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Effect of dehydration on ruminal degradability of lucerne

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Abstract — The effects of industrial dehydration and a subsequent compression at high pressures on rumen degradability of lucerne were determined in 3 samples obtained at harvest or after the process of dehydration and compression of this forage. Rumen degradability of dry matter (DM) and nitrogen (N) was determined by the nylon bag technique in 3 ruminally cannulated wethers. Dehydration reduced effective DM degradability (from 63.4 to 59.4%), which was associated with an increase of both the rumen undegradable fraction (from 30.5 to 33.4%) and the lignin content (from 65.7 to 77.9 $g \cdot kg^{-1}$ of DM). Effective degradability of N was also reduced by dehydration (from 82.7 to 77.7%), mainly by a decrease in the degradation rate (from 30.8 to 12.4% $\cdot h^{-1}$). The compression process produced a small but significant increase of the solubility of both DM and N, which did not alter the values of effective degradability.

lucerne / dehydration / high pressure compression / rumen degradability

Résumé — **Effet de la déshydratation sur la dégradabilité dans le rumen de la luzerne**. Nous avons étudié les effets de la déshydratation industrielle suivie d'une procédure de compression à haute pression en utilisant 3 échantillons de luzerne récoltés soit à la fauche soit après des procedés de déshydratation et de compression du fourrage. La dégradabilité de la matière sèche (MS) et de l'azote a été déterminée par la technique des sachets de nylon sur 3 moutons portant des canules du rumen. La déshydratation a produit une diminution de la dégradabilité de la MS (de 63,4 à 59,4 %), qui a été associée à une augmentation de la fraction non dégradable (de 30,5 à 33,4 %) et de la teneur en lignine (de 65,7 à 77,9 $g \cdot kg^{-1}$ de MS). Pour l'azote, la dégradabilité a été aussi réduite par la déshydratation (de 82,7 à 77,7 %), principalement par la chute de la vitesse de dégradation (de 30,8 à 12,4 % $\cdot h^{-1}$). L'emballage à haute pression a produit une augmentation modérée, mais significative, de la solubilité de la MS et de l'azote, qui, cependant, n'a pas d'effet sur la dégradabilité.

luzerne / déshydratation / emballage à haute pression / dégradabilité du rumen

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1. INTRODUCTION

Lucerne is a major forage for feeding productive ruminants in some countries because of its high digestibility and its high protein content. Extensive degradation in the rumen may, however, reduce protein utilisation [4], as a consequence of considerable losses of protein, produced by ammonia absorption from the rumen. Heating has been extensively used in the dehydration process as well as to reduce rumen protein degradability. Since extensive heating of forages can reduce the nutritional value due to the formation of undigestible protein-carbohydrate bonds [8], the studies of the heating effect have mainly been focused to determine treatment conditions that prevent heat damage. Moreover, studies including the original fresh forage as a control in order to enable the study of the effects of dehydration are scarce. The aim of the present work was to evaluate the effect of the modern forage dehydration process, which combines high temperature and short time, on ruminal degradability of lucerne. In addition, the effect of a subsequent compression at high pressure was also studied.

2. MATERIALS AND METHODS

2.1. Feed sample

The effect of the dehydration process and a subsequent compression on ruminal degradability of a commercial crop of lucerne (Estival, Pioneer®) was studied in a third cut harvested at the beginning of flowering (5% of the plants). Samples were taken at harvest and immediately after the process of dehydration and compression. The dehydration procedure included a field wilting period (final moisture of the sample = 43.2%) and the passage of the forage through a three pass drier for 3 minutes. Drier outflow temperature was 90–92 °C. The compression process consisted of the application of high pressures (300–500 $kg \cdot cm^{-2}$) on the material to produce 50 kg bales, with a volume only of one-fifth of that of conventional bales. Fresh forage was immediately freeze-dried. All materials were ground to pass a 2 mm screen for degradability trials and 1 mm screen for chemical analysis. Forages were analysed for dry matter (DM), organic matter (OM), crude protein (CP) [1], neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) [16]. Fibre fractions were calculated free of ash. Neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) were performed by Kjeldhal analysis on NDF and ADF residues, respectively, and contents were expressed as a percentage of total nitrogen.

2.2. Rumen degradability

All the forages were incubated by the in situ method in the rumen of three cannulated wethers, which were fed with a 2/3 forage (40% dehydrated lucerne and 60% lucerne hay) and 1/3 concentrate diet, distributed at an intake level of 40 g $DM \cdot kg^{-0.75}$ in two equal-weight meals at 9 and 17 h. The NDF and CP contents of this ration were 435 and 161 $g \cdot kg^{-1}$ (on DM), respectively.

Samples of lucerne were incubated in nylon blutex bags (120 T, Tissages Tissues Techniques, France; 46 μm pore size) with 11×7 cm of internal dimensions, made by heat-sealing. Approximately 3 g of ground material were weighted into the bags and incubated in the rumen of each wether for 3, 6, 12, 24, 48 and 72 hours. Two series of incubation were conducted for each feed, in order to obtain two bags per animal and incubation time. All bags were inserted at the morning feeding time. After being removed from the rumen, they were washed with tap water and deep frozen. When thawed for analysis, the bags were washed 3 times for 5 min in a turbine washing machine, dried at 80 °C for 48 h and analysed for DM and N. 3 additional bags of each feed were reserved for a zero incubation

that involved the washing procedure without prior rumen incubation. Buffer nitrogen solubility was also determined [9].

Degradation characteristics of DM and N were described using the model of Ørskov and McDonald [12]. Effective degradability (ED) was estimated using the passage rate through the rumen (k_p) of the dehydrated lucerne included in the diet, which had been marked by immersion [9] with 10 mg Yb·g^{-1} of feed. To determine k_p values, a pulse dose (40 g) of labelled dehydrated lucerne was fed to each animal immediately before the first daily meal. A total of 22 samples of faeces were obtained from the rectum of each animal, the first before supplying the marker and the rest between 12 and 144 h afterwards. These samples were dried, milled and analysed for Yb [9]. The pattern of Yb concentrations in the faeces over time was described by fitting the model of Dhanoa et al. [7] and rate constants derived from the decreasing phase of concentrations were used as k_p values for all samples. The transit and degradation kinetics were fitted for each animal by non-linear regression. The analysis of variance was performed by examining the effect allocated to feed and animal for degradation characteristics and only that allocated to feed for N buffer solubility. Mean values were compared using orthogonal contrasts.

3. RESULTS

The proportions of NDIN and ADIN and ADL content increased apparently as a result of dehydration, whereas the other chemical components remained fairly constant (Tab. I). On the contrary, a similar chemical composition was observed in both dehydrated samples.

In Table II the results for the degradation characteristics and buffer N solubility of fresh, dehydrated, and dehydrated and compressed lucerne are presented. Estimates of ED are based on k_p values of 2.28 ± 0.22%·h^{-1} (mean ± S.E.), derived from the 3 employed wethers. Dehydration reduced (20.4%) the soluble fraction ($P < 0.001$) and increased the non soluble-degradable ($P = 0.002$) and the undegradable ($P = 0.034$) fractions of DM. The rate of degradation did not change. As a result, ED of DM was reduced by about 4 percentage units ($P = 0.002$). The dehydration process transformed ($P < 0.001$) part of the nitrogenous components in the soluble fraction to the non soluble-degradable fraction, while the undegradable fraction did not change. On the contrary, the dehydration process markedly reduced (60%) the degradation rate ($P = 0.017$). As a consequence, ED of N was reduced by 5 percentage units ($P < 0.001$). The compression process caused a small but significant

Table I. Chemical composition (g·kg^{-1} DM) of lucerne samples.

Item	F	D	DC
Dry matter (g·kg^{-1})	264	873	896
Organic matter	906	903	897
Crude protein	156	159	164
Neutral detergent fibre	468	480	480
Acid detergent fibre	357	368	364
Acid detergent lignin	65.7	76.8	78.9
Neutral detergent insoluble nitrogen(1)	6.80	14.6	17.4
Acid detergent insoluble nitrogen(1)	6.19	8.12	8.49

(1) As % of total nitrogen.
F: fresh; D: dehydrated; DC: dehydrated and compressed.

Table II. Effects of dehydration and compression on nitrogen solubility and rumen degradation characteristics of lucerne.

Item	F	D	DC	SEM	F vs D, DC[(1)]	D vs DC[(1)]
Dry matter						
a (%)	37.6	26.2	26.9	0.17	< 0.001	0.040
b (%)	31.9	40.1	39.9	0.86	0.002	0.908
u (%)	30.5	33.7	33.1	0.77	0.034	0.615
k_d (%·h^{-1})	9.6	10.3	10.4	0.61	0.376	0.916
ED (%)	63.4	59.0	59.7	0.48	0.002	0.379
Nitrogen						
Buffer solubility (%)	49.4	31.4	35.0	0.64	< 0.001	0.001
a (%)	51.1	37.0	39.6	0.31	< 0.001	0.004
b (%)	34.1	47.1	46.2	0.77	< 0.001	0.439
u (%)	14.8	15.9	14.2	0.52	0.699	0.083
k_d (%·h^{-1})	30.8	13.6	11.1	0.38	0.017	0.675
ED (%)	82.7	77.3	78.0	0.46	< 0.001	0.377

(1) Probability of the orthogonal contrast.
F: fresh; D: dehydrated; DC: dehydrated and compressed. *a*, *b* and *u* represent soluble, non-soluble degradable, and undegradable fractions, respectively. k_d: fractional degradation rate of fraction *b*. ED: effective degradability. SEM: standard error of the mean.

increase in the soluble fraction of DM (P = 0.04) and more importantly of N (P = 0.004). This last effect was also detected for the buffer solubility of N (P = 0.001). Nevertheless, this increase in solubility had no effect on the ED of DM and N.

4. DISCUSSION

The application of thermal treatments to forages or concentrates usually leads to an increase of both ADIN and NDIN contents as observed for dehydration in the present results. The increase in ADIN gives evidence of the occurrence of partial or total Maillard reactions, which increase with the intensity of the thermal treatment [18]. ADIN has therefore been suggested as a laboratory method to identify overheated samples of dehydrated lucerne [8]. In addition, it has also been suggested that this fraction can be used to estimate unavailable N [14]. Nevertheless, several observations disagree with this hypothesis. Therefore, partial rumen degradation has been observed for artificial ADIN resulting from Maillard reactions [20] and ADIN of feed not subjected to thermal treatments, such as green or ensiled lucerne [2]. In the present study, the increase produced by the dehydration process in the ADIN proportion was, however, relatively small and did not influence nitrogen availability, as indicated by the lack of variation of the undegradable fraction. Broderick and Craig [5] suggested that heat treatment decreases ruminal protein degradation by partly reducing protein solubility and by partly blocking reactive sites for microbial proteolytic enzymes, which agree with the reductions observed in both the "*a*" fraction and the degradation rate. In addition, the reduction of the nitrogen degradation rate may be related to the increase of the proportion of NDIN, as a consequence of the slower degradation of protein-fibre complexes that may be degraded at rates similar to that of the cell wall. A correlation study

carried out with 21 samples of dehydrated lucerne has shown a depressive effect of increased NDIN on the nitrogen degradation rate [15].

The ED of N for fresh lucerne agrees with that observed by Aufrère et al. [3]. On the contrary, the corresponding values obtained for dehydrated samples were higher than those reported by Vérité et al. [19] and Kowalski et al. [11] (60% and 64%, respectively). These disagreements can be associated with the factors related to sample characteristics and, also, with differences in methodology. So, all the above cited values were calculated for a k_p value ($6\%\cdot h^{-1}$) higher than that used in our work. The high ED of N of fresh lucerne, which is a consequence of its high solubility and the fast degradation of its main protein (rubisco) [3], usually reduces its nitrogen utilisation in high productive ruminants. Therefore, heat treatments can improve nitrogen value by increasing the flow of feeding proteins to the duodenum. However, in our work, dehydration only led to a moderate reduction of ED (6.1%). No other effects of this reduction should be expected on the feed nitrogen value since different studies carried out with different feeds [10, 13] indicate that heat treatments yielding no heat damage, improve the content of by-pass protein without impairing intestinal digestibility of this fraction, in spite of the increased nitrogen fibre-bound contents of the feeds.

On the contrary to that which is observed for N, the reduction produced by dehydration on the ED of DM was mainly associated with an increase of the undegradable fraction. This occurrence, which was in agreement with an increase in ADL content, resulted in a reduction of feed availability, which agreed with the decrease of digestibility usually observed [6, 17].

Compression at high pressures increased the soluble fraction of DM and N as well as N buffer solubility, which indicates a major accessibility to the cellular contents by rumen fluid.

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REFERENCES

[1] AOAC, Official Methods of Analysis (15th ed.), Association of Official Analytical Chemists, Arlington, VA, 1990.

[2] Aufrère J., Boulbehane D., Graviou D., Dégradation dans le rumen de l'azote des parois d'une même luzerne, verte ou ensilée, Ann. Zootech. 43 (1994) 273.

[3] Aufrère J., Boulbehane D., Graviou D., Andrieu J.P., Demarquilly C., Characterisation of in situ degradation of lucerne proteins according to forage type (green forage, hay and silage) using gel electrophoresis, Anim. Feed Sci. Technol. 50 (1994) 75–85.

[4] Broderick G.A., Alfalfa silage or hay versus corn silage as the sole forage for lactating dairy cows, J. Dairy Sci. 68 (1985) 3262–3271.

[5] Broderick G.A., Craig W.M., Effect of heat treatment on ruminal degradation and escape, and intestinal digestibility of cottonseed meal protein, J. Nutr. 110 (1980) 2381–2389.

[6] Demarquilly C., Influence de la déshydratation à basse température sur la valeur alimentaire des fourrages, Ann. Zootech. 19 (1970) 45–51.

[7] Dhanoa M.S., Siddons R.C., France J., Gale, L., A multicompartmental model to describe marker excretion patterns in ruminant faeces, Br. J. Nutr. 53 (1985) 663–671.

[8] Goering H.K., A laboratory assessment on the frequency of overheating in commercial dehydrated alfalfa samples, J. Anim. Sci. 43 (1976) 869–872.

[9] González J., Rodríguez C.A., Andrés S.G., Alvir M.R., Rumen degradability and microbial contamination of fish meal and meat meal measured by the in situ technique, Anim. Feed Sci. Technol. 73 (1998) 71–84.

[10] González J., Sánchez L., Alvir M.R., Estimation of intestinal digestibility of undegraded sunflower meal protein from nylon bag measurements. A mathematical model, Reprod. Nutr. Dev. 39 (1999) 607–616.

[11] Kowalski Z.M., Pisulewski P.M.P., Peyraud J.L., Kaminski J., The effect of drier outflow temperature on rumen protein degradability and intestinal digestibility of rumen-undegraded protein of dehydrated grass and lucerne, Ann. Zootech. 44 (Suppl.) (1995) 88.

[12] Ørskov E.R., McDonald I., The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage, J. Agric. Sci. 92 (1979) 499–503.

[13] Pereira J.C., Carro M.D., González J., Alvir M.R., Rodríguez C.A., Rumen degradability and intestinal digestibility of brewers' grains as affected by origin and heat treatment and of barley rootlets, Anim. Feed Sci. Technol. 74 (1998) 107–121.

[14] Pichard G., van Soest P.J., Protein solubility of ruminant feeds, in: Proc. Cornell Nutr. Conf., 1–3 November 1977, Cornell University, Ithaca, NY, pp. 91–98.

[15] Repetto J.L., Degradabilidad ruminal de la alfalfa deshidratada. Tesis Doctoral, 1997, Universitat de Lleida, Spain.

[16] Robertson J.B., van Soest P.J., The detergent system of analysis and its application to human foods, in: James W.P.T., Theander O. (Eds.), The Analysis of Dietary Fibre in Food, Marcel Dekker, New York, 1981, pp. 123–158.

[17] Thomson D.J., Beever D.E., The effect of conservation and processing on the digestion of forage by ruminants, in: Ruckenbush Y., Thivend P. (Eds.), Digestive Physiology and Metabolism in Ruminants, Lancaster, England, 1980, pp. 291–308.

[18] van Soest P.J., Nutritional Ecology of the Ruminant, O & B Books Inc., Oregon, USA, 1982.

[19] Vérité R., Michalet-Doreau B., Chapoutot P., Peyraud J.L., Poncet C., Révision du système des protéines digestibles dans l'intestin (PDI), Bull. Tech. C.R.Z.V. Theix INRA 70 (1987) 19–34.

[20] Waters C.J., Kitcherside M.A., Webster A.J.F., Problems associated with estimating the digestibility of undegraded dietary nitrogen from acid-detergent insoluble nitrogen, Anim. Feed Sci. Technol. 39 (1992) 279–291.