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Nutritive evaluation of some browse plant species collected from Algerian arid rangelands by chemical analyses and *in vitro* gas production

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Abstract. The objective was to evaluate the nutritive value of various Algerian browse and shrub species (*Atriplex halimus*, *Artemisia campestris*, *Artemisia herba-alba*, *Astragalus gombiformis*, *Calobota saharae*, *Retama raetam*, *Stipagrostis pungens*, *Lygeum spartum* and *Stipa tenacissima*). Chemical composition, and *in vitro* gas production kinetics for assessment of tannins using buffered rumen fluid were determined. Volume of gas (G) produced was recorded at several incubation times 3, 6, 9, 12, 16, 21, 26, 31, 36, 48, 72, 96, 120 and 144 h after inoculation time. France model $G = A(1\text{-}e^{-c(t-L)})$ was used to estimate the fermentation kinetics parameters. In general, protein content in dicotyledon species was always greater than in monocotyledon grasses, these showing higher NDF and ADF and lower lignin contents than dicots. The values of degradation coefficient (ED) are between 0.623 g/g DM for *A. campestris* and 0.126 g/g DM for *S. tenacissima*. After 144 hours of incubation time, the highest cumulative gas production was observed for *S. pungens* (269 ml/g DM) and the lowest was obtained by *A. halimus* (185 ml/g DM). The lowest *in vitro* digestibilities were observed in monocotyledons (being particularly low for *S. tenacissima*), whereas dicots had significantly higher values. The CP was not correlated to gas production at all kinetic points. Chemical composition (NDF and CP), *in vitro* digestibility were the main influential variables determining the ranking. In conclusion, *A. halimus, A. campestris, A. herba-alba* and *A. gombiformis* can be considered of high nutritional value.

Keywords. Algerian arid areas – Browse plants – Chemical composition – Gas production – Nutritive value.

Evaluation de la digestibilité de plantes Algériennes colléctées dans les régions arides par l'analyse chimique et la production de gaz in vitro

Résumé. *L'objective était l'évaluation de la valeur nutritive de plusieurs plantes et arbustes Algériennes* (Atriplex halimus, Artemisia campestris, Artemisia herba-alba, Astragalus gombiformis, Calobota saharae, Retama raetam, Stipagrostis pungens, Lygeum spartum *et* Stipa tenacissima*). Afin d'évaluer les effets des tanins, la composition chimique et la cinétique de production de gaz* in vitro *sont déterminées. La production de gaz (G) produite a été enregistrée à plusieurs points cinétiques 3, 6, 9, 12, 16, 21, 26, 31, 36, 48, 72, 96, 120 et 144 heures d'incubation. Le modèle de France* $G = A(1\text{-}e^{-c(t-L)})$ *est utilisé pour estimer les paramètres cinétiques de fermentation. En général, les concentrations en protéines des plantes dicotyledones sont plus importantes que celles des fourrages monocotyledones, qui présentent un contenu élévé en NDF et ADF et une concentration faible en lignine. Les valeurs du coefficient de dégradation (ED) sont comprises entre 0,623 g/g MS pour A. campestris et 0,126 g/g MS pour* S. tenacissima*. Après 144 heures de temps d'incubation,* S. pungens *enregistre la production de gaz cumulative la plus élevée (269 ml/g MS), alors que* A. halimus *observe la valeur la plus faible (185 ml/g MS). Les digestibilités in vitro les plus faibles sont observées pour les plantes monocotylédones (étant particulièrement faible pour* S. tenacissima*), tandis que les plantes dicotylédones présentent des valeurs de digestibilités très appréciables. La matière azotée totale n'est pas corrélée à la production de gaz en tous points cinétiques. La composition chimique (NDF et CP), la digestibilté in vitro sont les principales variables déterminant le classement des espèces. En conclusion,* A. halimus*,* A. campestris*,* A. herba-alba *et* A. gombiformis *peuvent être considérées comme des plantes possédant une valeur nutritive très appréciable.*

Mots-clés. *Composition chimique – Plantes – Production de gaz – Valeur nutritive – Zones arides Algériennes.*

I – Introduction

Browse plants in arid zones represent an important fodder reserve for livestock in harsh conditions that can be used by grazing ruminants in periods of feed scarcity, especially during severe droughts. Some valuable information is available about the nutritive value of some shrubby species (acacias, forages, saltbushes and spineless cactus) planted in large scale in north Africa (Nefzaoui and Chermiti, 1991; Ben Salem *et al.*, 2000). However, in spite of their abundance in the rangelands and their evergreen foliage throughout the year, many other wild browse species have been, generally, undervalued mainly because of insufficient knowledge about their potential feeding value and the impact of tannins compounds. Indeed, tannins are in feedstuffs such as fodder legumes and browse plants. In spite of their limited nutritional value, these forage resources are indispensable as feeds for herbivores when their production systems are based on grazing range lands.

The use of in vitro gas production methodology to estimate digestion of feeds is based on measured relationships between the *in vivo* digestibility of feeds and *in vitro* gas production, in combination with the feed's chemical composition (Menke and Steingass, 1988). *In vitro* gas methods primarily measure digestion of soluble and insoluble carbohydrates (Menke and Steingass, 1988), and the amount of gas produced from a feed on incubation reflects production of volatile fatty acids, which are a major source of energy for ruminants. Gas arises directly from microbial degradation of feeds, and indirectly from buffering of acids generated as a result of fermentation.

The objective of this study was to evaluate nutritive value of forages collected from arid zone in Algeria, by determining the chemical composition, phenol compounds and measurement of *in vitro* gas production kinetics.

II – Materials and methods

Plant material was collected in Bousâada district, north central Algeria (N 35° 15.768', E 04° 13.885', 496-981 m altitude), in the Saharan Atlas region, at the northern edge of the Sahara Desert between the Atlas Mountains and the el-Hodna depression and salt lake. The area has a dry desert climate characterized by high temperatures (24 to 41°C) and scarce and erratic annual precipitations (350-700 mm). Selection of the species was based on the available information on their consumption by grazing small ruminants, and on their relative abundance in the area of study. Nine browse plant species were used in this study: six dicotyledon plants namely *Atriplex halimus* L., *Artemisia campestris* L., *Artemisia herba-alba* Asso, *Astragalus gombiformis* Pomel, *Calobota saharae* (Coss. & Durieu) Boatwr. & B.-E. van Wyk (formerly *Genista saharae* or *Spartidium saharae*), and *Retama raetam* (Forssk.) Webb & Berthel, and three monocotyledon plants, namely *Stipagrostis pungens* (Desf.) De Winter (formerly *Aristida pungens*), *Lygeum spartum* Loefl. ex L. and *Stipa tenacissima* L. Samples were collected when plants were at a flowering (*A. halimus* and *L. spartum*) or at a mature stage (the rest of species) and they may be more important for grazing animals. Between six and ten specimens of each plant species were sampled to obtain a representative aliquot of the edible biomass, taken to the laboratory, pooled, oven-dried at 50 ºC (Makkar, 2003), and ground to pass a 1 mm screen.

Chemical composition of the plant material and the corresponding chemical analysis, especially those regarding tannins content (Makkar *et al*., 1993; Makkar, 2003) are thoroughly described in Boufennara *et al*. (2012).

Four mature Merino sheep (body weight 49.4 ± 4.23 kg) fitted with a permanent ruminal cannula were used for the extraction of rumen fluid. Animals were fed lucerne hay *ad libitum* (167 g CP, 502 g NDF, 355 g ADF and 71 g ADL /kg DM) and had free access to water and mineral/vitamin block. Samples of rumen contents were withdrawn prior to morning feeding, transferred into thermos flasks and taken immediately to the laboratory, where rumen fluid was strained through four layers of cheesecloth and kept at 39 ºC under a constant flow of CO_2.

Gas production profiles were obtained using an adaptation of the technique described by Theodorou *et al.* (1994). Ground samples (500 mg) were incubated in 50 ml of diluted rumen fluid (10 ml mixed rumen fluid + 40 ml medium prepared under a CO_2 atmosphere) in 120 ml serum bottles. Six bottles containing only diluted rumen fluid were incubated as blanks and used to compensate for gas production in the absence of substrate. Once filled up, all the bottles were closed with rubber stoppers, crimped with aluminium seals, shaken and placed in the incubator at 39ºC. Volume of gas produced was recorded at several incubation times (3, 6, 9, 12, 16, 21, 26, 31, 36, 48, 72, 96, 120 and 144 h after inoculation time) using a pressure transducer (Delta Ohm DTP704-2BGI, Herter Instrument SL, Barcelona). At the end of the incubation (after 144 h), the contents of each serum bottle were filtered using sintered glass crucibles (coarse porosity no. 1, pore size 100–160 µm) under vacuum. Then the residue was washed out with a neutral detergent solution at 100ºC during 1 h and oven-dried at 100ºC for 48 h to estimate the potential DM disappearance (D144, g/g DM). Incubations were performed using three different inocula (rumen fluid from three sheep used separately) with two bottles per rumen fluid inoculum (for a total of six observations –three replicates– per sample). In order to estimate the fermentation kinetic parameters, gas production data were fitted using the exponential model proposed by France *et al.* (2000): $G = A\,(1-e^{-c(t-T)})$ for $t \geq L$, where G (ml/g) denotes the cumulative gas production at time t; A (mL/g) is the asymptotic gas production; c (h^{-1}) is the fractional rate of substrate fermentation and L (h) is the lag time. According to France *et al.* (2000), the extent of degradation in the rumen (ED, g/gDM) for a given rate of passage (k, h^{-1}) was estimated as:

$$ED = \frac{c - D144}{c + k} e^{-KL}$$

where D144 is the dry matter disappearance after 144 hours of incubation. To calculate ED, a rate of passage of 0.03 h^{-1} (characteristic for sheep fed a forage diet at maintenance level) was used.

One way analysis of variance (Steel and Torrie, 1980) was performed on gas production data, with browse species as the only source of variation (fixed effect) and source of inoculum (random effect) as a blocking factor. Pearson linear correlation coefficients were determined pair-wise between the variables studied. Tukey's multiple comparison test was used to determine which means differed from the rest. Analysis of variance and correlation were performed using the GLM and CORR procedures of the SAS software package (SAS Institute, 2008), respectively.

III – Results and discussion

Data of *in vitro* fermentation kinetics are shown in Table 1. The lowest *in vitro* digestibilities were observed in monocotyledons (being particularly low for *S. tenacissima*), whereas dicots had significantly higher values. Similar trends were observed for the *in vitro* fermentation kinetics estimated form the gas production curves. The values of extent degradation (ED) are between 0.623 g/g DM for *A. campestris* and 0.126 g/g DM for *S. tenacissima*. These results could be explained for *A. campestris* by the low levels of cell wall fraction NDF, ADL and also by their high concentrations of CP. Estimated constant rate of gas production (c) differ significantly between browse species. The highest rate of gas was observed with Asteraceae plants and the lowest was found for *S. tenacissima* witch did not differ significantly to *L. spartum* and *S. pungus*. Although the grasses showed higher asymptotic gas (parameter A) than dicots (P<0.05), their fermentation rate (c) and ED were significantly (P<0.05) lower for dicot species. The NDF fraction is significantly and negatively correlated with gas production for the early stage of fermentation, less than 26 hours [(r = -0.72, P <0.01, t = 3h); (r = -0.80, P <0.01, t = 26 h)]. The CP is not correlated to gas production at all kinetic points. The same situation was reported by many authors (Areghoreb, 2000; Khazaal *et al.*, 1993). The rate of degradation (c) was strongly correlated with NDF (r = -0.91; P<0.001) and ADF (r = -0.79; P = 0.012), whereas extent of degradation (ED) was positively correlated with c (r = 0.97, P<0.001).

Table 1. ***In vitro*** **fermentation kinetics (estimated from gas production curves) of Algerian forages**

Plant family	Plant species	A (ml/g DM)	C h^{-1}	D144 (g/g DM)	ED (g/g DM)
Dicotyledons					
Chenopodiaceae	*A. halimus*	174^{c}	0.0412^{b}	0.835b^{c}	0.452^{b}
Asteraceae	*A. campestris*	226^{abc}	0.0784^{a}	0.894^{a}	0.623^{a}
	A. herba-alba	208b^{c}	0.0818^{a}	0.822^{c}	0.578^{a}
Fabaceae-Leguminosae	*A. gombiformis*	206b^{c}	0.0760^{a}	0.874^{ab}	0.620^{a}
	C. saharae	207b^{c}	0.0472^{b}	0.666^{de}	0.401^{b}
	R. raetam	226ab^{c}	0.0391^{b}	0.707^{d}	0.385^{b}
Monocotyledons					
Poaceae – Gramineae	*S. pungens*	295^{a}	0.0169^{c}	0.634^{e}	0.190^{c}
	L. spartum	277^{ab}	0.0154^{c}	0.550^{f}	0.172^{c}
	S. tenacissima	253^{ab}	0.0118^{c}	0.469^{g}	0.126^{c}
R.S.D.[1]		16.8	0.00247	0.0087	0.0135

A: asymptotic gas production, c: fractional rate of fermentation; D144: DM disappearance after 144 h of incubation; ED: extent of degradation for a fractional passage rate of 0.03 h^{-1}; [1]Residual standard deviation.
a, b, c, d, e, f, g Means in a column with different superscripts are significantly different ($P < 0.05$).

After 144 hours of incubation time, the highest cumulative gas production was observed for *S. pungens* (269 ml/g DM) and the lowest was obtained by *A. halimus* (185 ml/g DM). The cumulative gas production for *A. Gombiformis* (217 ml /g DM) relatively low, in spite of its very high content in protein contents, confirms the observations of Aregheore (2000) and Khazaal *et al*. (1993). Indeed, these authors relate that the contribution of CP to gas production does not constitute an influence factor. On the another hand, the result obtained with *S. pungens* could be attributed to its moderated content in free CP and/or to the complexation of the ammonia produces by deamination with the carbon dioxide gas (Krishnamoorthy *et al*.,1995). Cell wall content (NDF et ADF) were negatively correlated with gas production at all incubation times and estimated parameters. This may tend to reduce the microbial activity through increasing the adverse environmental conditions as incubation time progress. Gas production can be regarded as an indicator of carbohydrate degradation and the low gas production for *S. tenacissima* (Fig. 1) is explained by condensed tannin's binding to the carbohydrate and by the inhibition of enzymes or microorganisms (Sallam, 2005), complexing with lignocellulose, and preventing the microbial digestion.

However, since gas production on incubation of feeds in buffered rumen fluid is associated with feed leaves, the low gas production for *S. tenacissima and A. halimus*, could be related to low feeding value of these feeds.

IV – Conclusions

Chemical composition (NDF and CP), *in vitro* digestibility were the main influential variables determining the ranking. *A. halimus, A. campestris, A. herba-alba* and *A. gombiformis* can be considered of high nutritional value such as vetch oat and alfalfa, whereas highly fibrous and low digestible grasses (*S. pungens*, *L. spartum* and *S. tenacissima*) should be considered emergency roughages.

Fig. 1. Cumulative gas production profiles of the Algerian browse species.

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