Ann. Rech. Vét. 1977, **8**, *(1)*, 1-6.

CHOPPING VERSUS GRINDING AND PELLETING OF HAY : EFFECT ON AVAILABILITY OF TRACE ELEMENTS (Cu, Zn and Mn) AND MAJOR ELEMENTS (Ca, P and Mg)

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Résumé

INFLUENCE DU BROYAGE DES FOINS SUR LA DIGESTIBILITE DES OLIGO-ELEMENTS (Cu, Zn et Mn) ET DES ELEMENTS MAJEURS (Ca, P et Mg). — Douze moutons en croissance (Limousin x Romanov) d'un poids moyen de 28 kg sont maintenus en cages à bilan en plastique ou en plexiglas. Ils reçoivent au cours de deux périodes expérimentales successives un foin de luzerne *ad libitum,* sous forme normale (hachée en brins de 3 cm de long environ) ou broyée (à la grille de 0,6 mm) et agglomérée en bouchons de 6 mm de diamètre.
En comparaison de la forme longue, le broyage de la luzerne a entraîné :
— une augmentation de la quantité de matière sèche ingérée de 34 % ;
— une diminution du C.U.D. de la matière sèche de 8,2 points (50,7 contre 58,9) ;
— une accélération de la vitesse de transit dans le tube digestif estimée au cours de la première période de bilan (temps moyen de séjour de l'indigestible : 38 à 41 heures contre 52 à 54 heures) selon la méthode de Balch (1950) modifiée par Castle (1956). Les temps de séjour des particules dans le rumen ont été de 46 heures pour la forme longue et 40-41 heures pour la forme broyée et dans l'intestin de 22-24 heures et 13-16 heures respectivement ;
— une diminution de la digestibilité et de la rétention des éléments minéraux. On a observé une diminution significative de la digestibilité et de la rétention du cuivre, du zinc et du manganèse avec la forme longue ;
— la digestibilité du magnésium et du calcium ont également significativement baissé.

Introduction

The grinding of forages modifies their nutritive value for ruminants (Campling *et al.,* 1963 ; Beardsley, 1964 ; Demarquilly and Journet, 1967 ; Francois and Compère, 1972) and increases the rate of passage of digesta through the alimentary canal.

Some other effects have been related to the physical structure of the feed : Hartmans and Bosman (1970) observe that copper is better utilized in hay than in grass from the same field (but cut younger). Several authors

(Rook and Balch, 1958 ; Kemp *et al.*, 1961 ; Rook and Campling, 1962) also observed a poor digestibility of magnesium in young grass. The low availability of copper and magnesium in young grass could result from an acceleration of the transit in the digestive tract, compared to hay, even if, for copper (Bosman, 1964, 1965, 1966), it proceeds also from sulfide synthesis in rumen (sulfide synthesis being more important in young grass highly digestible and rich in proteins).

Bovine often receive ground diets that may or may not be pelleted. We intended to examine the effect of transit speed on mineral digestibility (Cu, Zn, Mn, Ca, P and Mg) by comparing in sheep two physical forms of the same lucern hay.

Material and methods

1. — *Experimental procedure*

Twelve growing male lambs (Limousin x Romanov) weighing 28 kg were maintained in plastic metabolism cages, with wooden or aluminium floor to avoid trace element contaminations. They were equipped with harnesses and plastic bags for each morning's fecal collection quantitatively. Feeding and drinking troughs were also made of plastic. Contaminations were then reduced to a minimum (Lamand, 1974).

The lambs received a lucern hay (second cycle) chopped into pieces 3 cm long, or ground in a grinder equipped with a 0.6 mm sieve and pelleted in 6 mm diameter pieces without any adjuvant. Meal was offered, *ad libitum* (10 % refused food), twice a day (9 a.m. and 4 p.m.).

Animals were accustomed to the diet for three weeks, the balance trial took place on the fourth week and lasted five days. At the end of the first period, the experimental design was inverted : animals on chopped hay received ground hay and inversely. The second balance trial took place after three weeks during five days.

The ingested quantities and refusals were weighed each morning and sampled daily for dry matter and mineral analysis. Digestibility and retention of the elements were computed without taking the urinary excretion into account.

2. — *Analytical procedure*

Copper, zinc and manganese were determined by atomic absorption spectrometry (Perkin Elmer 303) after nitroperchloric digestion (Bellanger, 1971).

Calcium and magnesium were determined by atomic absorption spectrometry with lanthane (avoiding interferences) after dry ashing. Phosphorus was determined by colorimetric method (Kalckar, 1947).

3. — *Rate of passage of hay*

The rate of passage was measured by the coloured particles method, during the first balance trial (Balch, 1950, modified by Castle, 1956) on two animals from each group. The coloured particles excreted were counted in triplicate on fecal samples. This is rather time-consuming, but allows the quantification of the transit by the excretion curve of undigested coloured particles of a meal. From this curve it is possible to calculate the time of retention of the indigested and estimate the time required for the excretion of 5 % of the total undigested residues (t 5 %) which indicates the rate of passage of food through the omasum, the abomasum and the intestines, and the difference between the time taken for the excretion of 5 and 80 % of the total indigested residues (t 80-5 %) which gives an indication of the spread of the excretion curve, and of the rate of passage of the stained particles through the reticulo-rumen.

Results

1. — *Ingestion*

Feeds ingestion was very different according to the physical form of the hay. On the average, the ground and pelleted form was 34 % more ingested than the chopped hay. Ingestion per unit of metabolic weight ($W^{0.75}$) was 72.9 g for the chopped hay and 110.3 g for ground and pelleted hay ($P < 0.01$).

In contrast, the dry matter digestibility was 50.7 % for the ground and 58.9 % for the chopped hay ($P < 0.01$).

2. — *Availability of minerals*

The digestibility was expressed in percentage of the ingested and the retention in mg/d/100 kg live weight for trace elements and g/d/100 kg for major elements.

The results obtained showed (table 1) a significant drop in the digestibility and the retention of copper, zinc and manganese induced by grinding. Copper digestibility of chopped lucern was 16.7 % against 6.4 % only for the same ground and pelleted lucern ($P < 0.01$).

The copper retained from the pelleted hay was also diminished (2.6 mg/d/100 kg against 4.87, $P < 0.05$).

Table 1 : Influence of grinding on the digestibility and retention of trace elements (Cu, Zn and Mn).

Experimental diet	COPPER			ZINC			MANGANESE		
	Content mg/kg D.M.	Digestibility %	Retention mg/100 kg	Content mg/kg D.M.	Digestibility %	Retention mg/100 kg	Content mg/kg D.M	Digestibility %	Retention mg/100 kg
Lucern hay chopped (about 3 cm long)	8.4	16.7	4.9	26.5	23.8	23.2	35.5	24.5	34.2
Lucern hay ground and pelleted	8.6	6.4**	2.6*	34.5	14.2**	23.1 N.S.	37.7	10.6**	19.3*

N.S. : not significant.
* : $P < 0.05$.
** : $P < 0.01$.

Table 2 : Influence of grinding on the digestibility and retention of major elements (Mg, Ca, P).

Experimental diet	Mg			Ca			P		
	Content g/kg D.M.	Digestibility %	Retention g/100 kg	Content g/kg D.M.	Digestibility %	Retention g/100 kg	Content g/kg D.M.	Digestibility %	Retention g/100 kg
Lucern hay chopped (about 3 cm long)	1.9	45.3	3.1	18.7	28.6	20.6	1.8	46.5	3.2
Lucern hay ground and pelleted	1.9	37 **	3.3 N.S.	17.4	20.3*	16.4 N.S.	2.0	42.9 N.S.	3.8 N.S.

N.S. : not significant.
* : $P < 0.05$.
** : $P < 0.01$.

The digestibility of zinc was also affected after lucern grinding and pelleting (23.8 % for the chopped form and 14.1 % for the ground and pelleted form ; $P < 0.01$). The retention of zinc was not significantly modified.

The digestibility of manganese was 24.5 % for the chopped form, and 10.6 % for the ground and pelleted form ($P < 0.01$). The retention changed according to rather identical percentage for it was also about 19.3 mg/d with the ground and pelleted form, and 34.2 mg/d with the chopped form ($P < 0.05$). The digestibility and the retention of manganese and copper were significantly different between the two lots.

The lucern grinding led to a significant fall of the availability of magnesium (37.6 % against 45.2 %) and calcium (20.3 % against 28.6 %) [table 2]. The availability of phosporus was not changed by the technological treatment. The retention of these three elements did not change significantly.

3. — *Digestive transit*

The average retention of the indigested in the alimentary canal was between 52 and 54 hours for the lucern chopped hay (long form). It diminished for the ground form and was no more than 38 to 41 hours. The t 80-5 %, representative of rumen was 46 hours for the long form and 40-41 hours for the ground form. In the intestine, the values for t 5 % were respectively 22-24 hours and 13-16 hours for the ground hay.

Discussion and conclusions

The physical form of food has a very strong influence upon the ingested quantities and the availability of the dry matter. These results are classical (Demarquilly and Journet, 1967 ; Demarquilly, 1972 ; Francois and Compère, 1972).

The average retention time of the indigested shows a rise of the transit speed of the ground and pelleted lucern, compared with chopped lucern. It has been remarked (Ellis and Huston, 1967) about Balch's method, that it would give retention times variable with the mesh size of the gauze ; but the curves given here can be compared with each other, because the conditions of measure, already described have been the same for every faeces sample.

Either with the method of Balch (Demarquilly and Journet, 1967) or with an improved method including also a couple of radiolanthanides (^{144}Ce, ^{144}Pr) as unabsorbed tracer (Francois and Compère, 1972), it is not the increased rate of passage which induces a rise in the consumption of ground and pelleted hay, but the rise in consumption which induces a faster rate of passage. As a matter of fact, to identical ingestion level of ground and pelleted hay corresponds same rate of passage.

The results show that the acceleration of the transit speed of the food in the alimentary tract correlates with a change in the digestive utilization of trace elements (Cu, Zn, Mn).

The availability and the retention decrease from 62 to 41 % according to the considered trace element after grinding at the 0.6 mm sieve and pelleting in 6 mm diameter cylinders.

The described experimentation does not show the cause of the diminished availability and the retention of the trace elements. We assume that it is due to the acceleration of the transit in the small intestine.

One characteristic of the diet used here is its high calcium content related to phosphorus. The low calcium availability (lower than the phosphorus one) is a common finding and this digestibility coefficient still decrease after grinding although the availability of phosphorus does not decrease significantly.

In some instances the hay magnesium content is rather low, and the effect of grinding on digestibility is a factor to consider in the estimation of the minimal dietary magnesium allowance.

The observation of a drop in Mg digestibility confirms the results of Larvor and Brochart (1960) which put into evidence the influence of the physical structure of the diet on the blood magnesium. In this experiment made on a couple of bovine twins, the grinding of a fibrous part of the diet gave a significant drop of blood magnesium and not of calcium and phosphorus.

Some authors observed that the consumption of young grass leads to a drop of the Mg digestibility (Rook and Balch, 1958 ; Kemp *et al.*, 1961 ; Rook and Balch, 1962 ; Rook and Campling, 1962) which could be linked at least in part, to a faster rate of passage.

This drop of the digestibility could be one of the causes of the hypomagnesemia after

sudden outdoor grazing (grass tetany). It is possible to prevent partly this hypomagnesemia, by administration of long hay ; powdered hay is less efficient (Larvor, Brochart and Ladrat, 1960). These results have been contested by Rook and Campling (1962) who do not observe a decrease in the Mg digestibility in two cows fed a ground diet ; but our data confirm the decrease in Mg digestibility and suggest that the structure of the diet can play a part in the hypomagnesemia of grass tetany.

The hypocalcemia which occurs during grass tetany is not related to the decrease in calcium digestibility, but is a direct consequence of the drop of blood Mg leading to an impairment of bone calcium exchanges (Larvor *et al.*, 1964) and to endocrine modifications (Rayssiguier *et al.*, 1976).

(Accepted for publication June 1976.)

Summary

Twelve growing sheep (Limousin x Romanov) which had an average weight of 28 kg were kept in plastic metabolism crates. During two successive experimental periods, they received lucern hay ad libitum, under normal form (chopped into about 3 cm pieces) or ground (at the 0.6 mm sieve) and pelleted into 6 mm diameter pellets.

Compared with the long (chopped) form, the grinding of lucern induced :

— a 34 % rise of the quantity of the ingested dry matter ;

— a decrease in the digestibility of dry matter (58.9 % for long vs 50.7 % for ground, i.e. a 8.1 units decrease) ;

— an increase in the rate of passage through the alimentary tract estimated during the first balance period (average retention of the indigested : 52-54 h for long vs 38-41 for chopped form) according to Balch's method (1950) modified by Castle (1956). The 80-5 % time of particles (index of passage through the rumen) has been : 46 hours for the long form and 40-41 hours for the ground form. The 5 % time (index of passage through omasum + intestine) has been 22-24 h for the long form and 14-16 h for the ground form ;

— a decrease of the digestibility and of the retention of most minerals has been observed, significant for the digestibility of Cu, Zn, Mn, Mg and Ca, and for the retention of Cu and Mn (tables 1 and 2).

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