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Comparison of the voluntary intake by lactating cows of two maize silages with different in situ dry matter degradability

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Abstract — The relationship between dry matter degradability of two maize silages measured in situ and dry matter intake, milk yield, milk composition and weight gain was studied in a changeover experiment with 20 dairy cows. The animals were fed a balanced diet based on maize silage and concentrate with the same quantities of concentrate given with both silages. The two maize silages had equal levels of dry matter but were different in their neutral detergent fibre (NDF) levels (473 and 414 g·kg⁻¹) and dry matter degradability values measured in situ over 48 h (53.9 and 57.6 %). The dry matter intake of the low-NDF, highly degradable silage was significantly higher than that of the high-NDF, low degradable material (12.8 vs. 13.5 kg DM·d⁻¹) but no significant difference was observed for milk yield, fat protein and lactose milk content, milk lactose or weight gain between the two silages (23.7 vs. 23.4 kg·d⁻¹, 41.2 vs. 41.4 g·kg⁻¹, 31.6 vs. 31.6 g·kg⁻¹, 46.5 vs. 46.2 g·kg⁻¹ and 498 vs. 515 g·d⁻¹ for, respectively, high- and low-NDF content maize silage). Although higher intake was linked to better dry matter degradability of maize silage, there was no effect on production, probably because of the late stage of lactation of the cows used in this experiment. (© Elsevier / Inra)

dairy cows / maize silage / feed intake / dry matter degradability

Résumé — Comparaison de l'ingestion de deux ensilages de maïs avec des dégradabilités de la matière sèche différentes par des vaches laitières. L'influence de la dégradabilité de la matière sèche de deux ensilages de maïs mesurée in situ sur la quantité de matière sèche d'ensilage ingérée, la

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production de lait, sa composition et le gain de poids a été étudiée dans un essai en inversion avec 20 vaches laitières. Les animaux recevaient une ration complète à base d'ensilage de maïs et de concentré. L'apport de concentré était le même pour les deux lots. Les deux ensilages de maïs avaient des teneurs en matière sèche sensiblement égales mais différaient par leurs teneurs en NDF et leurs valeurs de dégradabilité de la matière sèche mesurée sur 48 h (53,9 et 57,6 %). Ils ont montré une différence hautement significative pour les valeurs de consommation (12,8 vs. 13,5 kgMS·j⁻¹ pour respectivement l'ensilage de maïs à hautes et basses teneurs en NDF). La production de lait, le taux butyreux, le taux protéique, le taux de lactose ou le gain de poids n'ont pas été significativement différents entre les deux ensilages (23,7 vs. 23,4 kg·j⁻¹; 41,3 vs. 41,4 g·kg⁻¹; 31,6 vs. 31,6 g·kg⁻¹; 46,5 vs. 46,3 g·kg⁻¹ et 498 vs. 515 g·j⁻¹ pour respectivement des teneurs hautes et basses en NDF). Un niveau d'ingestion plus élevé a été relié à une dégradabilité plus importante de la matière sèche de l'ensilage de maïs. Mais, il n'a pas été possible de mettre en évidence un effet de l'augmentation de l'ingestion de l'ensilage de maïs sur la production et la composition du lait probablement en raison du stade de lactation tardif des animaux sur lesquels ont été effectuées les mesures. (© Elsevier / Inra)

vache laitière / ensilage de maïs / ingestion / dégradabilité de la matière sèche

1. INTRODUCTION

Maize silage plays a key role in the feeding of ruminant farm animals. This forage is easy to grow and conserve, and possesses high and relatively constant energetic values while the relatively low level of protein is easily corrected by supplementation with high protein concentrate. Variation in nutritive value and voluntary intake should have a major effect on milk production and thus exert a large influence on profitability. It is therefore important to have precise knowledge of the energy and protein values and of the potential intake of this type of forage. Several works attempted to predict potential intake from feed characteristics. Significant negative correlations of neutral detergent fibre (NDF) and voluntary dry matter intake (DMI) have been reported in subsequent studies with sheep and/or cattle [14, 17, 23].

To predict intake, most researchers use rumen degradability and digestibility in the whole digestive tract. On the one hand, degradability is measured in rumen cannulated animals in which the samples to be studied are placed in nylon bags incubated in

the rumen and the rate of disappearance is used to calculate an overall value for degradability [15, 16, 18]. These measures of degradability can then be used to predict potential intake by means of established regression equations [4, 10]. This relationship is to be expected as the faster food material is broken down into small particles the faster it can leave the rumen, making place for more food to be ingested. Therefore, a more rapidly degradable forage has a lower fill value than a similar one with slower degradability.

Digestibility, on the other hand, is a measure of disappearance from the whole digestive tract and therefore does not give a clear picture of the rumen degradation. Digestibility can be measured by faecal collection from sheep or lactating cows, or estimated by incubation of food samples with rumen fluid [20], enzymes [1] or gas production [13].

The aim of this work is to see how differences in dry matter (DM) degradability measured in situ affect food intake, milk production and milk composition by cows fed on two maize silages.

2. MATERIALS AND METHODS

2.1. Silage characteristics

The two maize hybrids used in the experiment were Cracotte and DEA harvested at the same stage of maturity. They were grown in the same field with the same agronomic treatments, including irrigation. In order to achieve a similar DM content for the two silages, Cracotte was harvested 129 days after sowing and DEA after 119 days. The two silages had already been shown to have consistent differences in degradability in three successive years (L'Alliance Élevage, unpublished values).

2.2. Experimental design

Silages made from the two hybrids were compared in a changeover experiment in which half of the cows were given DEA in the first period and the other half were given Cracotte. Each of the two experimental periods consisted of 15 days of adaptation period followed by a 28-days measurement period.

2.3. Animals

Twenty Holstein-Friesian lactating cows including eight in the first lactation were allocated to two groups balanced according to stage of lactation and pregnancy, weight at calving, milk production and food intake during the first 84 days of the current lactation.

All animals were introduced to the first treatment on the same date at which time they were at least in the 14th week of lactation.

Table 1 shows the characteristics of the two groups.

2.4. Feeding and treatment

The cows were tethered with individual access to feed and water. They were given maize silage *ad libitum*, which was offered twice per day and 200 g of sodium bicarbonate per day were added on top of the silage.

In addition, a fixed amount of 4.03 kg DM of concentrate was dispensed automatically in three portions per day and 0.51 kg DM of soybean meal twice per day. The morning allocation of concentrate was accompanied by 200 g of a mineral/vitamin premix and 12 g of protected methionine.

2.5. Variables measured

Offered and refused quantities of forage and concentrate were measured individually every day of the week. Chemical analysis of each silage (DM, ash, crude protein, starch, cell walls) was made on an average sample obtained from daily sampling during the experimental periods. For concentrates, a chemical analysis was carried out on a composite sample of each concentrate obtained at delivery.

Milk yield was measured for each animal at each milking. Milk composition was measured

Table 1. Characteristics of each group.

	Group 1 Means (SD)	Group 2 Means (SD)
Days of lactation ¹	158.3 (36.2)	161.8 (26.4)
Days of pregnancy ¹	62.8 (34.3)	72.3 (26.6)
Weight in calving (kg)	646.9 (84.3)	655.3 (72.6)
Number of lactation	2.5 (1.8)	2.7 (1.6)
Milk yield (kg·d ⁻¹)	33.9 (5.1)	35 (4.7)
Fat content (g·kg ⁻¹)	39.4 (3.8)	39.8 (4.8)
Protein content (g·kg ⁻¹)	29.4 (1.8)	29.5 (2.2)
DMI ² (kg·d ⁻¹)	16.8 (2.2)	17.4 (2.2)

¹ At the beginning of the first experimental period; ² feed intake during the first 84 days of lactation; SD: standard deviation; DMI: dry matter intake.

individually for six successive milkings for every two last weeks of each experimental period.

Cows were weighed on two successive days every second week from the 1st day of the experimental period.

DM degradability of each silage was measured by the in situ methodology on part of the composite sample which was used for chemical analysis. This methodology of DM degradability of each dried and ground maize silage was described by Valentin et al. [22].

2.6. Statistical analysis

The individual means for each period were subjected to the general linear model of analysis of variance [19] for effects of treatment, experimental period and animal. The following model was used: $Y_{ijkl} = \mu + C_i + P_j + T_k + E_{ijkl}$, where μ was the overall mean; C_i , P_j , T_k were the effects of cow, period and treatment, respectively; and E_{ijkl} was the error term. When treatment differed

($P < 0.05$), comparisons between treatments were made using the least squares difference test.

No statistical analysis was performed on the values for DM degradability in view of the absence of replicate measurements.

3. RESULTS

3.1. Nutritional values and degradability of maize silages

Table II gives the chemical composition, nutritional value of each diet constituent and DM degradability for each silage. The values for DM and starch were very similar. However, levels of nitrogen were higher for DEA than for Cracotte (92 vs. 80 g·kg⁻¹). Cell walls were higher for DEA than Cracotte. In situ DM degradability was higher for Cracotte (57.6 %) than for DEA (53.9 %).

Table II. Nutritional composition of each diet constituent and degradability values of each maize silage.

	Silage DEA	Silage Cracotte	Concentrate ¹	Soybean meal
DM (%)	29.0	30.8	89.4	86.3
Chemical composition (g·kg ⁻¹ DM)				
Ash	47	40	59	68
Crude protein	92	80	241	545
Starch	295	293	NA	NA
Fibre	257	220	84	70
NDF	473	414	219	212
ADF	277	215	108	89
Lignin	32	29	26	18
Nutritional value (g·kg ⁻¹ DM)				
UFL	0.89	0.91	1.06	1.16
PDIN (g)	54	48	176	330
PDIE (g)	68	69	172	230
In situ degradability (%)				
DM degradability	53.9	57.6	NA	NA

UFL: net energy value for milk production [9]; PDIN: digestible proteins in the small intestine when nitrogen is limiting in diet [9]; PDIE: digestible proteins in the small intestine when energy is limiting in diet [9]; dry matter (DM) degradability value obtained with the model of Kristensen et al. [11]; NA: not available; ¹ Concentrate composition (% DM): wheat 20, barley 20, dehydrated sugar beet pulp 23.1, molasses 5.2, urea 0.5, animal fat 4.8, salt 1, sodium bicarbonate 0.01, soybean meal 12.7, protected soybean meal 12 %.

3.2. Intake

Table III gives the nutritional value and the animal performance for each diet.

The level of DM intake varied according to maize used for ensilage, there being a highly significant difference in favour of Cracotte (diet 2). The difference between the two maize silages is 650 g DM·d⁻¹. Energy intakes (16.6 and 16.9 UFL·d⁻¹ for diet 1 and 2, $P < 0.05$) and protein intakes (1 572 and 1 526 g·d⁻¹ for PDIN values, $P < 0.001$, 1 684 and 1 742 g·d⁻¹ for PDIE values, $P < 0.001$, for diets 1 and 2) were significantly different according to treatment.

3.3. Milk yield and composition

There was no significant effect of treatment on the yield, 4 % fat-corrected yield of

milk, nor was there any effect on milk fat and protein content or lactose concentration in milk.

3.4. Weight gain

There was no significant difference in weight gain over the 4-week treatment period, even if this gain was slightly higher for Cracotte than DEA (respectively, 515 and 498 g·d⁻¹).

3.5. Requirements in energy and nitrogen of dairy cows

Requirements included requirement for maintenance, milk production and milk content, energy and nitrogen quantities supplied by the diet. Energetic requirements were

Table III. Effect of maize hybrid on feed intake, milk yield, milk content and weight gain.

Hybrid	Diet 1 DEA	Diet 2 Cracotte	Significance Level (P)	SE
DMI maize silage (kg·d ⁻¹)	12.8	13.5	< 0.001	0.19
DMI total concentrate (kg·d ⁻¹)	4.5	4.5	NS	0.03
Total DMI (kg·d ⁻¹)	17.4	18.0	< 0.001	0.20
NDF intake with MS (kg·d ⁻¹)	6.1	5.6	< 0.001	0.17
NDF intake with total diet (kg·d ⁻¹)	7.1	6.6	< 0.001	0.17
UFL fed with MS (g·d ⁻¹)	11.4	12.3	< 0.05	0.40
PDIN fed with MS (g·d ⁻¹)	693	647	< 0.001	19.9
PDIE fed with MS (g·d ⁻¹)	873	930	< 0.001	30.5
Total UFL fed (g·d ⁻¹)	16.6	16.9	< 0.05	0.39
Total PDIN fed (g·d ⁻¹)	1572	1526	< 0.001	22.6
Total PDIE fed (g·d ⁻¹)	1684	1742	< 0.001	32.3
Milk yield (kg·d ⁻¹)	23.7	23.4	NS	1.23
Corrected milk (kg·d ⁻¹)	24.1	23.9	NS	5.70
Fat content (g·kg ⁻¹)	41.3	41.4	NS	2.57
Protein content (g·kg ⁻¹)	31.6	31.6	NS	1.37
Lactose content (g·kg ⁻¹)	46.5	46.3	NS	0.22
Weight gain (g·d ⁻¹)	498	515	NS	566

MS: maize silage; SE: standard error; DMI: dry matter intake; UFL: net energy value for milk production [9]; PDIN: digestible proteins in the small intestine when nitrogen is limiting in diet [9]; PDIE: digestible proteins in the small intestine when energy is limiting in diet [9]; NS: not significant.

largely covered by the two diets (107 % for DEA and 103 % for Cracotte) regarding the French UFL system. However, nitrogen requirements were less correctly covered by the two diets (101 % PDI for DEA and 97 % for Cracotte) regarding the French PDI system.

4. DISCUSSION

4.1. Intake in relation to silage characteristics

The two maize silages studied were harvested at the same stage of maturity in order to obtain similar, relatively high DM contents close to 300 g·kg⁻¹, designed to optimize intake by dairy cows [7].

Maize silages fed by animals were different in cell walls content (NDF) and DM degradability measured in situ. DEA silage had a higher fibre content than Cracotte but a lower DM degradability, the latter difference probably explained by the former. It has been previously observed that the level of NDF would account for 30 % of the variability in DM degradability ($n = 160$, $P < 0.01$ %, L'Alliance Élevage, unpublished observations) and the undegradable fraction of NDF is more closely related to the DM degradability value ($r^2 = 50$ %, $rsd = 3.5$, $n = 85$, $P < 0.01$ %; L'Alliance Élevage, unpublished observations). In the current experiment, undegradable NDF was higher for DEA than Cracotte (309 vs. 280 g·kg⁻¹, respectively) and could appear as an explaining factor of DM degradability.

The small difference in intake of the two silages might be linked to a better DM degradability for Cracotte than DEA. The more quickly degraded a silage in the rumen, the lower the rumen fill and so a shorter residence time is less limiting for feed intake than a less degradable silage [24]. The lower NDF content could explain a shorter residence time in the rumen for Cracotte and with the higher degradability contribute to the enhanced food intake. Mertens [14]

showed that the NDF content could explain 58 % of the voluntary DMI for 126 grasses and 61 legumes fed to sheep. This positive relationship between DM degradability and feed intake was already shown in an experiment on dairy cows in early lactation [21]. In this work, feed intake was different among the four groups of dairy cows fed with four different silages (400 g to 1.6 kg DM·d⁻¹) and differences of DM degradability values were between 0.66 and 5.37 %.

4.2. Feed intake and animal performances

In this study, an increase of DMI of 650 g DM·d⁻¹ was without any significant effect on milk yield, milk composition or weight gain. Small differences were always in favour of the DEA silage for milk production and composition (240 g of milk, 0.64 and 0.52 g·kg⁻¹ for fat and lactose concentration, respectively). The additional energy with Cracotte seemed to be used in body weight gain even if the difference was low and not significant between the two silages (0.3 UFL).

The lack of an effect on performance of feed intake of forage with an equal concentrate intake has been observed in previous experiments [2, 3]. In the first trial [2], difference of intake of 900 g DM·d⁻¹ for the first group was not linked to a better milk production or milk composition but to a better weight gain. In the second trial [3], the first group had a higher feed intake than the second and third group (from 1 to 1.4 kg DM·d⁻¹) but with the lowest milk yield, milk fat content and weight gain than the overall groups. A better utilization of maize silage could permit an increase of milk yield and/or weight gain or both or any effect. However, some factors linked to experimental protocol or to silages could explain the lack of significant effect of intake of Cracotte on animal performances.

Weight gain was determined by double weighing every 2 weeks and then weight gain was measured for each treatment. This

measurement was open enough to criticism because it was very linked to numerous variation factors: individual variability of each animal [5, 12] and the magnitude of variation could be observed on large time periods (except in early lactation where loss of weight are very important). It is therefore possible to think that in our experiment, its duration was too short in order to diminish this individual variability and to permit a significant difference of weight gain between groups in late lactation.

The lack of an effect of a better feed intake on milk yield could be also due to the low difference of energy consumed by animals (0.3 UFL) or explained by the stage of lactation of animals in experiments. They seemed to be less sensitive to a higher intake and therefore gave a lower reply to animal performances.

5. CONCLUSION

The conclusions of our study are in agreement with the previous results from Demarquilly and Chenost [6] and Hovell et al. [8], who observed a positive relationship between voluntary intake and digestion rate measured *in situ*. DM degradability criteria of maize silage seemed to be a good indicator of forage intake although it was not the only one. Nevertheless, it seemed interesting to confirm observations made with a more important number of maize hybrids, with longer experimental periods and cows in different stages of lactation in order to quantify the effect of a higher degradability and then a higher intake on weight gain or on an increase of milk yield.

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