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Kinetics fermentation and gas production of the neutral detergent-soluble fraction of fresh forage, silage and hay of *Avena sativa*

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RIASSUNTO – Cinetica di fermentazione e produzione di gas della frazione solubile nel detergente neutro del foraggio fresco, insilato e affienato di *Avena sativa* – *La fermentazione della frazione solubile nel detergente neutro (NDS) di tre foraggi di avena (fresco, insilato ed affienato) è stata stimata con il metodo di sottrazione delle curve usando la tecnica in vitro della produzione di gas. La velocità massima di fermentazione (R_M) fu sempre maggiore per l'NDS, seguita dal foraggio intero e dall'NDF. Inoltre, l'R_M dell'NDS risultò più elevata per il foraggio fresco (0.106 h^{-1}), seguito dal fieno (0.078 h^{-1}) e dall'insilato (0.048 h^{-1}). È confermata la validità del metodo di sottrazione delle curve, utile anche per valutare le trasformazioni che avvengono durante la conservazione dei foraggi.*

KEYWORDS: oats, cumulative gas production, neutral detergent soluble fraction.

INTRODUCTION – Neutral detergent treatment to evaluate the structural polysaccharides (NDF) removes soluble sugars, pectin substances, starch and the non-carbohydrate fraction (Van Soest, 1991). Despite the widely recognized importance of neutral detergent-soluble carbohydrates (NDS) in the early stages of forage digestion, little is known about their digestion kinetics because most *in vitro* methods have studied the disappearance of insoluble cell wall components. However, knowledge of the degradation characteristics of both fractions is very important to formulate balanced diets for high-yielding animals. Using the *in vitro* gas production system, Schofield and Pell (1995) measured the kinetics fermentation of the NDS fraction using the curve subtraction method. The aim of this experiment was to study the fermentation kinetics of the NDS fraction of oats (*Avena sativa* L.) forages (fresh, silage and hay).

MATERIAL AND METHODS – Three forages of oats, fresh (FO), ensiled (EO) and hay (OH) were used in this study. The three forages were analysed according to the standard procedures (ASPA, 1980). The isolated NDF fraction for fermentation studies was prepared as described by Doane *et al.* (1997). For each substrate, whole forage (WF) and its isolated NDF were incubated at 39°C with a bicarbonate-phosphate-buffer, reducing solution and rumen fluid according to Theodorou *et al.*, (1994). The rumen fluid was collected before morning feeding from two mature buffaloes fed a standard diet (NDF 43.5 and CP 12 %, DM). The fermentation kinetics was measured with the gas production technique using the automated pressure evaluation system (APES) described by Davies *et al.* (2000). The gas volumes produced by the NDS fraction at each time were calculated from the difference between the average gas yields of the WF and its respective NDF, adjusted to represent the amount of NDF present in the initial WF sample (Schofield and Pell, 1995). The cumulative gas data were fitted to the model described by Groot *et al.* (1996): $G(t)=A/[1+(B/t)^C]$ where G represents the amount of gas (ml) produced per g of OM incubated at time t; A denotes its asymptotic value (at t = ∞); B (h) is the time at which A/2 has been formed, and C is a constant determining the curve sharpness. Moreover, the fractional rate (R) at each time and the *maximum* rate (R_M) were calculated (Groot *et al.*, 1996).

Table 1. Chemical composition of the tested forages.

		Fresh oats	Ensiled oats	Oats hay
Crude protein	% DM	5.97	5.24	5.50
Crude fibre	"	29.8	33.7	39.6
NDF	"	60.3	65.7	68.1
NDS	"	39.7	34.3	31.9
ADL	"	4.50	5.70	6.15

NDS (fraction soluble in neutral detergent) = 100 – NDF.

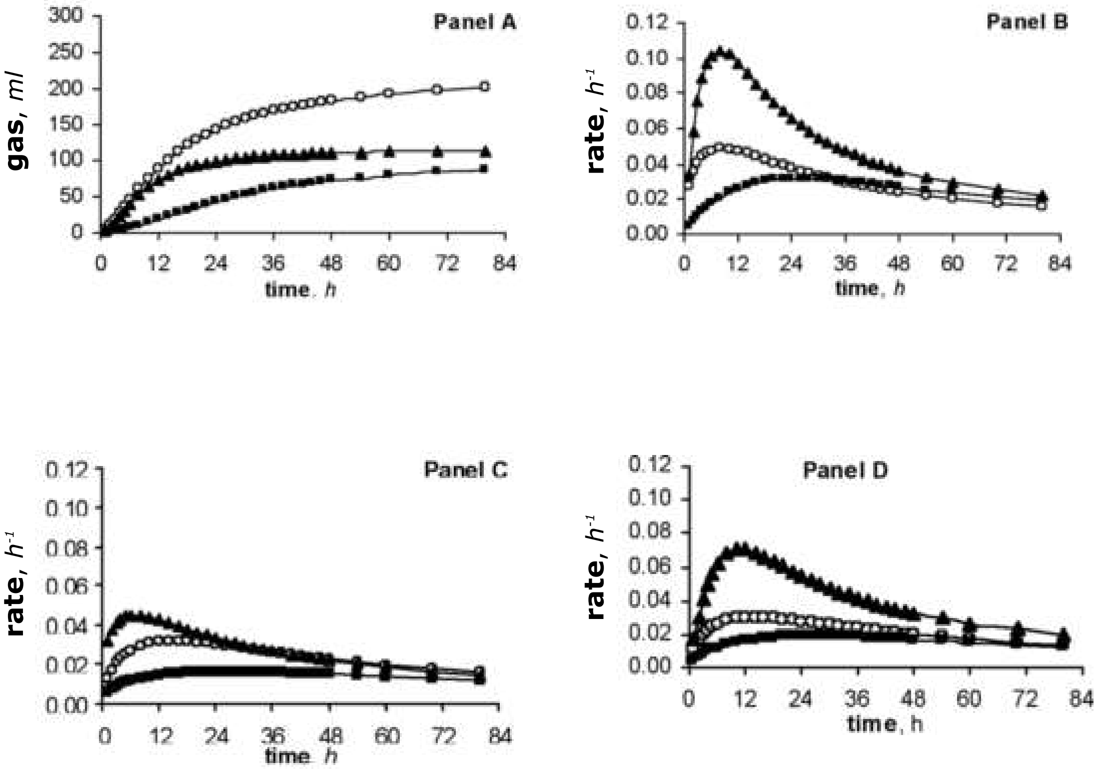
RESULTS AND CONCLUSIONS – As expected, the three forages (Table 1) showed a decrease in protein and an increase in the fibrous fraction due to the preservation methods. The NDF curve for FO (Figure 1, panel A) showed a pronounced lag time in gas production. The latter derived from the NDS fraction was at each time higher than NDF and plays an important role in the early stages of fermentation. The NDS fraction gas production of EO and OH was higher than NDF only until 36 h for the lower soluble carbohydrate content of the two forages (data not illustrated). As expected, for each forage, the trend of R_M was: NDS>WF>NDF (Figure 1 – panel B, C, D), according to our previous results (Calabrò *et al.*, 2001). Regarding the three forages the R_M of NDS showed the following tendency: FO>OH>OE (0.106, 0.078, 0.048 h^{-1}, respectively) (Table 2). Also Doane *et al.* (1997) found a lower R_M for NDS in the silage compared to the fresh forage and they explained the result with the presence in the silage of substantial amount of organic acids, especially lactate, which contribute to the whole fermentative process less efficiently than the glucose. Besides, the fermentative process of FO NDS, reached the *maximum* value, decreases more rapidly compared to OH and EO, probably due to its higher content in soluble sugars compared to the preserved forages. R^2 and RDS values indicate in all case the good fitting of the NDS data, estimated with the subtraction curves method, to the model used. The results of this trial confirm the validity of the curve subtraction method to study the fermentation kinetics of the neutral detergent soluble fraction of forages and to evaluate modification during forage preservation. This is a major result as many methods used to evaluate silage quality do not permit measurement of the fermentation kinetics of the soluble carbohydrate fractions and thus correct estimation of the energy available from the feed and the rate at which this energy is available. The curve subtraction method could contribute to resolve these problems.

Table 2. Model parameters for WF, isolated NDF and NDS of each forage.

	Fresh oats			Ensiled oats			Oats hay		
	WF	NDF	NDS	WF	NDF	NDS	WF	NDF	NDS
A, *ml/g*	222	101	115	272	213	122	275	200	103
B, *h*	15.9	28.5	8.74	24.7	48.4	16.9	21.7	36.7	11.9
RM, h^{-1}	0.052	0.032	0.106	0.032	0.016	0.048	0.038	0.022	0.078
R^2	0.999	0.993	0.999	0.996	0.993	0.998	0.999	0.996	0.996
RSD	1.04	2.61	1.07	4.70	2.61	1.57	2.28	3.05	2.12

R^2: gas production variability explained by the model. All R^2 values are significant (P<0.001; n: 30). RSD: residual standard deviation.

Figure 1. Cumulative gas production and fermentation rate over time.



Panel A: Cumulative gas production (ml per amount of each fraction present in 1 g of OM for FO); Panel B, C and D: fermentation rate (h^{-1}) of FO, EO and OH, respectively. ***Circles****: WF;* ***Squares****: NDF;* ***Triangles****: NDS.*

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