The Common Reed (*Phragmites australis*) as a Source of Roughage in Ruminant Nutrition

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Abstract

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The use of common reed *(Phragmites australis)* as a potential source of roughage in ruminant nutrition was investigated *in vitro*. The fermentation parameters (total gas production, methane, total and individual volatile fatty acids) of *Phragmites australis*, meadow hay, wheat straw, barley, amorphous cellulose and glucose were compared. Fermentation was carried out in 120 ml serum bottles and measurements were made by means of the pressure transducer technique. Amino acids, chemical and mineral composition of *Phragmites australis* were determined. *Phragmites australis* had a relatively high content of magnesium (2.65 g·kg $^{-1}$), potassium (10.9 g·kg $^{-1}$) and manganese (97.0 mg·kg^{-1}). *Phragmites australis* dry matter digestibility ranged within the dry matter digestibility of meadow hay (50.2%) and wheat straw (36.6%) and achieved 41.8 %. Methane production of *Phragmites australis* was significantly higher compared to that of wheat straw and meadow hay. The total gas production of barley, amorphous cellulose and glucose was significantly higher (P < 0.001) compared to *Phragmites australis*. *Phragmites australis* gave a high acetate/propionate ratio (4.4) compared to other substrates, as well. Our results of the *in vitro* experiment thus indicate a potential use of *Phragmites australis* as a new source of roughage with favourable content mainly of nitrogen, K and Mn. However, further research is needed to obtain information from *in vivo* experiments.

Phragmites australis, rumen fermentation, methane, volatile fatty acids, in vitro

Phragmites australis is a large perennial rhizomatous grass, or reed especially common in alkaline and brackish environments (Haslam 1972). *Phragmites australis* used in the present experiment is a tall plant (2.0 - 4.0 m) found in freshwater wetlands, and it is interesting as a source of cellulose and energy. Cattle and horses graze this grass during winter as a protein source, but common reed is unpalatable after maturity. Young shoots are used as a vegetable. The stalks exude a manna-like gum that may be eaten. The rhizomes and roots also serve as emergency food. *Phragmites australis* is an efficient colonizer of disturbed environments because it seeds profusely and spreads vegetatively by a vigorous system of rhizomes and stolons (Hara et al. 1993; Marks et al. 1994). *Phragmites australis* is typically the dominant species on the areas that it occupies. The aggressive nature of *Phragmites australis* is a direct reflection of the adaptive features of its life cycle. In the last decade, *Phragmites australis* has been expanded on the land with the highest content of MgO near the factory Slovmag (Lubeník Slovakia). The objective of the present *in vitro* study was to determine the fermentation parameters of *Phragmites australis* and explore its possible use in ruminant nutrition.

Materials and Methods

The ruminal fluid inoculum used in the present experiment was obtained from the two rumen fistulated Merino sheep fed meadow hay and ground barley at a ratio of 80:20. The samples of rumen fluid were taken 3 h after the morning feeding, transferred to the laboratory in a water bath preheated to 39 ± 0.5 °C, squeezed through four layers

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of gauze and purged with CO_2. The rumen fluid was mixed with McDougall's buffer (McDougall 1948) at a ratio of 1:2 and pumped by an automatic pump at 35 ml doses into each of preheated fermentation bottles (120 ml serum bottles) containing substrates and incubated in the incubator for 72 h at 39 ± 0.5 °C.

The fermentation bottles contained 0.25 g of substrate. The following six substrates were used: *Phragmites australis*, meadow hay, wheat straw, barley, amorphous cellulose and glucose. *Phragmites australis* came from Lubenik region (Slovakia). Dry stalks and leaves from *Phragmites* were used. The fibrous material (meadow hay, wheat straw and *Phragmites australis*) was ground and afterwards passed through three successive sieves with a mesh size of 0.15 - 0.4 mm. Six replicates were used for all experimental groups (rumen inoculum, substrate) and six replicate bottles were used for the control (rumen inoculum, no substrate).

The volume of released accumulated gas was measured after 72 h by the mechanical pressure transducer technique developed by Váradyová et al. (1998). Gases from each fermentation bottle were collected in a 2 ml glass syringe at the end of the incubation and immediately analyzed for methane concentration by gas chromatography. The concentration of volatile fatty acid (VFA) in the medium was determined after 72 h by gas chromatography (Cottyn and Boucque 1968) using crotonic acid as the internal standard and a Perkin-Elmer 8500 gas chromatograph. Hydrogen recoveries were calculated according to Demeyer and Van Nevel (1975). Dry matter digestibility (DM digestibility) was estimated from the difference of the substrate weight before and after 72 h incubation (Mellenberger et al. 1970). *Phragmites* was analyzed for dry matter (DM; 24 h at 103 ºC) and ash (4 h at 550 ºC). Nitrogen content was determined using the Kjeldahl procedure (AOAC 1990) and Kjeltec Auto 1031 Analyzer (Tecator). Crude fat was determined using the Twieselman apparatus. A single amino acid analysis was carried out as described by Van Vuuren et al. (1992) using the AAA 400 apparatus (Ingos Praha). Concentrations of minerals were determined using an apparatus Spectral AA 30 Varian.

The means of the individual parameters were compared using the Student-Newman-Keuls test (Graphpad InStat, GraphPad Software, Inc. San Diego, USA).

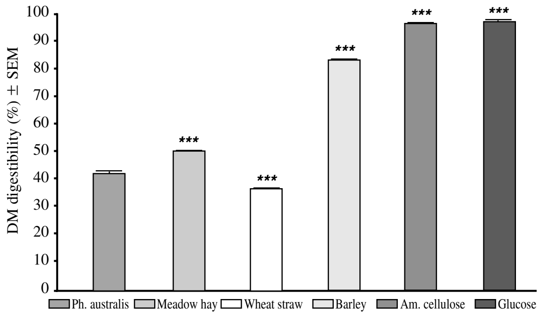

Fig. 1. DM digestibility of *Phragmites australis*, meadow hay, wheat straw, barley, amorphous cellulose and glucose incubated with rumen inoculum *in vitro*, for 72 h. Significance: **P* < 0.05; ****P* < 0.001.

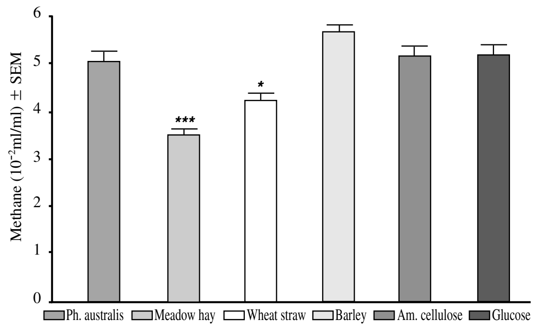

Fig. 2. Methane production of *Phragmites australis*, meadow hay, wheat straw, barley, amorphous cellulose and glucose incubated with rumen inoculum *in vitro*, for 72 h. Significance: **P* < 0.05; ****P* < 0.001.

Results

In comparison to the *Phragmites australis*, the DM digestibility of all substrates (meadow hay, barley, amorphous cellulose and glucose) was higher (P < 0.001) except for wheat straw, where the DM digestibility was lower (Fig. 1). As compared to *Phragmites australis*, significantly lower values (P < 0.001; P < 0.05) of methane production were obtained for meadow hay and wheat straw (Fig. 2). Total gas production of barley, amorphous cellulose and glucose in our study was higher (P < 0.001) compared to the *Phragmites* (Table 2). Total VFA production was significantly lower in meadow hay, wheat straw (P < 0.001) and in barley (P < 0.01), however, it was higher in amorphous cellulose (P < 0.001). Acetate production was lower in barley, amorphous cellulose and glucose (P < 0.001) compared to *Phragmites*. Propionate was higher in all substrates (P < 0.001). As compared to *Phragmites*, iso-valerate and n-valerate were significantly lower (P < 0.001) in meadow hay, wheat straw, amorphous cellulose and glucose. Iso-

Table 1
Amino acids, chemical and mineral composition of *Phragmites australis*

Amino acids		Chemical composition	
Thr ($g \cdot kg^{-1}$)	4.393	Dry matter (%)	93.8
Val ($g \cdot kg^{-1}$)	3.604	N-substances ($g \cdot kg^{-1}$)	120.6
Ile ($g \cdot kg^{-1}$)	3.158	Crude fat ($g \cdot kg^{-1}$)	18.2
Leu ($g \cdot kg^{-1}$)	6.042	Crude fibre ($g \cdot kg^{-1}$)	278.3
Tyr ($g \cdot kg^{-1}$)	4.962	Ash ($g \cdot kg^{-1}$)	67.3
Phe ($g \cdot kg^{-1}$)	4.995	N-free substances ($g \cdot kg^{-1}$)	453.4
His ($g \cdot kg^{-1}$)	2.200	Organic matter ($g \cdot kg^{-1}$)	870.5
Lys ($g \cdot kg^{-1}$)	5.082	Mineral composition:	
Arg ($g \cdot kg^{-1}$)	7.247	Ca ($g \cdot kg^{-1}$)	2.660
Met ($g \cdot kg^{-1}$)	0.378	Mg ($g \cdot kg^{-1}$)	2.649
Asp ($g \cdot kg^{-1}$)	9.819	K ($g \cdot kg^{-1}$)	10.899
Ser ($g \cdot kg^{-1}$)	4.330	Na ($g \cdot kg^{-1}$)	0.534
Glu ($g \cdot kg^{-1}$)	9.376	P ($g \cdot kg^{-1}$)	1.575
Pro ($g \cdot kg^{-1}$)	7.081	Fe ($mg \cdot kg^{-1}$)	58.750
Gly ($g \cdot kg^{-1}$)	4.307	Mn ($mg \cdot kg^{-1}$)	96.964
Ala ($g \cdot kg^{-1}$)	6.981	Zn ($mg \cdot kg^{-1}$)	26.964
Cys ($g \cdot kg^{-1}$)	0.199	Cu ($mg \cdot kg^{-1}$)	8.452

butyrate and n-butyrate of the amorphous cellulose were lower ($P < 0.001$). N-butyrate of barley and glucose and also n-caproate of barley was higher ($P < 0.001$) compared to *Phragmites australis.* The A/P ratio for all the substrates used was significantly lower compared to *Phragmites.* Hydrogen recovery in barley, amorphous cellulose and glucose was significantly higher, however, in meadow hay was lower ($P < 0.05$) compared to *Phragmites.*

Discussion

The data on chemical and mineral composition and also composition of amino acids of *Phragmites* used in our experiment are summarized in Table 1. These data indicate that

Table 2
Production of total gas, volatile fatty acids (VFA), acetate/propionate ratio (A/P) and 2-H recovery of substrates incubated for 72 h.

	Control	*Ph.australis*	Meadow hay	Wheat straw	Barley	Am. cellulose	Glucose	SEM
Total gas (ml)	26.8	45.9	50.0	46.7	61.7***	73.3***	72.6***	1.2
Total VFA (mM)	52.6	59.4	39.7***	33.2***	51.0**	77.3***	61.0	1.3
Acetate (mol%)	68.2	68.1	67.4	68.0	60.5***	60.3***	60.0***	0.3
Propionate (mol%)	15.4	16.3	18.4***	19.2***	20.0***	28.2***	21.6***	0.2
Iso-butyrate (mol%)	1.2	1.2	1.0	1.0	1.2	0.9***	1.0	0.04
N-butyrate (mol%)	10.6	10.2	9.9	9.6	13.9***	7.7***	13.8***	0.2
Iso-valerate (mol%)	1.9	1.8	1.6**	1.6**	1.8	1.2***	1.5***	0.1
N-valerate (mol%)	2.5	2.3	1.7***	1.9***	2.1	1.7***	1.8***	0.04
N-caproate (mol%)	0.3	0.2	0.2	0.2	0.5***	0.1	0.4*	0.1
A/P	4.4	4.2	3.7***	3.6***	3.0***	2.1***	2.8***	0.1
2H-recovery (%)	38.7	44.0	39.2*	41.5	51.6***	53.7***	48.9*	0.6

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ different from *Phragmites australis;* (n = 6); SEM = standard error of the mean

Phragmites is a good source of nitrogen substances and also of potassium, and especially manganese. The amount of manganese (97 mg·kg^{-1}) was higher than in other roughage. For comparison the Mn content of meadow hay of the medium quality is 35.5 mg·kg^{-1} DM (Kováč et al. 1987). Sviatko (1991) reported the Mn content in meadow hay of 94.9 mg·kg^{-1} DM. The availability of limiting nutrients, mainly nitrogen and, to some extent manganese and potassium, is therefore of special importance for common reed. We previously tested the fermentation parameters of meadow hay, wheat straw, beech sawdust, barley straw, maize stalk, sugarcane bagasse. The DM digestibility in the fermentation process with the same inoculum ranged from 37.5% to 55.8% for wheat straw and meadow hay, respectively (Zeleňák et al. 1987; Váradyová et al. 2000). The DM digestibility of *Phragmites australis* in the study ranged within the DM digestibility of meadow hay (50.2%) and wheat straw (36.6%) and achieved 41.8 %. However, no significant differences were observed in the production of total gas in *Phragmites,* meadow hay and wheat straw. According to some authors (France et al. 1993; Getachew at al. 1998) gas production is a more sensitive parameter of fermentation than DM digestibility. This suggests that *Phragmites australis* may be compared to the roughage with lower DM digestibility such as wheat straw. The fibrous materials in this study yielded high acetate/propionate ratios. This was due to a relatively low propionate production as described in literature (Czerkawski 1986; Durand et al. 1988; Zeleňák 1991).

It is concluded that in many ecosystems common reed *(Phragmites australis)* serves as an excellent stabilizer of soil and acts as an efficient nutrient sink through its accumulation of large quantities of persistent biomass. Our results indicate a possibility of using *Phragmites australis* (especially as a source of nitrogen, K and Mn) as a partial replacement of roughage for ruminants. The results of the present *in vitro* experiment will provide a basis for *in vivo* experiments with the final goal to use this new roughage as a partial replacement in agricultural practice. Further *in vivo* studies are expected to provide data on biochemistry, energy and ecology.

Trsť obecná *(Phragmites australis) ako* potenciálny zdroj objemového krmiva vo výžive prežúvavcov

Sledovali sme možnosť využitia trsti obecnej *(Phragmites australis)* ako potenciálneho zdroja náhrady objemového krmiva vo výžive prežúvavcov. V podmienkach *in vitro* boli porovnávané fermentačné parametre (produkcia plynov, metánu a unikavých mastných kyselín) trsti obecnej s inými substrátmi (lúčne seno, pšeničná slama, jačmeň, amorfná celulóza a glukóza). Fermentácia prebiehala v 120 ml fľašiach na sérum a merania plynu sa uskutočnili mechanickým tlakovým manometrom. Pri trsti obecnej boli stanovené základné živiny, minerálne látky a aminokyseliny. Z chemického hľadiska bola trsť obecná bohatým zdrojom dusíkatých látok. Z hľadiska minerálneho zloženia bola bohatá na draslík (10,9 gkg^{-1}) a na mangán (97,0 mg·kg^{-1}). Namerané hodnoty stráviteľnosti trsti obecnej (41,8%) boli medzi stráviteľnosťou lúčneho sena (50,2 %) a pšeničnej slamy (36,6%). Metánová produkcia pri trsti obecnej bola vyššia v porovnaní s lúčnym senom a pšeničnou slamou. Produkcia celkových plynov bola vyššia pri jačmeni, amorfnej celulóze a glukóze ($P < 0{,}001$)v porovnaní s trsťou obecnou. Bol zaznamenaný vysoký pomer acetát / propionát (4,4) pre trsť obecnú v porovnaní s ostatnými substrátmi. Dosiahnuté výsledky poukazujú na možnosť náhrady suchých objemových krmív trsťou obecnou, ktorá je dobrým zdrojom dusíka, draslíka a mangánu, avšak jej praktické využitie vyžaduje ďalšie pokusy hlavne v *in vivo* podmienkach.

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