Effect of diet composition on the kinetics of osmotic pressure in the rumen of dairy goats

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SUMMARY - An experiment was conducted on 8 cannulated dairy goats which received four different mixed diets of lucerne hay and concentrate. On a dry matter (DM) basis, the two high forage diets contained 55% lucerne hay, 10% sugar beet pulp and 35% concentrate, while the two low forage diets consisted of 30% lucerne hay, 35% sugar beet pulp and 35% concentrate. The compound feed consisted of 74% either barley (a rapidly degradable source of starch) or maize (a slowly degradable one). Each goat received each diet according to a latin square design. During each period, samples of rumen juice were taken before and 2, 4, 6 and 8 hours after the morning feed. Osmotic pressures were similar between diets (about 300 mOsm/kg H_2O) before the morning feed. They were significantly increased by the barley diets during the 8 hours following the meal. A peak of 350 mOsm/kg H_2O was observed for barley diets 2 hours after feeding, thereafter the osmotic pressures decreased to a plateau of about 320 mOsm/kg H_2O for the rest of the sampling period. With the maize concentrate, osmotic pressure did not vary significantly for the high forage diet, and slightly increased (10%) for the low forage diet. Thus, the kinetics of osmotic pressure can be significantly modified by diet composition.

Key words: Dairy goats, rumen osmotic pressure, starch source, forages/concentrates ratio.

RESUME - *"Effet de la composition du régime sur la cinétique de la pression osmotique dans le rumen de chèvres laitières". Une expérience a été menée sur 8 chèvres laitières canulées qui recevaient quatre régimes mélangés différents de foin de luzerne et de concentré. Sur la base de la matière sèche (MS), les deux régimes riches en fourrage contenaient 55% de foin de luzerne, 10% de pulpe de betterave sucrière et 35% de concentré, tandis que les deux régimes pauvres en fourrage consistaient en 30% de foin de luzerne, 35% de pulpe de betterave sucrière et 35% de concentré. L'aliment composé consistait de 74% soit d'orge (une source d'amidon rapidement dégradable) ou de maïs (source lentement dégradable). Chaque chèvre recevait chaque régime selon un dispositif en carré latin. Pendant chaque période, des échantillons de jus de rumen ont été prélevés avant et 2, 4, 6 et 8 heures après le repas du matin. Les pressions osmotiques étaient similaires entre les régimes (environ 300 mOsm/kg H_2O) avant le repas du matin. Elles augmentaient de façon significative avec les régimes d'orge pendant les 8 heures suivant le repas. Un pic de 350 mOsm/kg H_2O était observé pour les régimes d'orge 2 heures après la prise d'aliment, et ensuite les pressions osmotiques diminuaient jusqu'à atteindre un plateau d'environ 320 mOsm/kg H_2O pour le reste de la période d'échantillonnage. Avec le concentré de maïs, la pression osmotique ne variait pas significativement pour le régime riche en fourrage, et augmentait légèrement (10%) pour le régime pauvre en fourrage. Par conséquent la cinétique de la pression osmotique peut être modifiée de façon significative par la composition du régime.*

Mots-clés : *Chèvres laitières, pression osmotique du rumen, source d'amidon, ratio fourrage/concentré.*

Introduction

Osmotic pressure is a ruminal parameter which is not often measured compared to pH, volatile fatty acids or ammonia for example. Osmotic pressure is believed to influence voluntary dry matter intake (Bergen, 1972; Welch, 1982) and to decrease cellulose digestion, at least *in vitro* (Bergen, 1972) when it is higher than 400 mOsm/ kg H_2O. However, other authors disagree with these theories (Forbes, 1995). In fact, it is very difficult to test the effects of osmolality *per se*, since experimental changes in osmotic pressure are very often due to additions of Na^+ salts of volatile fatty acids, which implies changes in VFA and Na^+ concentrations and not only in osmotic pressure.

The aim of this work was to improve knowledge about within-day variations of osmotic pressure for diets usually fed to dairy ruminants. Therefore, it involved kinetic studies on osmotic pressure in the rumen of lactating goats receiving diets which differed in their rate of rumen concentrate degradation or in the forage-concentrate ratio.

Material and methods

The data were obtained from 8 cannulated mid-lactation dairy goats (Alpine or Saanen breeds). Two compound feeds were given separately. They contained either barley (a rapidly degradable source of starch, R) or maize (a slowly degradable one, S), soyabean cake and a mineral mixture (74%, 23% and 3% of DM respectively). Each of them was mixed with either a high forage (H, 55% hay, 10% sugar beet pulp and 35% concentrate) or a low forage diet (L, 30% hay, 35% sugar beet pulp and 35% concentrate) according to a 2 x 2 factorial design. The composition of diets is given in Table 1. Each goat received each diet according to a latin square design. This paper describes only the first two periods.

Table 1. Composition of diets

Rate of starch degradation	Rapid	Rapid	Slow	Slow
Forage/concentrate ratio	55/45	30/70	55/45	30/70
Diet	HR	LR	HS	LS
% of DM				
Lucerne hay	27.5	15	27.5	15
Dehydrated lucerne	27.5	15	27.5	15
Dehydrated sugar beet pulp	10	35	10	35
Barley	26	26	0	0
Maize	0	0	26	26
Soyabean meal	8	8	8	8
Mineral and vitamin mixture	1	1	1	1

R: rapidly degradable starch; S: slowly degradable starch; H: high level of forage (55%); L: low level of forage (30%)

Samples were withdrawn from the rumen through the cannula, just before the morning feed and then at 2, 4, 6 and 8 hours. They were immediately filtered on a nylon bag cloth (Michalet-Doreau *et al.,* 1987), and frozen at -20ºC. Just before the analysis, they were centrifuged at 4000 rpm for 15 min. Osmolalities were determined with an osmometer (Mark 3 Osmometer manufactured by Fiske® Associate) using the freezing point depression procedure. Some parameters of the apparatus were adapted for rumen samples (Giger-Reverdin and Prado, unpublished).

Measurements were performed using each goat on 2 separate days within a period. Means of duplicates concerning a goat within a period were used as basic data. Kinetics of osmolalities for the different diets are given in Table 2. With this experimental design, it was possible to test the effects of the types of concentrate which were included at a level of 35% DM in all diets, of the cell-wall degradation rate (since the high forage diets differed from the low forage ones in the lucerne/sugar beet pulp ratios) and the interaction between these two parameters.

Results

Before the morning meal, osmotic pressures did not differ significantly between diets and were about 300 mOsm/kg H_2O, with a lower value for LS diet (280 mOsm/kg H_2O). The peak value was obtained 2 hours after the meal and remained marked for R diets, but was little less so for S diets. At 2 h, the effect of concentrate was highly significant and it remained statistically significant for later

sampling. For the rapidly degradable diets (HR and LR), there was a plateau, of 320 to 330 mOsm/ kg H_2O during at least 4 hours, which was statistically higher than the initial value. For the slow degradable diet with a high forage ratio (HS), there was no statistical difference between sampling times, which means that this parameter was very stable. For the other slow degradable diet (LS), the 4 hours value did not differ from the initial one, this was so for later samples, even if they remain a little higher. There is no forage level-type of concentrate interaction.

Table 2. Kinetic of osmolality (mOsm/kg H_2O)

Time of sampling	Diets				Effects			
	HR	LR	HS	LS	Forage	Starch	F x S	RSD
0 h	302^{a}	299^{a}	295^{a}	281^{a}	NS	NS	NS	18
2 h	350^{b}	351^{b}	304^{a}	313^{b}	NS	0.01	NS	23
4 h	327^{bc}	327^{c}	296^{a}	298^{ab}	NS	0.01	NS	15
6 h	320^{ac}	327^{c}	303^{a}	304^{ab}	NS	0.04	NS	17
8 h	320^{ac}	322^{c}	295^{a}	298^{ab}	NS	0.06	NS	24

R: rapidly degradable starch; S: slowly degradable starch; H: high level of forage (55%); L: low level of forage (30%)
a,b,c: Means not bearing the same superscript letters within columns are significantly different ($P<0.05$); NS: non significant

As the initial osmotic pressure was a little lower for LS diet, the evolution in osmolalities can be expressed as percentage of the initial value (Table 3). Effects of concentrate are only statistically significant 2 and 4 hours after the morning feed. For the 6 and 8 hours samples, relative values for LS diet are of the same order of magnitude as for HR diets. High percentages of hay in the diet tend to smooth out variations in osmotic pressure.

Table 3. Kinetic of osmolality (expressed as % of the initial value)

Time of sampling	Diets				Effects			
	HR	LR	HS	LS	Forage	Starch	F x S	RSD
0 h	100^{a}	100^{a}	100	100^{a}				
2 h	116^{b}	117^{b}	103	112^{bc}	0.09	0.01	NS	5
4 h	108^{c}	110^{c}	101	106^{ac}	NS	0.03	NS	5
6 h	106^{c}	110^{c}	103	108^{bc}	0.06	NS	NS	4
8 h	106^{c}	108^{c}	100	106^{ac}	NS	NS	NS	7

R: rapidly degradable starch; S: slowly degradable starch; H: high level of forage (55%); L: low level of forage (30%)
a,b,c: Means not bearing the same superscript letters within columns are significantly different ($P<0.05$); NS: non significant

Discussion

The measured osmolalities in this experiment agree with those generally observed for other ruminants (Rémond *et al.*, 1995). They are of the same order of magnitude as for plasma before the morning feed and increased up to 350 mOsm/kg H_2O about 2 hours after the morning feed. For the R diets, it would have been interesting to have values one hour after the meal, as increases in osmolalities might have occurred at this time (Rémond *et al.*, 1995). It is impossible to know if the value measured at 2 h is a peak value or is situated in the decreasing phase of the curve. This is of

importance, as some authors state that above 350 mOsm/kg H_2O, intake and ruminal motricity tend to decrease (Welch, 1982).

It is well known that the rate of degradation of starch influences ruminal kinetics of ammonia and volatile fatty acid production (Sauvant *et al.,* 1994): rapidly degradable starch induces more ruminal disturbances for pH, volatile fatty acids and ammonia concentrations than slowly degradable starch. This work emphasizes the fact that osmotic pressure varies in the same manner, even if the level of cereal was only 26% DM. These results agree with those obtained by Focant (1986) in small ruminants (sheep and goats): volatile fatty acids concentrations were directly proportional to osmotic pressure when there was no addition of minerals, because they count for the major part of its variation. Our results agree also with those of Bennink *et al.* (1978) on different diets who found that when fermentation is rapid, increased volatile fatty acid production increases osmotic pressure as absorption of organic acids is decreased, and then modifies pH values, and thus degradation of feeds. A new steady-state between fermentation and disappearance is reached which needs to be evaluated, at least by the *in sacco* method. Effect of the concentrate was less marked when relative values were tested instead of absolute ones, by taking into account all 4 data periods, it should be possible to test if this difference which is due to the low initial value of LS diet depends on the diet or is a hidden "goat" effect.

As the kinetics of water and dry matter intakes greatly influence osmotic pressure, these parameters need to be taken into account when they are available and might explain some between-animal effects which increase residual standard deviations.

Conclusion

Goats seem to show osmolality kinetics which closely resemble those for other ruminants and give values of the same order of magnitude. This work emphasizes that the rate of starch degradation, even given at low levels (one quarter of diet DM), might modify kinetic of ruminal osmolality. These results need to be confirmed with the complete latin square data and other zootechnical parameters.

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