Ann Zootech (1994) 43, 379-387
© Elsevier/INRA

Note

Comparison of the intake and digestibility of different diets in llamas and sheep: a preliminary study

JP Dulphy, C Dardillat, M Jailler, JP Jouany

INRA, Station de Recherches sur la Nutrition des Herbivores, Theix, F 63122 Saint-Genès-Champanelle, France

(Received 8 June 1993; accepted 28 December 1993)

Summary — Three diets (hay, straw with soya cake with or without barley) were fed to 3 llamas and 3 sheep. The 2 species ingested the same quantity of hay, but llamas ingested 14% more straw (in g/kg LW). OM digestibility of straw was higher in llamas (+ 3.8 points). Mean retention time of DM was higher in llamas (32 h against 25 h for sheep). Reticulo rumen pH was more stable in llamas and also higher than in sheep. In conclusion the ability of llamas to use low quality roughage seems to be more efficient than that of sheep.

intake / digestibility / roughage / sheep / llama

Résumé —Comparaison de l'ingestibilité et de la digestibilité d'un foin et d'une paille par des lamas et des moutons. Étude préliminaire. *Les quantités de MS ingérées de 3 rations (un foin, une paille + tourteau de soja sans ou avec orge) et la digestibilité des 2 rations à base de paille ont été comparées chez des lamas et des moutons munis de fistules du rumen. Des mesures complémentaires ont été faites pour caractériser les conditions de la digestion des rations étudiées dans les réservoirs prégastriques. Par rapport à leur poids vif, lamas et moutons ont ingéré la même quantité de foin (17,4 g/kg PV), mais les lamas ont ingéré 14% de paille en plus (13,2 g* vs *11,6 g/kg PV). L'apport d'orge n'a eu aucun effet sur les quantités de paille ingérées. La digestibilité de la MO de la paille a été supérieure de 3,8 points chez les lamas (+ 4,4 points pour les parois végétales). Après le repas principal du matin, et rapportée au poids vif des animaux, la quantité de contenu frais des compartiments 1 et 2 des lamas a été très légèrement plus élevée de 5% que celle du réticulo-rumen des moutons, mais supérieure de 34% avant (respectivement + 6 et + 42% pour les contenus secs). Dans ces conditions le temps de séjour moyen de la MS dans ces réservoirs gastriques a été de 32 h chez les lamas* vs *25 chez les moutons. Le pH des contenus stomacaux est beaucoup plus stable et plus élevé chez les lamas que chez les moutons. Cet essai confirme la bonne aptitude des lamas à utiliser des fourrages pauvres et apporte quelques éléments d'explication. Des études plus approfondies sont cependant nécessaires.*

ingestion / digestibilité / fourrage / ovins / lamas

INTRODUCTION

The nutritional value of a forage for ruminants is determined by 2 factors, intake and digestibility. Very few comparative studies of nutritional value of forage have been performed in llamas and sheep. Three reports concern intake: one by Warmington *et al* (1989) with rye-grass straw; one by Cordesse *et al* (1992) with lucerne hay and ammonia-treated straw; and one by Dulphy *et al* (1994) with hay. For these 4 forages the overall intake in llamas was 16 g dry matter (DM)/kg live weight (LW), compared with 21 g in sheep, *ie* 49 and 59 g/kg body weight $(W)^{0.75}$ respectively. Three reports concern digestibility: Hintz *et al* (1973), and above-cited works of Warmington *et al* (1989) and Cordesse *et al* (1992). The average organic matter (OM) digestibility of the 5 forages studied was 64.3% in the llamas and 61.0% in sheep.

Because of their uncommon physiological characteristics (Engelhardt and Höller, 1982) there is growing interest in the study of camelids. However, little has been published on quantitative aspects. It was therefore decided to perform a trial comparing 3 diets, distributed simultaneously to llamas and sheep. This trial was a continuation of the studies performed by Kayouli *et al* (1993a) and Dardillat *et al* (1994) on the ruminal conditions in llamas, which are more efficient in digesting plant cell walls than sheep.

MATERIALS AND METHODS

Animals

Three llamas and 3 sheep were used. The animals were 4-year-old castrated males. The average LW of llamas, 98 kg (90–106 kg), was higher than that of sheep, 71 kg (69–74 kg). All animals had been fitted with a rumen fistula with a diameter of 90 and 75 mm, respectively, since the age of 2 years.

Feed

Three diets were studied: A – hay from natural grassland; B – wheat straw with addition of 150 g soya cake (SC) and 20 g mineral mixture; and C – the same straw and same supplements with 350 g of ground and pelleted barley. Table I shows the characteristics of the diets.

Experimental design

The experimental design for each species was a latin square: 3 diets, 3 animals, 3 periods of 5 weeks each. The forages were distributed in a single meal, with refusal being fixed at approximately 20% of the daily intake. The forage was distributed at 9 am, 30 min after the distribution of the feed supplements (SC, minerals and barley). The trial took place from October to December 1992, and the animals were in 2 climatised rooms. Two llamas developed digestive troubles after 3 weeks. These troubles occurred after the main measurements and had few repercussions, but it was impossible to record feed intake behaviour of the 2 sick animals.

Table I. Characteristics of the feed used .

	Hay	*Straw*	*Soya cake*	*Barley*
DM content (g/kg)	886	889	895	896
Ash (g/kg DM)	77	120	77	58
Crude protein [a] (g/kg DM)	94	58	518	115
Cell-wall constituents (g/kg DM)	706	769	115	167

[a] Crude protein: N x 6.25.

Measurements

The forage offered and refused was weighed daily. The digestibilities of diets B and C were determined from total faeces collected in metabolism crates over a period of 6 d in the third week of each period.

During the next 1-week period, the reticulo-rumen of the sheep and compartments 1 and 2 of the llamas were manually emptied twice, once before diet distribution and once 150 min after distribution. The digesta were weighed, sampled and returned to the stomach. A 3-day interval was respected between the both emptyings.

In addition, water intake (for a total of 17 d per animal per period) and the feed intake activities of the llamas (3 d per animal per period) were recorded (Ruckebusch, 1963). This was not done for sheep.

Chemical analyses and statistical calculations

The methods used for the analyses of dietary and digestive content components have been described previously (Chiofalo *et al,* 1992). Standard deviation and comparisons between means were calculated with the SAS package (1985). For each parameter (except digestibility) a total of 18 results was used. The effect of period (2 *df*), and that of individuals (5 *df*) were determined to keep that of species (1 *df*). A possible effect of experimental room was included in the error term of the model used.

RESULTS

DM intake

There were no refusals for soya cake, minerals and barley supplements. The period of measurement had no effect on intake level. Under these conditions, llamas and sheep had the same hay intake in relation to their LW but the llamas ingested 14% more straw. Addition of barley had no effect on straw intake (table II).

Because of the tolerated level of refusal, the animals could be slightly selective in their intake. Surprisingly, llamas seemed to be more selective when offered hay, whereas sheep had a greater selectivity for straw (see table II), for the composition of refusals).

Digestibility

On average, llamas digested straw more efficiently (+ 3.8 units) particularly when no barley was added (+ 5.0). If the ability of the 2 species to digest the supplements is equal, then the presence of barley seemed to reduce the efficiency of llamas in digesting straw, which remains higher in this species. The digestibility of straw cell walls was 4.4 units higher in llamas and 5.7 units higher when there was no barley in the diet. The non-digestible nitrogen content was greater in the llamas (+ 3.5 g per kg ingested DM).

Characteristics of reticulo-ruminal contents

The digesta contents of the fermentative compartments (compartments 1 and 2 for llamas and the reticulo-rumen for sheep) are given in table III, together with the amount of DM ingested the day before the fermentation compartments were emptied.

Before the main meal, the quantity of fresh and dry content accounted for respectively 16.5% and 1.8% of the LW in llamas and 12.3 and 1.3% in sheep, *ie* + 34 and + 42% in llamas. After the main meal the respective values were 19.1 and 2.4% in llamas and 18.2 and 2.2% in sheep, *ie* + 5 and + 6% in llamas. If the average amount of content is considered to be close to the half-total of the values observed before and after the main meal, it is possible to calculate the mean residence time of digesta in the

Table II. DM intake and comparison of diet digestibility.

	Diets for llamas			Diets for sheep			RSD		
	Hay	*Straw + SC*	*Straw + SC + barley*	*Hay*	*Straw + SC*	*Straw + SC + barley*	*Llama*	*Sheep*	*Difference*
Forage DM intake									
Total (g)	1 702	1 295	1 285	1 232	811	833	48	112	S
g/kg LW	17.4	13.2	13.1	17.4	11.4	11.7	0.71	1.83	NS
g/kg $W^{0.75}$	54.5	42.2	40.4	50.8	33.4	33.7	2.2	5.30	S
Diet digestibility (%)									
Organic matter	–	52.4	55.8	–	50.2	57.6	2.4	2.8	NS
Cell-wall constituents	–	47.8	43.9	–	42.5	41.4	3.3	1.5	S
Undigestible crude protein of diets (g/kg DM)	–	49	50	–	47	45	6.0	0.6	NS
Forage digestibility (%)									
Organic matter	–	48.3	44.2	–	43.3	41.6	3.2	1.4	S
Cell-wall constituents	–	47.9	43.4	–	42.2	40.3	3.3	1.5	S
Composition of refusal (g/kg DM)									
Ash	66	114	109	110	107	106	–	–	–
Crude protein	55	47	37	69	34	33	–	–	–
Cell-wall constituents	724	804	810	705	818	819	–	–	–

RSD: residual standard deviation; SC: soya cake; S: significant $P < 0.05$; NS: non-significant.

Table III. Digesta content in the reticulo-rumen (sheep) and in compartments 1 and 2 (llamas).

	Diets for llamas			Diets for sheep			RSD		
	Hay	*Straw + SC*	*Straw + SC + barley*	*Hay*	*Straw + SC*	*Straw + SC + barley*	*Llamas*	*Sheep*	*Difference*
Before the main meal									
Fresh content									
total (g)	16 802	15 622	16 066	9 506	7 775	8 877	1 205	295	S
g/kg LW	171	159	164	134	110	125	10.0	2.6	S
Dry content									
total (g)	1 896	1 684	1 669	902	785	966	168	69	S
g/kg LW	19.3	17.2	17.0	12.7	11.1	13.6	1.5	0.95	S
Forage DM intake on previous day (g)	1 668	1 187	1 103	1 247	786	905	108	91	S
After the main meal									
Fresh content									
total (g)	18 689	18 545	18 774	12 973	12 386	13 393	271	992	S
g/kg LW	191	189	192	183	174	189	0.52	12.8	NS
Dry content									
total (g)	2 396	2 202	2 523	1 494	1 449	1 933	41	139	S
g/kg LW	24.4	22.5	25.7	21.0	20.4	27.2	0.31	1.59	NS
Forage DM intake on previous day (g)	1 704	1 206	1 122	1 269	873	915	52	121	S
Forage DM intake before emptying (g)	673	451	622	679	643	590	17	66	NS

RSD: residual standard deviation; SC: soya cake; S: significant $P < 0.05$; NS: non-significant.

reticulo-rumen. This time was 32 h in llamas and 25 h in sheep; the corresponding turnover rates for DM were 3.07 and 3.95%/h for llamas and sheep respectively (table IV). For cell walls, the mean residence times in the rumen were 36 and 28 h, with turnover rates of 2.78 and 3.67%/h in llamas and sheep, respectively.

The increased retention time in llamas, by comparison to sheep, was accompanied by a higher proportion of the cell walls in the digesta both before the meal (735 *vs* 712 g/kg DM) and after it (735 *vs* 700 g/kg DM) (table V). In llamas, the pH of digesta was 7.11 and 7.07 before and after the main meal. These values were higher and more stable than in sheep (6.78 and 6.56) (table V). In addition, the ammonia nitrogen content after the main meal was higher in sheep, probably because they had a greater proportion of soya cake than llamas in the diets.

It is also interesting to note that the DM content of the rumen digesta was increased in llamas when they received the hay diet (120 for llamas *vs* 104 g DM/kg of content for sheep). This increase was accompanied by a slightly higher osmotic presure in llamas (287 *vs* 268 m osm/ml).

For the straw diets, there was a significant difference between the 2 species in the distribution of particles according to their size. The amounts of fecal particles ≥ 1 mm found per 100 g of fecal DM were 3.4 g in the llamas and 1.5 g in the sheep.

DISCUSSION

Although the number of animals used in this preliminary trial was rather small, the first findings of this comparative study include various interesting points, especially because the literature concerning this subject is scarce.

In relation to their LW, the llamas had a DM intake comparable to that of sheep, as previously observed by Warmington *et al* (1989). The results of Cordesse *et al* (1992), who reported lower DM intake for llamas,

Table IV. Turnover rate of reticulo-rumen contents.

	Diets for llamas			*Diets for sheep*		
	Hay	*Straw*	*Straw + SC + barley*	*Hay*	*Straw*	*Straw + SC + barley*
Dry matter						
Total intake (g)	1 686	1 331	1 562	1 258	965	1 360
Mean content (g)	2 146	1 943	2 096	1 198	1 117	1 450
Turnover rate/h (%)	3.27	2.85	3.10	4.34	3.60	3.91
Mean retention time (h)	30	35	32	23	28	26
Cell walls (NDF)						
Total intake (g)	1 190	935	923	888	654	773
Mean content (g)	1 606	1 436	1 503	880	780	980
Turnover rate/h (%)	3.08	2.71	2.56	4.20	3.49	3.29
Mean retention time (h)	32	37	39	24	29	30

SC : soya cake. NDF: neutral detergent fiber.

Table V. Characteristics of reticulo-rumen contents.

	Diets for llamas			*Diets for sheep*			*RSD*		
	Hay	*Straw + SC*	*Straw + SC + barley*	*Hay*	*Straw + SC*	*Straw + SC + barley*	*Llamas*	*Sheep*	*Difference*
Before main meal									
DM content (g/kg)	113	108	103	93	100	108	3	7.8	NS
Ash content (g/kg DM)	97	171	173	99	173	154	3.5	7.2	NS
Cell-wall constituents (g/kg DM)	746	741	719	722	700	715	13	14	S
Osmotic pressure (m osm/ml)	280	249	277	256	244	268	8	5	NS
pH	7.09	7.18	7.06	6.73	6.85	6.75	0.11	0.12	S
Ammonia-nitrogen ($N\text{-}NH_3$) (mg/l)	158	142	156	123	192	189	11	22	NS
After main meal									
DM content (g/kg)	128	119	134	115	118	144	1.2	5.3	NS
Ash content (g/kg DM)	93	165	157	89	165	143	5	6.6	NS
Cell-wall constituents (g/kg DM)	750	738	716	742	698	657	14	17	S
Osmotic pressure (m osm/ml)	295	270	300	282	268	288	8	12	NS
pH	7.05	7.11	7.04	6.51	6.88	6.29	0.19	0.09	S
Ammonia-nitrogen ($N\text{-}NH_3$) (mg/l)	156	202	215	149	292	305	15	38	S

RSD: residual standard deviation; SC: soya cake; S: significant $P < 0.05$; NS: non-significant.

were obtained with specific forages that possibly were unpalatable to these animals because of the high nitrogen content (as observed in another camelid, the dromedary). Further studies are therefore needed to have reliable comparative data between animals. Neither sheep nor llamas modified their straw intake when concentrates were added to the diet. The same observation was made in sheep when concentrates were limited 30% of total DM intake (Dulphy *et al,* 1983).

In terms of diet digestibility, however, llamas seem to be more efficient than sheep, which is consistent with other published results. It remains to be confirmed if this increased efficiency persists when starch is added to the diet. The observation is surprising, however, since it has been shown that llamas can regulate the pH of their forestomach content very efficiently (Dardillat *et al,* 1994). It is likely that this negative effect comes from the starch itself since it was observed in both animal species.

We have no direct comparisons between water intake in llamas and sheep. Data obtained from llamas were on average 2.87 l/kg DM intake. They were higher than the value of 2.1 l/kg DM reported by Warmington *et al* (1989). There are no published observations on the comparison of intake behaviour of llamas and sheep. We observed an ingestion time of 335 min/d and rumination time of 520 min/d for llamas fed hay and straw. The values for hay and straw were nearly identical. A striking observation is the low frequency of rumination periods, 6.3/d, and thus the extended length of each period. Therefore a comparative study involving sheep would be novel and of interest.

In relation to their live weight or their intake, llamas had greater digesta content than sheep in their 2 first forestomachs. Dardillat *et al* (1994) obtained a comparable result in relation to the DM intake. Under these conditions, there is probably an increased retention time of DM, which would largely explain the greater digestibility of straw in llamas. This higher ability to digest straw was previously observed by Kayouli *et al* (1993b) in dromedaries. This difference in digestibility could also be explained by greater cellulolytic activity of the ruminal microbes in llamas (Kayouli *et al,* 1993a). However, further studies are required in which the 2 mechanisms will be investigated simultaneously.

In this study, the maximum capacity of the 2 forestomachs were comparable for both species. The main physico-chemical difference was a higher pH in llamas, a finding that contradicts the results of Vallenas and Stevens (1971), but is consistent with the observation that llamas buffer their stomach contents better than sheep (Dardillat *et al,* 1994). Osmotic pressure was always higher in llamas, particularly those fed diets with hay and straw with barley. At pH 7, buffers must be important to neutralise volatile fatty acids, which are in an ionic form near neutrality. These 2 factors can explain the higher osmotic pressure.

Similar to results reported by Warmington *et al* (1989), a higher proportion of large particles were found in the faeces of llamas than in those of sheep. However, in relation to the DM excreted in the faeces, the amount found really excreted per day was not different, which is further evidence that llamas, like other small ruminants, are efficient in reducing feed into small particles.

Although further studies are needed, the ability of llamas to use low-quality roughage, observed by Warmington *et al* (1989), was confirmed by this study. A more comprehensive understanding of digestive and physiological mechanisms involved would be of help in research on how to improve the use of roughage by all ruminants.

REFERENCES

Chiofalo V, Dulphy JP, Baumont R (1992) Influence of the method of forage conservation on feeding behaviour, intake and characteristics of reticulo-rumen content, in sheep fed *ad libitum*. *Reprod Nutr Develop* 32, 377-392

Cordesse R, Inesta M, Gaubert JL (1992) Intake and digestibility of four forages by llamas and sheep. *Ann Zootech* 41, 91-92

Dardillat C, Baumont R, Jouany JP (1994) Contenus gastriques du lama et du mouton. *Ann Zootech* 43, 279

Dulphy JP, Breton J, Louyot JM, Bienaimé A (1983) Étude de la valeur alimentaire des pailles de céréales traitées ou non à la soude. III. Influence du niveau d'apport d'aliment concentré. *Ann Zootech* 32, 53-80

Dulphy JP, Jouany JP, Martin-Rosset W, Theriez M (1994) Aptitudes comparées de différentes espèces d'herbivores domestiques à ingérer et digérer des fourrages distribués à l'auge. *Ann Zootech* 43, 11-32

Engelhardt WV, Höller H (1982) Salivary and gastric physiology of camelids. *Verh Dtsch Zool Ges* 195-204

Hintz HF, Schryver HF, Halbert M (1973) A note on the comparison of digestion by New World camels, sheep and ponies. *Anim Prod* 16, 303-305

Kayouli C, Dardillat C, Jouany JP (1993a) Comparative study of the muralytic activity of rumen microbes measured *in situ* in llamas and sheep. *Ann Zootech* 42, 184

Kayouli C, Jouany JP, Demeyer DI, Ali-Ali, Taoueb H, Dardillat C (1993b) Comparative studies on the degradation and mean retention time of solid and liquid phases in the forestomachs of dromedaries and sheep fed on low-quality roughages from Tunisia. *Anim Feed Sci Technol* 40, 343-355

Ruckebusch Y (1963) Recherches sur la régulation centrale du comportement alimentaire chez les ruminants. Thèse Université de Lyon, 213 p

SAS Institute (1985) SAS Users'guide. SAS Institute Inc, USA

Vallenas A, Stevens CE (1971) Volatile fatty acid concentrations and pH of llama and guanaco forestomach digesta. *Cornell Vet* 61, 239-252

Warmington BG, Wilson GF, Barry TN (1989) Voluntary intake and digestion of rye-grass straw by llama x guanaco crossbreds and sheep. *J Agric Sci Camb* 113, 87-91