periods consisted of 2 weeks of adaptation to the diet, 5 days of intake and total tract digestibility measurements, 3 days of duodenal sampling, 1 week of rumen sampling and 1 week of nylon bag incubation. Eight Black-belly rams (mean liveweight: $45{\cdot}7 \pm 3{\cdot}1$ kg), were fitted with rumen and duodenal cannulae and were maintained in metabolism cages. *Digitaria decumbens* grass was cut daily. One part was offered fresh to four rams, whereas the remainder was dried at 60 °C for 20 h in a forced-draught oven and offered the following day to the other four rams. The forage was fed in two equal meals a day at 12 h intervals. The forage amount provided was 1·5 times greater than the voluntary intake of the animals.

Measurements

Intake, total tract digestibility and urine excretion were measured daily by weighing the amounts of food offered, refusals, faeces and urine. Duodenal flows were estimated according to the double-marker method of Faichney (1980) with faecal lignin and CrEDTA as markers of the particulate and aqueous phases, respectively. The mean daily duodenal digesta sample was constituted by taking twelve 100 ml samples over three consecutive days at 0, 6, 12, 18, 2, 8, 14, 20, 4, 10, 16 and 22 h after the morning meal distribution. Fifty ml of this sample were kept to represent whole digesta (DG) and 50 ml were divided into a liquid-rich phase (LR) and a particle-rich fraction (PR) by squeezing the digesta through a nylon filter of 150 μm pore size. Samples of DG and PR were pooled and stored at −20 °C before freeze-drying, prior to chemical analysis. The rumen of each animal was manually emptied and the total content weighed, 3, 6 and 12 h after the morning meal. Two consecutive emptyings on one animal took place at intervals of 72 to 81 h. The morning meal was interrupted after 3 h of free access. The digesta was mixed thoroughly by hand. Three subsamples were taken for dry matter (DM) determination. One subsample was used to determine digesta particle size. Large particles and small particles were isolated following a wet sieving procedure with two sieves: 1·0 mm and 16 μm. The rate of organic matter (OM) disappearance in the rumen was estimated by the difference in the amount of OM in the rumen 3 and 12 h postfeeding, divided by the amount of OM in the rumen 3 h postfeeding and divided by time interval (9 h). Similar estimates have been made with the NDF and ADF component. The rumen turnover rate was estimated by the ratio: daily excretion of lignin in faeces/amount of lignin in rumen 3 h post feeding * 24). Bacterial samples were isolated by carrying out two successive centrifugations (800 ***g*** and 27000 ***g*** during 30 min) of LR as described by Yang (1992). The kinetic degradation of the consumed herbage was measured using a nylon bag. The effective degradabilities of DM (ED) in the rumen were calculated as following: $ED = a + (bc/(c + 0{\cdot}05))$, where, a is the rapidly degradable fraction, b the slowly degradable fraction and c the fractional degradation rate of disappearance of the degradable fraction using the model of Ørskov and McDonald (1979). The nylon bags were 50 cm^2, with a pore size of 50×50 μm, filled with 3 g of dry or 15 g of fresh herbage of the basal diet. The fresh or dried grass was manually cut in 2 mm long particles. The incubation times in the rumen of the sheep fed the basal diet (fresh or dried herbage) were 3, 6, 12, 24, 48, 72 and 96 h. The rumen liquid used for ammonia analysis was removed on two consecutive days, 0, 3, 6 and 12 h after the morning meal.

Chemical analytical methods

DM concentrations were determined by drying at constant weight at 60 °C in a forced-draught oven. These samples were then ground (1 mm) prior to chemical analysis. The OM content was measured after a 10 h pyrolysis at 550 °C. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were estimated following the methods of Van Soest & Wine (1967). Nitrogen concentration was determined on fresh frozen faeces using the Kjeldahl method. Microbial nitrogen was estimated using the method of Zinn & Owens (1986). The efficiency of microbial synthesis was calculated as daily duodenal microbial nitrogen flow (g/day) divided by the amount of OM apparently digested in the rumen (kg/day). The ammonia contents were estimated on the rumen liquid using the Kjeldahl method.

Statistical analyses

Data were analysed using the General Linear Model procedure of SAS (1987) including the period, animal and forage treatment effects.

The analysis of the residues led to the elimination of one ram (fresh diet).

RESULTS

Diet composition

The differences between forages were not significant. The mean DM content (g of DM/kg) of the roughages were 187 (S.E. 3) and 736 (S.E. 70) for the fresh and dried forage, respectively. The NDF, ADF and crude protein (CP) contents (g/kg of DM) were 721, 705 (S.E. 18); 369, 353 (S.E. 13) and 91, 89 (S.E. 4) for the fresh and dried herbages respectively.

Table 1. *Intake and total tract digestion of dried or fresh* Digitaria decumbens *grass given* ad libitum *to seven Black-belly rams*

	Grass		S.E. (D.F. = 5)
	Dried	Fresh	
Dry matter intake (g/day/$W^{0.75}$)	53·2	61·0	2·0
Water consumption (g/day)	4929·0	1154·0	493·0
Total tract digestibility (coefficient)			
Organic matter	0·709	0·736	0·007
Crude protein	0·544	0·588	0·014
Neutral detergent fibre	0·727	0·753	0·004
Acid detergent fibre	0·716	0·748	0·004

Table 2. *Estimates of rapidly degradable fraction* (*a*), *slowly degradable fraction* (*b*) *and fractional degradation rate* (*c*) (*per h*) *and effective dry matter degradation of dried or fresh* Digitaria decumbens *grass incubated in nylon bags in the rumen of seven rams feeding these two grasses*

	Grass		S.E. (D.F. = 5)
	Dried	Fresh	
Rapidly degradable fraction	0·197	0·160	0·008
Slowly degradable fraction	0·497	0·570	0·004
Fractional degradation rate	0·038	0·048	0·002
Effective DM degradation*	0·414	0·436	0·005

* The data *a*, *b* and *c* were estimated according to the model of Ørskov and McDonald (1979). The effective degradation was calculated as: $a+bc/(c+0{\cdot}05)$.

Intake

The daily DM intake of the fresh forage (Table 1) was 1·15 times higher ($P < 0{\cdot}05$) than for the dried one. The mean DM intake during the first 3 h after the morning meal was $15{\cdot}1 \pm 1{\cdot}0$ g/kg.$W^{0{\cdot}75}$. Over these first 3 h, in contrast to the mean 24 h intake, there was no difference between the diets. Water consumption was 4·3 times higher ($P < 0{\cdot}003$) with the dried forage than with the fresh one. Nevertheless, after taking account of the water content of the roughage, the total quantity of ingested water was similar for both diets.

Total tract digestion

The total tract digestion (Table 1) of the OM, the NDF and ADF were on average 2·7 to 3·2 digestibility units higher ($0{\cdot}09 < P < 0{\cdot}04$) for the fresh forage than for the dried one. For CP, the difference ($P < 0{\cdot}09$) was 4·4 digestibility units.

Rumen digestion

The fractional degradation rates (model of Ørskov and McDonald) of DM degradation were 26% higher ($P < 0{\cdot}002$) for the fresh forage compared to the dried one. Moreover, the effective DM degradation recorded with the fresh grass was higher ($P < 0{\cdot}04$) compared to the dried one (Table 2). No significant difference ($P > 0{\cdot}29$) was observed between diets, for the rumen OM digestibility (Table 3). In contrast to the rumen OM digestibility, there was a difference between the diets for the NDF ($P < 0{\cdot}05$) and the ADF components ($P < 0{\cdot}07$). The mean ammonia content of the rumen liquid was 101 and 112 (S.E. 4, $P < 0{\cdot}07$) g/l for the fresh and dried forage respectively. The mean pH values were 6·4 and 6·3 (S.E. 0·05).

Nitrogen utilization

The total nitrogen duodenal flow was similar for both diets (Table 3). Nevertheless, the microbial duodenal flow was higher ($P < 0{\cdot}02$) with the fresh *Digitaria decumbens* compared to the dried one although the efficiency of the microbial synthesis was similar for both diets. Urinary nitrogen excretion was slightly lower ($P < 0{\cdot}06$) with the dried forage than with the fresh one.

Rumen content and turnover

The rumen turnover of diet particles, estimated as the lignin passage rate, was 1·6 times higher ($P < 0{\cdot}05$) with fresh than with the dried *Digitaria decumbens* (Table 3). The total rumen organic matter, NDF,

Table 3. *Rumen digestion and lignin passage rate of dried or fresh* Digitaria decumbens *grass fed* ad libitum *to seven Black-belly rams*

	Grass		S.E.
	Dried	Fresh	(D.F. = 5)
Rumen digestibility (coefficient)			
Organic matter	0·481	0·516	0·021
Neutral detergent fibre	0·692	0·763	0·019
Acid detergent fibre	0·686	0·740	0·022
Nitrogen intake (g/day)	12·3	14·2	1·016
Duodenal flows (g/day)			
Total nitrogen	19·5	19·4	0·699
Microbial nitrogen	11·4	13·2	0·387
Urinary nitrogen (g/day)	5·5	5·9	0·100
Microbial synthesis efficiency (g nitrogen/kg OMADR*)	33·0	33·5	3·300
Lignin passage rate (per h)	0·015	0·24	0·001

* OMADR: Organic matter apparently digested in the rumen.

Table 4. *Amounts of organic matter* (*OM*), *NDF*, *ADF*, *ADL present in the rumen at increasing postfeeding intervals*, *as total matter or large particles* (*LP*) *in Black-belly rams fed* ad libitum *with a fresh or a dried* Digitaria decumbens *grass* (D.F. = 5)

	3 hours			6 hours			12 hours		
Treatment	Dried	Fresh	S.E.	Dried	Fresh	S.E.	Dried	Fresh	S.E.
OM (g)	1010	734	44	959	707	21	674	543	35
NDF (g)	720	516	34	695	521	19	480	396	25
ADF (g)	385	279	18	370	275	10	251	210	13
ADL (g)	88	65	6	78	60	2	63	55	2
LP_{OM} (g)	365	222	17	340	231	13	208	156	15
LP_{NDF} (g)	332	204	15	310	212	12	187	142	13
LP_{ADF} (g)	184	115	9	173	122	7	103	79	8
LP_{ADL} (g)	31	20	2	29	21	1	21	16	2

ADF and ADL collected 3, 6 and 12 h after the morning feeding were higher ($0·004 < P < 0·08$) for the rams fed with dried than for those fed with fresh grass (Table 4). The rates of disappearance (per h) of rumen OM (0·031, S.E. 0·009), NDF (0·030, S.E. 0·009) and ADF (0·031, S.E. 0·009) were not different between the diets. The corresponding values of large particle rates of disappearance (per h) were not different, OM (0·038, S.E. 0·009), NDF (0·038, S.E. 0·008) and ADF (0·038 (S.E. 0·008). The proportion of large particles (NDF) in rumen digesta was higher with the dried than with the fresh forage (0·429 and 0·372 respectively; S.E. 0·007, $P < 0·007$).

DISCUSSION

The experimental design of this study was intended as a strict evaluation of dehydration of a tropical forage on intake and digestion. This experiment differs from most of the published studies where the fresh and dried forages are not similar except for Beever *et al.* (1971, 1974), Beever & Thomson (1981), who compared dried and frozen materials. However, in these experiments, it was assumed that freezing the forage did not affect its intake and digestion (Beever *et al.* 1969). In the present experiment, comparison of the fresh and dried forages is more relevant because it was carried out with only 24-hour intervals.

The most important result of the present experiment is the difference in dry matter intake between fresh and dried forages. Earlier observations have shown that, compared to dried forage, voluntary intake of fresh forage decreases with its water content, when the herbage initially contains less than 250–350 g of DM/kg (Vérité & Journet 1970; Grant *et al.* 1974; John & Ulyatt 1987). Below this threshold, estimates from the cited literature indicate that DM intake decreases by 1·8–3·2 g/kg.$W^{0·75}$ for each increase in water content in fresh forage of 10 g/kg. However, when the DM content of the fresh forage rises to 250

g/kg, most of the authors (Minson 1966; Demarquilly 1970) report similar voluntary intake for fresh and dried herbage. Therefore, results of the current study indicate a greater increase in the intake of fresh *Digitaria decumbens* than generally reported. In addition, in the current experiment, the higher intake of the fresh forage agrees with a faster DM fractional degradation rate and rumen turnover and a higher rumen digestibility of cell wall. Poppi *et al*. (1981*a*, *b*) have already show a positive correlation between intake of *Digitaria decumbens* and rumen turnover. The rate of digesta flow through the rumen, by passage rate and degradation, appears to be the main cause of differences in dynamics of digestion between the fresh and the dried herbage. As a consequence, the accumulation of fibrous material was always greater in the sheep fed dried forage than fresh forage. Similar results were reported in earlier studies (Vérité & Journet 1970; Ulyatt & MacRae 1974). Because of the lower proportion of large particles in the rumen of animals fed with fresh forage, the hypothesis of a lower resistance of cell wall to breakdown could be used to explain the faster rumen turnover (Poppi *et al*. 1985; McLeod & Minson 1988). This resistance of cell wall to breakdown may be an important factor in variation of the voluntary intake of tropical forage (McLeod *et al*. 1990; Wilson 1994). Nevertheless, similar rates of rumen OM, NDF and ADF disappearance with the two diets seem questionable. This result disagrees substantially with findings on values for fractional degradation rate and rumen particle passage rates. The contradiction probably reveals a methodological artefact possibly related to different intake behaviours between rams eating fresh or dried forage. The intake rate of DM is lower with the fresh *Digitaria decumbens* than with the dried one. In fact, it was observed in the current trial that the rams consuming dried materials ended their first meal much sooner than the others, although the DM intake was the same 3 h after the beginning of the morning meal. Similar observations were reported by John & Reid (1986). Consequently, the method used to estimate the rates of rumen DM disappearance underestimates the values obtained with fresh forage.

As well as resulting in a lower DM matter intake, the drying of the forage slightly decreases the total tract digestibility of the organic matter and fibrous material. The nitrogenous compounds are even more adversely affected. These results are similar to those of most of the previous studies (Demarquilly 1970; Vérité & Journet 1970; Beever *et al*. 1976) which conclude that, particularly with CP, drying has an important effect when the temperature of dehydration is > 100 °C. The estimated values of the rumen digestibility of the fibrous components broadly agree with those observed for the total tract digestibility. Vérité *et al*. (1986) and Minson (1990), reviewing the literature, conclude there is higher efficiency of microbial nitrogen synthesis with fresh forages. The current study does not confirm these results although higher microbial nitrogen flows are observed. The latter result agrees with those of Beever *et al*. (1974).

The conclusions of the current trial are that intake and digestibility of fresh *Digitaria decumbens* are higher than those of the dried grass. Consequently, the amount of nutrients flowing in the digestive tract is higher for the animals fed fresh herbage. Measurements with dried grass underestimate the nutritive value of the corresponding fresh one. For animals fed exclusively with green forage, measurements of forage intake and digestibility must be made with fresh grass.

The authors would like to thank B. Calif, E. Delval, S. Rozan-Marcellus, D. Feuillet, A. Kantaparedy and G. Désirée for their technical assistance. The research was supported by the European Union (FEDGA) and the Region Guadeloupe (FWI).

REFERENCES

Aumont, G., Caudron, I., Saminadin, G. & Xande, A. (1996). Sources of variation in nutritive values of tropical forages from the Caribbean. *Animal Feed Science and Technology* **51**, 1–13.

Beever, D. E., Cammell, S. B. & Wallace, A. (1974). The digestion of fresh, frozen and dried perennial ryegrass. *Proceedings of the Nutrition Society* **33**, 73A–74A.

Beever, D. E. & Thomson, D. J. (1981). The effect of drying and processing red clover on the digestion of the energy and nitrogen moieties in the alimentary tract of sheep. *Grass and Forage Science* **36**, 211–219.

Beever, D. E., Thomson, D. J. & Cammell, S. B. (1976). The digestion of frozen and dried grass by sheep. *Journal of Agricultural Science*, *Cambridge* **86**, 443–452.

Beever, D. E., Thomson, D. J., Pfeffer, E. & Armstrong, D. G. (1969). Effect of drying grass on sites of its digestion in sheep. *Proceedings of the Nutrition Society* **28**, 26A–27A.

Beever, D. E., Thomson, D. J., Pfeffer, E. & Armstrong, D. G. (1971). The effect of drying and ensiling grass on its digestion in sheep. Sites of energy and carbohydrate digestion. *British Journal of Nutrition* **26**, 123–133.

Demarquilly, C. (1970). Influence de la déshydratation à basse température sur la valeur alimentaire des fourrages. *Annales de Zootechnie* **19**, 45–51.

Faichney, G. J. (1980). The use of markers to measure digesta flow from the stomach of sheep fed once daily. *Journal of Agricultural Science*, *Cambridge* **94**, 313–318.

Grant, R. J., Van Soest, P. J., McDowell, R. E. & Perez, C. B. (1974). Intake, digestibility and metabolic loss of Napier grass by cattle and buffaloes when fed wilted, chopped and whole. *Journal of Animal Science* **39**, 423–434.

John, A. & Reid, C. S. W. (1986). Factors affecting rate of feed intake by sheep. *Proceedings of the New Zealand Society of Animal Production* **11**, 108.

John, A. & Ulyatt, M. J. (1987). Importance of dry matter content to voluntary intake of fresh grass forages.

Proceedings of the New Zealand Society of Animal Production **47**, 13–16.

McLeod, M. N., Kennedy, P. M. & Minson, D. J. (1990). Resistance of leaf and stem fractions of tropical forage to chewing and passage in cattle. *British Journal of Nutrition* **63**, 105–119.

McLeod, M. N. & Minson, D. J. (1988). Large particle breakdown by cattle eating ryegrass and alfalfa. *Journal of Animal Science* **66**, 992–999.

Minson, D. J. (1966). The intake and nutritive value of fresh, frozen and dried *Sorghum almum*, *Digitaria decumbens* and *Panicum maximum*. *Journal of the British Grassland Society* **21**, 123–126.

Minson, D. J. (Ed.) (1990). *Forage in ruminant nutrition*. San Diego, California 92101: Academic Press, Inc.

Ørskov, E. R. & McDonald, I. (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science*, *Cambridge* **92**, 499–503.

Poppi, D. P., Hendrickson, R. E. & Minson, D. J. (1985). The relative resistance to escape of leaf and stem particles from the rumen of cattle and sheep. *Journal of Agricultural Science*, *Cambridge* **105**, 9–14.

Poppi, D. P., Minson, D. J. & Ternouth, J. H. (1981*a*). Studies of cattle and sheep eating leaf and stem fractions of grasses. I. Voluntary intake, digestibility and retention time in the reticulo-rumen. *Australian Journal of Agricultural Research* **32**, 99–108.

Poppi, D. P., Minson, D. J. & Ternouth, J. H. (1981*b*). Studies of cattle and sheep eating leaf and stem fractions of grasses. II. Factors controlling the retention of feed in the reticulo-rumen. *Australian Journal of Agricultural Research* **32**, 109–121.

Statistical Analysis Systems Institute (1987). SAS/STAT, Guide for Personal Computer. Cary, NC: SAS Institute.

Ulyatt, M. J. & MacRae, J. C. (1974). Quantitative digestion of fresh herbage by sheep. I. The sites of digestion of organic matter, energy, readily fermentable carbohydrate, and lipid. *Journal of Agricultural Science*, *Cambridge* **82**, 295–307.

Vérité, R., Durand, M. & Jouany, J. P. (1986). Influence des facteurs alimentaires sur la protéosynthèse microbienne dans le rumen. *Reproduction Nutrition Développement* **26** (1b), 181–201.

Vérité, R. & Journet, M. (1970). Influence de la teneur en eau et de la déshydratation de l'herbe sur sa valeur alimentaire pour les vaches laitières. *Annales de Zootechnie* **19**, 255–268.

Van Soest, P. J. & Wine, R. H. (1967). Use of detergent in the analysis of fibrous feed. IV. Determinations of plant cell constituents. *Journal of the Association of Official Agricultural Chemists* **50**, 50–55.

Wilson, J. R. (1994). Cell wall characteristics in relation to forage digestion by ruminants. *Journal of Agricultural Science*, *Cambridge* **122**, 173–182.

Yang, W. Z. (1992). *Etude de la cinétique de la colonisation des aliments dans le rumen des moutons. Conséquence sur la compartimentation de la biomasse et la dynamique à la sortie du rumen dans le cas de différents types de rations*. PhD thesis, University Blaise Pascal, Clermont-Ferrand II, France.

Zinn, R. A. & Owens, F. N. (1986). A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. *Canadian Journal of Animal Science* **66**, 157–166.