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How does sward accessibility affect the choice of feeding sites and intake in horses?

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Abstract
Grass represents a large part of the diet of horses, which has important consequences for their nutritional management, as well as for the management of biodiversity in grasslands. However, very little is known on the factors affecting their daily intake and patch selection at pasture, including the effect of vegetation characteristics such as sward accessibility. This question was the subject of this study: three groups of three 2-yr-old saddle horses were grazed on a semi-natural pasture that was managed to produce three contrasting vegetative sward heights of similar quality, i.e. 6, 11 and 17 cm, in a Latin-square design. The different sward heights were offered either alone to the animals or in pair-wise preference tests. Daily food intake was measured individually using faecal collection on swards offered alone. In preference tests, animals spent more time grazing on the taller sward where they realised higher instantaneous intake rates. Voluntary intake was not affected by sward height and averaged 20gDM/kgLW/day, but depletion that affected sward heights could have reduced the potential variations in DMI.

Key words: horses, pastures, intake, feeding choices, sward accessibility

Introduction
The number of equids has been increasing over the last decades in Europe and horses have reached a million in France (OESC, 2006), particularly because of the increasing demand of horses for leisure activities. Grass represents 70 to 100% of the diet of these horses on an annual basis (Martin-Rosset et al., 1984) so horses play an increasingly important role in the management of grasslands. Moreover, in France, horses breeders have recently obtained an "agricultural status"and can now request European Union financial support for the preservation of rural landscapes if they contribute to the maintenance of grassland productivity and biodiversity.

In the current context, to improve the management of domestic livestock in the long-term, it is necessary to improve our skills in feeding horses from grasslands, while contributing to the diversity of these habitats. A great deal of knowledge is available on ruminants, but very little is known of the capacity of swards to meet the nutritional requirements of grazing horses and on the impact of these herbivores on grasslands. As a consequence, it is now essential to get information about voluntary intake and feeding choices by horses at pasture and to identify how they are affected by plant or animal factors.

Dry matter intake has been well studied for horses fed fresh or dry forages *ad libitum* in the stable (Martin-Rosset and Doreau, 1984; Chenost and Martin-Rosset, 1985; Boulot, 1987; Cymbaluk, 1990; Dulphy et al., 1997a,b) and the primary factor affecting voluntary intake is the level of requirements (Martin-Rosset and Doreau, 1984). At pasture, references are very limited (but see Duncan, 1992; Mesochina, 2000; Fleurance et al., 2001; Menard et al., 2002) and the causes of variation in intake levels have received almost no attention (but see Mesochina, 2000).

Choices of sites for feeding can vary over the course of the grazing season according to variations in resource availability and quality. Duncan (1992) showed that horses generally selected feeding sites offering higher biomass of green forages, but shifted to sites offering the higher total biomass when green forages availability declined, particularly in winter. A study led by Naujeck et al. (2005) showed that horses selected swards higher than 7cm when offered choices between 3.5, 4.5, 7.5 and 15cm, but no data of grass quality were available to evaluate the effects of variations in resource quality on the choices. As these swards were cut from a height of 15cm to the height to be tested the day before the tests and shorter swards may have been stemmier, and of lower quality, with higher fibre content.

The aim of this study was to improve our knowledge of characteristics of grass swards which are likely to affect intake and the choice of feeding sites by horses at pasture. We have studied the preferences and the variations of intake in horses submitted to different grass accessibility levels, keeping their quality constant. The horses were offered pair-wise choices between vegetative swards of different heights (short, intermediate and tall swards). Instantaneous and daily voluntary intake were also measured on each of these swards offered alone. We hypothesized that horses will show a preference for the taller swards where they could maximize their intake rates.

Material and Methods

The experiments lasted from May to October 2006, at the experimental farm of Chamberet (Corrèze, France) at an altitude of 440m. Nine 2 year-old female saddle horses (Anglo-Arab and French Saddle horses) were used for the experimentations and were accustomed with the experimental measures before the tests.

Experimental design and procedure

The experimental design was a latin-square (3 groups, 3 tests, 3 periods). The 3 groups of horses were balanced for their live weight (mean Live Weight, LW, 514kg 6.0 S.E.) and paternal origin but the composition of the three groups was changed between the three periods in order to control for a possible group effect on the horses' individual feeding behaviour. The first two periods lasted from 1st of May until mid June. A one-month drought in June forced us to postpone the third period, from mid-September to the first week of October.

Three vegetative sward types of different accessibility and constant quality were prepared by mowing at 4cm and allowing regrowth (3 days for the Short sward (S), 11 days for the Intermediate sward (I) and 19 days for the Tall sward (T)). The sward heights obtained averaged respectively: 6.1cm 0.04 S.E., 11.0cm 0.07 S.E. and 17.7cm 0.11 S.E.). For the tests where swards were offered alone or in pair-wise choices, we defined the sizes of test areas so that the 3 sward types supplied the same total amount of dry matter and the horses grazing a single sward type should not be limited in their daily intake by the forage available For this purpose we used biomass data estimated from previous studies on the same area (S: 60gDM/m²; I: 150gDM/m²; T: 240gDM/m²; Mesochina, 2000, Fleurance, personal records) and the maximum intake levels measured for growing horses available in the literature (150gDM/kg$LW^{0.75}$/day, Menard et al., 2002). This area was then multiplied by two to allow for trampling.

Each period of the latin-square design was divided into 3 weeks of tests: experimental trays, swards offered alone and pair-wise choices (see details in Table 1). The animals were weighted the first day of each week of the tests.

- Experimental trays

Each group was offered the same sward (as in the 'swards offered alone week') on three successive days on experimental trays indoors. The experimental trays were made up using turfs including 10cm of soil, cut out of the pasture on the morning of the tests. The dimensions (112*72*10cm) were established in preliminary tests, to allow the horses to take 20 bites without depletion affecting grass height on the trays. The horses were fastened for 5h before the test to make sure that they would be motivated to eat.

- Swards offered alone

Each group was offered a single sward type to graze (S, I or T) during 7 days, a new area being provided every day.

- Pair-wise choices

Each group was offered a binary choice (S/T, I/T, S/I) during 7 days, a new plot being provided every day. A plot consisted of four strips of one of the sward types alternated with four strips of the second sward type offered in the pair-wise choice. The dimensions of the strips depended on the area calculated for each treatment (see above).

Table 1: The timing of the tests for the 3 periods

Period	Individuals (N°)	1st week: experimental trays	2nd week: swards offered alone	3rd week: pair wise choices
1	7, 8, 9	S	S	I/T
	4, 5, 6	I	I	S/T
	1, 2, 3	T	T	S/I
2	1, 4, 7	S	S	I/T
	2, 5, 8	I	I	S/T
	3, 6, 9	T	T	S/I
3	3, 4, 8	S	S	I/T
	1, 5, 9	I	I	S/T
	2, 6, 7	T	T	S/I

Vegetation

Sward heights and biomasses were measured each day of the tests for the three situations. Sward heights were measured at the start and the end of each test, using a sward stick (as described in Fleurance et al., 2001). Biomasses were measured at start from grass samples cut from the ground in a 25*25cm² cell. These grass samples were then analysed for dry matter (DM), ash, Crude Protein (CP, Kjeldahl method N x 6.25), Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) (Goering and Van Soest, 1970).

Animal behaviour and voluntary intake

For the pair-wise choices and when the swards were offered alone, the first day of the week was used to accustom the animals to the new test. The behaviour of the horses was then recorded using scan sampling (one observation/individual each 15mn); the 24h observations were divided in eight 3-hours sessions spread over days 2 to 4 of the week. We estimated total daily grazing time, and also preferences, by the time spent on each sward type. Bite rates (bite/mn) on each sward type were also recorded all through the day, associated with a grass height measurement where the animal was grazing.

Daily intake on the swards offered alone was estimated by total faecal collection and digestibility was estimated from faecal crude protein (as described in Mesochina et al., 1998). Individual faeces were identified by giving each horse 60g of small coloured plastic balls (one colour per horse) in 140g of oats every morning. The faeces were collected twice a day during days 5 to 7.

Bite mass (in gDM) was estimated by weighing the trays before and after the horses had grazed, dividing the weight loss (corrected by evapo-transpiration losses) by the number of bites taken (the method is described in Fleurance et al., 2005).

Instantaneous intake rates were calculated for each individual on each sward from the bite mass measured on trays and the bite rate during the first 3h of 'swards offered alone' test (when differences of heights between swards were the same as those offered on trays).

Statistical analyses

The animals were treated as replicates for statistical analyses as the design of the plots allowed the animals to stay in close proximity while grazing different swards. They could switch from a sward to another independently from their companions, and thus make their own choices.

We compared the sward types using the ANOVA procedure of SAS (Statistical Analysis System, 1999). We tested for the differences between sward types ('heights', 'biomasses' or 'quality'), 'period' and their interaction. The period effect was often significant so we took it into account in the analyses. For feeding time, preferences, bite and chew rates, bite mass and intake rates, we used the Mixed Proc of SAS (Mixed Models with the Residual Maximum Likelihood algorithm), to test the effect of the 'sward' type (S, I, T), integrating the 'period' and 'individual' effects in the random variables. For intake levels, as the biomasses obtained were slightly different from those expected (see Table 2), we integrated in the mixed model a factor 'food supply' (total biomass available to the horses; and its interaction with 'sward') since the total amount of DM offered in each situation could have affected intake levels. For each test, we performed pair-wise t-tests to compare sward types, with the Bonferroni adjustment for p-values.

Results

Sward characteristics

The swards differed significantly in accessibility (heights and biomass densities), and their quality remained nearly constant (NDF and CP contents) except for the protein content of the I sward which was higher than the others, and significantly so in the choice I/T and for the trays (Table 2). However, when considering each Period separately, there were no significant differences between the CP levels of swards offered in pair-wise choices. Depletion occurred, and the sward heights differed significantly between the start and the end of the experiments, but the heights were still different between swards at the end of the tests. The availability differed significantly between periods in some cases (heights: P2 < P1< P3; biomasses: P1 = P2 < P3; NDF: P1 < P2 < P3; CP: P1 < P2 < P3).

Table 2: The characteristics of the Short, Intermediate & Tall swards (means S.E.).

Test		Heights (cm)		Biomasses (gDM)	Quality	
		Start	End		Fibre (%NDF)	Crude Protein (%)
Choice S/T	Short	5.9 +-0.05[a]	5.2 +-0.07[a]	61.4a +-2.4[a]	48.5 +-1.9[a]	18.8 +-0.9[a]
	Tall	17.2 +-0.20[b]	7.6 +-0.3[b]	186.8 +-7.1[b]	47.4 +-1.9[a]	18.6 +-0.5[a]
Choice S/I	Short	5.8 +-0.06[a]	5.4 +-0.07[a]	63.1 +-2.2[a]	51.3 +-0.9[a]	17.8 +-0.9[a]
	Interm	12.1 +-0.12[b]	6.9 +-0.10[b]	132.8 +-3.4[b]	50.2 +-0.78[a]	18.6 +-0.7[a]
Choice I/T	Interm	10.3 +-0.12[a]	6.3 +-0.12[a]	99.5 +-3.1[a]	51.3 +-0.9[a]	20.4 +-0.6[a]
	Tall	17.5 +-0.19[b]	8.9 +-0.16[b]	188.9 +-5.0[b]	52.4 +-1.3[a]	17.6 +-0.7[b]
Swards alone	Short	6.5 +-0.08[a]	5.0 +-0.08[a]	71.1 +-2.5[a]	48.5 +-1.8[a]	17.6 +-0.7[a]
	Interm	10.4 +-0.12[b]	5.7 +-0.09[b]	124.2 +-3.1[b]	49.4 +-1.9[a]	19.8 +-0.8[a]
	Tall	17.5 +-0.20[c]	6.8 +-0.13[c]	199.1 +-5.1[c]	45.4 +-2.6[a]	17.8 +-0.6[a]
Trays	Short	5.9 +-0.10[a]	NA	59.4 +-4.2[a]	50.7 +-2.6[a]	15.3 +-1.3[a]
	Interm	11.5 +-0.23[b]	NA	112.3 +-4.2[b]	49.1 +-1.7[a]	21.2 +-0.7[b]
	Tall	21.5 +-0.37[c]	NA	246.5 +-11.2[c]	46.2 +-2.1[a]	15.8 +-1.1[a]

[a, b, c] Letters indicate significant differences within tests ($p<0.05$)

Daily DM intake and feeding time

There were no significant differences in intake levels between the swards, the factor 'food supply' was not significant, nor was its interaction. Horses ingested on the average 20gDM/kgLW/day (2.6 S.E.) whatever the accessibility level. The intake levels were slightly higher in Period 3 than in the two other periods ; there were also significant inter-individual variations.

Whatever the situation, horses always fed for about the same total time (14h05mn +/-28mn), which was very stable between periods and individuals.

Preferences

As depletion occurred, we present the initial preferences (during the 3 first hours, when differences of heights were maximum). For the three pair-wise choices the horses fed significantly longer on the taller swards (between 65 and 95%, Figure 1); this pattern was rather constant between periods and individuals.

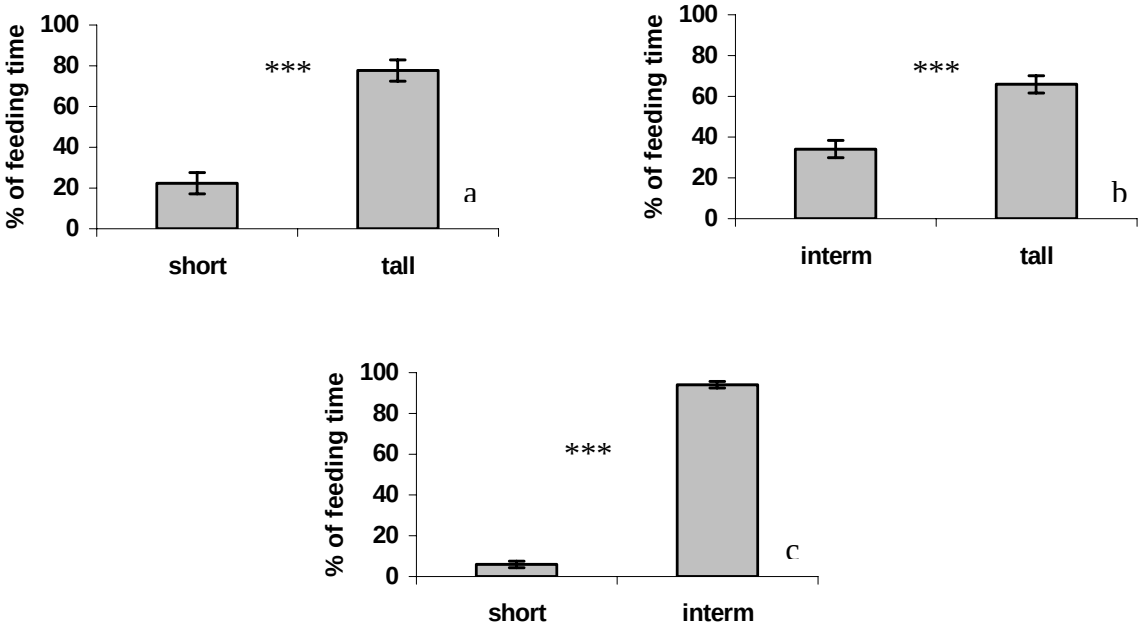

Figure 1: Proportion of feeding time during the 3 first hours spent on each sward type for the three pair-wise choices - a: choice short/tall; b: choice intermediate/tall; c: choice short/intermediate - *** p< 0.001)

Instantaneous intake rates

Bite rates, measured on the same swards, were significantly lower on the taller grass while bite masses, measured on the trays, were at least twice as high on this sward compared with the two others (Table 3). There was no effect of the period and variations between individuals were weak, especially for bite masses. Instantaneous intake rates differed between swards, being significantly higher for the tall sward (Figure 2). There were significant differences between periods and individuals.

Table 3: Bite rates, chew rates and bite masses for the three swards (means +-S.E.)

	Bite rate (bite/mn)	Bite mass (g)
Short	41.5 +-1.94[a]	0.34 +-0.08[a]
Intermediate	43.7 +-1.90[a]	0.51 +-0.08[a]
Tall	30.7 +-1.95[b]	1.06 +-0.08[b]

[a, b, c] Letters indicate significant differences among swards (p<0.05)

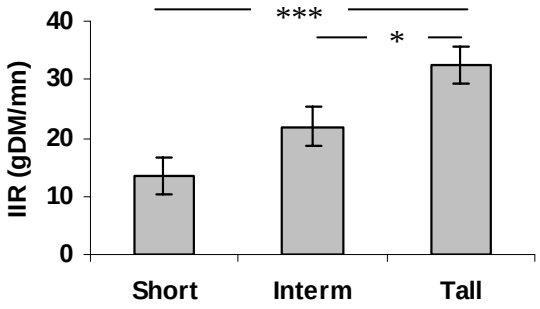

Figure 2: Instantaneous intake rates for the three swards (means +-S.E.) - * p<0.05, *** p<0.001

Discussion

The sward types initially always differed significantly in both heights and biomasses, and were similar in quality (Table 2) particularly when we consider the swards offered in pair-wise choices or alone within each period. Quality is therefore unlikely to have had an effect on preferences or intake by the horses.

At the daily scale, horses fed 14h whatever the sward offered, which is consistent with the literature (12-16h in a review, Duncan, 1992). They ingested on average 20gDM/kgLW/day and intake levels did not differed significantly between swards. On shorter swards (<3cm, 72-83 gDM/m²), Mesochina (2000) found that horses needed to increase their feeding time until 17h to maintain their voluntary intake.

The daily voluntary intake measured in this study is very close to the one obtained by Mesochina (2000, 21gDM/kgLW/day) on the same type of 2 years old horses conducted on the same pastures (Chamberet). However, these values are low compared to the few other references available in the literature for horses assumed to have similar requirements (from 26 to 32gDM/kgLW/day for growing draught horses conducted on wet natural grasslands, Menard et al., 2002). Among the possible explanations, one is that the lower grass quality of the pastures used in the other studies (Ménard et al., 2002: 9<CP<25%DM and 48<NDF<64%DM; present study: 15<CP<21%DM and 45<NDF<52%DM) might have conduced the horses to achieve higher dry matter intakes. Moreover, these studies all concerned hardy breeds whereas we worked with saddle sport horses that were selected for years more for their athletic performances than for their optimal foraging (Rivero and Barrey, 2001).
The dry matter consumption measured in the present study was 10.3kgDM/individual/day.The net energy supplied by the grass here reached the recommended allowance established by INRA (Martin-Rosset, 1990) and the digestible protein supply was three times higher than the recommendations. Live weight gains realised by these animals (between 570 and 740g/day) were higher than expected for 2 year-old horses (450-550g/day). As a consequence, it appears that horses achieved to realise optimal growth even with these low intake levels, due to the high quality of the grass offered.

During the 3 first hours of the tests (when differences of height were maximal) the horses selected the taller swards strongly (all the individuals spent between 65 and 95% of their feeding time on these, Figure 1). These preferences are consistent with the differences in short-term intake, as the horses realised lower bite rates and higher bite masses on the taller sward, implying lower costs in resource acquisition. Instantaneous intake rates were significantly higher for the tall sward, and even if the intermediate and short swards did not differ significantly, the mean IIR tended to be higher for the intermediate one.

To summarize, these horses fed for the same total time and consumed the same amounts of grass per day whatever the sward offered; however they realised the highest instantaneous intake rate on the tallest sward. This incoherence could be explained by the IIR estimated in this study which are those

realised when the sward heights were at maximum heights, since bite masses and bite rates were measured before depletion occurred. Over the day, grass heights decreased and IIR should have decreased too, particularly for the taller swards. This depletion could have also reduced the potential variations of intake if the swards heights had remained constant over the course of the day.

To test this last hypothesis, we divided the 24h into 4x6h periods for which we estimated instantaneous intake rates from the bite rates realised over these 6h, each bite rate measurement being associated with a height measurement where the animal was feeding. For bite masses, we created height ranges to associate with a potential bite mass: grass heights 8cm were related to the bite masses realised on the S sward, 9 grass heights 14cm were related to the bite masses realised on the I sward, grass heights 15cm were related to the bite masses realised on the T sward. It appears that the greater part of the depletion took place during the first 6h of grazing. During this interval, estimated instantaneous intake rate was significantly lower on the S sward compared with the two others (S = 14.0gDM/mn +/-2.51; I = 22.5 gDM/mn +/-2.51; 26.3 gDM/mn +/-2.52; $p<0.05$). IIR seemed then to decrease for the I and T swards, and no differences between swards remained for the rest of the day. On their 14h feeding, horses thus spent about 10h to graze on different sward types where they realised the same IIR. As a consequence, it seemed coherent not to observe differences of DM intake at the daily scale, while depletion prevented horses from achieving higher IIR on the taller sward all along the day.

To conclude, when offered a choice between different accessibility levels of good quality grass, horses showed preferences for the more accessible sward. This was particularly true for the first hours of the tests, when differences of grass heights were maximal, since we observed a strong selection for the taller swards where the horses realised higher instantaneous intake rates. Unfortunately, depletion involved a rapid levelling of IIR between swards and this may be why we did not observe differences of daily intake between the three accessibility levels.

The conditions of these tests contrast with what is observed in natural conditions, where horses face the heterogeneity of the vegetation. Indeed, horses are known to maintain patches of short grass where they graze preferentially, in a matrix of tall swards generally contaminated with faeces (Fleurance et al., 2001; Menard et al., 2002; Lamoot et al., 2005). This has for a long time been interpreted as an anti-parasite strategy, horses avoiding feeding on the tall swards to avoid the ingestion of gastrointestinal parasites (Taylor, 1954). However, a recent study suggested that the maintenance of patches of short swards of high quality could enable the horses to maximize their digestible nutrient intake (Fleurance et al., 2005). It would therefore be interesting to repeat these tests where there is a trade-off,, and the more accessible sward is of poorer quality.

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