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Original article

Effect of maturity stage and chopping length of maize silage on particle size reduction in dairy cows

Isabelle FERNANDEZ, Brigitte MICHALET-DOREAU*

Unité de Recherche sur les Herbivores, INRA-Theix, 63122 St-Genès-Champanelle, France

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Abstract — The effects of maturity stage and chopping length of maize silage on chewing behaviour, particle size reduction and rumen retention time were studied in four lactating cows fitted with a ruminal cannula, according to a 4 × 4 Latin square design. Maize silage made up 80% of the diet and the cows were fed at 90% of the ad libitum intake level. Chopping length had only a significant effect on the particle size of the maize harvested at the late maturity stage. For the latter, the proportion of particles larger than 2 mm (LP2) from the feed to the rumen content decreased from 73 to 38% for the coarse maize and from 58 to 37% for the fine maize, mainly by ingestive mastication. Eating time expressed per unit of feed intake did not vary significantly between these two silages (21.3 vs. 19.8 $min \cdot kg^{-1}$ DMI). Ingestive mastication in dairy cows thus reduces long particles more efficiently than short particles.

particle size / chewing behaviour / maize silage / dairy cows

Résumé — **Effet du stade de maturité et de la finesse de hachage de l'ensilage de maïs sur le comportement alimentaire et la réduction de la taille des particules chez les vaches laitières.** Quatre vaches laitières canulées du rumen ont reçu en quantités limitées et dans un dispositif en carré latin 4 × 4, quatre ensilages de maïs qui différaient par leur finesse de hachage et leur stade de maturité. La ration était composée de 80 % d'ensilage et 20 % de concentré. Les différences de taille de particules des ensilages ont été plus importantes au stade tardif que précoce. La mastication ingestive a réduit fortement la proportion de grosses particules (> 2 mm) (LP2) par rapport à la comminution totale. Cette diminution a été plus importante avec l'ensilage grossièrement haché qu'avec l'ensilage finement haché, respectivement de 73 à 38 % vs. de 58 à 37 %. Parallèlement, la durée unitaire d'ingestion par gramme de fourrage ingéré n'a pas varié significativement avec les deux ensilages (21.3 vs. 19.8 $min \cdot kg^{-1}$ MSI). La mastication était donc plus efficace pour l'ensilage haché grossièrement.

taille des particules / comportement alimentaire / ensilage de maïs / vaches laitières

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* Correspondence and reprints
Tel.: 33 (0)4 62 40 93; fax: 33 (0)4 73 62 42 73; e-mail: bdoreau@sancy.clermont.inra.fr

1. INTRODUCTION

Particle size plays a key role in the digestion and passage of feed through the gastrointestinal tract of ruminants and therefore in feed intake. When studying the passage of food from the rumen, digesta particles are usually divided into two pools: a small particle pool (< 2 mm) that leaves the rumen, and a large particle pool (> 2 mm) that has difficulty escaping [23]. The mean retention time of digesta depends on the sizes of the two particle pools and their outflow from the rumen. Most feed particle comminution to sizes small enough to leave the rumen is accomplished by chewing, and interrelationships exist between chewing activity, particle comminution, ruminal retention time and voluntary intake [9]. Only a few authors have studied particle comminution mechanisms with cattle in relation to control of feed intake and most results have been obtained with hay or haylage [4, 20, 26].

In this experiment, particle size reduction in maize silages differing in maturity stage and chopping length was studied in cows fed restricted amounts.

2. MATERIALS AND METHODS

2.1. Animals, experimental design and diets

Maize (Safrane variety, Limagrain Genetics) was grown in April 1999 in Limagne (France) at a density of 95 000 seeds per ha. Whole plants were harvested with a precision chop harvester (Claas SF80 model, no roller mill) at two theoretical chop lengths, fine (4.2 mm) and coarse (12.0 mm), and at two maturity stages, early stage (24% DM) and late stage (31% DM). The different types of maize were ensiled in small experimental silos with a capacity of 4 m^3.

Four multiparous Holstein cows (average initial body weight 602 ±72 kg, average days in milk 92 ± 57 d) were fitted with a permanent ruminal cannula made of polyamide and polyvinyl chloride (Synthesia, Nogent-sur-Marne, France). Surgery was performed more than 12 months before the initiation of the experiment, under general anaesthesia (Isoflurane, ICIU Pharma-vétérinaire, Paris, France). The cows were housed in individual tie stalls, and were randomly assigned to the 4 experimental diets in a 4 × 4 Latin square design. The dietary treatments were based on the experimental maize silages (79.3%) supplemented with 19.4% concentrate and 1.3% minerals. The concentrate was composed of 53.3% soybean meal, 10.1% wheat, 7.5% rapeseed meal, 10.1% barley, 15.1% beet pulp, 2% beet molasses, 1% calcium carbonate, 0.5% dicalcium phosphate, 0.3% magnesium oxide and 0.3% sodium chloride and the mineral composition was 6% P, 24% Ca and 5% Mg, respectively. The diets were formulated to contain 12.3% crude protein (on a DM basis) and to meet the cows' mineral requirements [16]. They were given twice daily in equal proportions at 09.00 and 16.00 h, and in restricted amounts (at 90% of the individual ad libitum DM intake). Each period of the Latin square lasted 29 days, a 14-day adaptation period followed by a 15-day experimental period.

2.2. Measurements

Feed intake was recorded daily. Feed samples were collected daily from d 15 to d 29. Silage samples were analysed daily for DM, 48 h in an 80 °C forced-air oven. Samples of the other ingredients were collected once weekly and analysed for DM. Dried composite samples of feeds were pooled within each period and ground to pass a 1-mm hammer mill screen before chemical analysis. A representative sample of maize silage was collected weekly during each period and frozen at –20 °C and pooled within each silage at the end of the trial, for sieve and silage analysis.

Chewing activity was recorded for three consecutive days (from d 24 to d 26), using a small balloon filled with a foam rubber placed in the sub-mandibular space and connected to a pressure gauge transducer. Signals from the transducers were recorded to determine ingestion and ruminating times. Feed intake during the first morning meal was measured by weighing refusals 2 h after feeding.

Ruminal mean retention time was determined from a single dose of Europium (20 g of Eu oxide·kg^{-1} DM feed) labelled on maize stover [11] given just before the morning meal on d 22. After washing (1 h, 40 °C) with a commercial detergent without EDTA, followed by four rinses with water, maize stover was macerated in a Eu acetate solution (15 mL·g^{-1} stover DM; 0.02 M) for 24 h. Labelled particles of stover were rinsed under tap water for 2 min and immersed for 1.5 h in a water bath (15 mL·g^{-1} stover DM) to remove loosely or unbound rare earth. Labelled particles were dried at 80 °C for 48 h. Faecal samples were collected from the rectum of each cow from d 21 to d 26 every 3 h for 12 h, then every 4 h for 36 h, then every 6 h for 36 h, and finally every 24 h until 168 h after marker distribution. Faecal samples were dried (80 °C for 48 h) and ground and passed through a 1-mm screen.

At the end of each period (on d 29), the rumen was manually emptied 5 h after the morning feeding and the contents were weighed. After homogenisation, dry matter content was determined and a representative sample (5 kg) was frozen at –20 °C for sieve analysis. Another sample was strained through a 250-μm nylon filter to separate the liquid and solid phases and weighed.

When the rumen was empty, the cows were fed maize silage alone. Boluses of maize silage, chewed, and delivered through the cardia, were collected by hand through the rumen cannula. Eight boluses were pooled for each cow per period and frozen at –20 °C for sieve analysis.

2.3. Chemical and physical analyses

Feed samples were analysed for DM, ash, crude protein [2], starch [12] and NDF and ADF using α-amylase [29].

Silage fermentation characteristics were measured on maize silage juice obtained with a grape press. pH was immediately determined with a digital pH-meter (CG840, Ag/AgCl electrode, Schott Gerate, Hofheim, Germany). Acetic acid and ethanol contents were determined by gas liquid chromatography [17], lactic acid content by Noll's method [22] and NH_3 content by Conway's method [7]. The DM content of maize silage was corrected for losses of volatile components during oven-drying [10].

Particle size distribution in maize silage, boluses and ruminal content were determined by wet sieving [13]. Samples (50 g of fresh matter) were sieved with a system (Retsch AS 200, Germany) that provided water spray and vibrations, equipped with six sieves of 8.00, 4.00, 2.00, 0.40, 0.10 and 0.05 mm aperture size, and a bottom pan. Three 5-min sievings were carried out using on average 12 L of water per sample. The material retained on each sieve was dried for 24 h in a forced-air oven at 60 °C, then for 48 h at 80 °C and weighed. Total filtration water, containing the finest particles (< 0.05 mm), was weighed, and five fractions (100 mL) were weighed and dried at 80 °C. Two replicates were completed for each sample.

The particle size distribution was expressed as DM percentage of particles collected on the different screens. Mean particle size was calculated by plotting the cumulative percentages of retained particles against the logarithm of sieve size [30]. The d75-d25 inter-fractile gap, which reflects heterogeneity of particle size distribution

[21], was calculated. The proportion of large particles larger than 2 mm (LP2) was determined by the sum of the particle proportions retained on 8, 4, and 2 mm aperture sieves, this being considered as the critical size for leaving the reticulo-rumen in cattle [23, 28]. As performed by Bailey et al. [4], the differences in particle size from feed to bolus and from bolus to rumen were expressed using differences in mean particle size and LP2 proportions.

Europium content in faecal content was determined by atomic absorption spectrophotometry (Model 2380 Spectrophotometer, Perkin-Elmer, Bois-d'Arcy, France) after extraction of the marker from the dried samples by the method of Hart and Polan [15]. The ruminal mean retention time was calculated by plotting the natural logarithm of marker concentration against time, with the linear descending part of the curve corresponding to the ruminal particulate outflow rate [27].

2.4. Statistical analysis

Data were analysed as a 4 × 4 Latin square design using the GLM procedure of SAS [24] with maize silage, period, and cow as the sources of variation. The means were considered significant at $P < 0.05$. The model was:

$$Y_{ijkl} = \mu + S_i + P_j + C_k + E_{ijkl}$$

where Y_{ijkl} = observation, μ = overall mean, S_i = effect of silage treatment (i = 1 to 4), P_j = effect of period (j = 1 to 4), C_k = effect of cow (k = 1 to 4) and E_{ijkl} = residual error.

3. RESULTS AND DISCUSSION

3.1. Maize silage characteristics

The chemical composition and fermentation characteristics of the four maize

Table I. Chemical composition and fermentation characteristics of the maize silages.

Maturity stage	Early		Late	
Chopping length	Fine	Coarse	Fine	Coarse
Chemical composition				
DM ($g \cdot kg^{-1}$)	244	240	308	328
OM ($g \cdot kg^{-1}$ DM)	952	949	955	956
Crude protein ($g \cdot kg^{-1}$ DM)	75	81	75	74
Starch ($g \cdot kg^{-1}$ DM)	255	246	326	304
NDF ($g \cdot kg^{-1}$ DM)	471	477	418	432
ADF ($g \cdot kg^{-1}$ DM)	272	283	238	230
Fermentation characteristics				
pH	37.1	37.8	38.5	38.1
Lactic acid ($g \cdot kg^{-1}$ DM)	47.0	46.3	37.1	52.5
Acetic acid ($g \cdot kg^{-1}$ DM)	11.2	7.7	7.2	10.2
Ethanol ($g \cdot kg^{-1}$ DM)	7.6	8.3	1.5	4.7
N-NH_3 ($g \cdot kg^{-1}$ DM)	0.42	0.44	0.32	0.53

DM: dry matter, OM: organic matter, NDF: neutral detergent fibre, ADF: acid detergent fibre, N-NH_3: ammonia nitrogen.

Table II. Particle size distribution of the maize silages.

Maturity stage	Early		Late	
Chopping length	Fine	Coarse	Fine	Coarse
(% DM retained on sieve)				
8.0 mm	15.5	21.9	9.3	45.4
4.0 mm	31.1	30.5	31.1	22.2
2.0 mm	18.7	10.9	19.5	8.0
0.4 mm	7.7	6.0	9.2	3.2
0.1 mm	1.3	1.7	2.2	0.9
0.05 mm	0.4	0.5	0.8	0.3
< 0.05 mm	25.4	28.5	28.1	19.9
Mean particle size (mm)	0.80	0.76	0.55	2.64
d75-d25 (mm)*	4.07	5.20	3.08	13.76
LP2 (% on DM basis)	61.0	61.0	58.0	73.0

* Extent of dispersion.
DM: dry matter; LP2 = sum of the particle proportions retained on 8, 4, and 2 mm sieve aperture.

silages are presented in Table I. The chemical composition did not vary with the chopping length of the maize silage. The increase of DM content from 24 to 32% was accompanied by an increase of starch content with 6% units and a decrease of NDF and ADF content with respectively 5 and 4% units. These variations were due to a relative increase in grain content with an advancing maturity stage.

The fermentation characteristics of the four maize silages indicated a normal preservation. At the early maturity stage, chopping length had no effect on fermentative parameters. At the late maturity stage, coarsely chopped silage was more fermented than the fine silage, resulting in higher lactic acid and ethanol concentrations, despite the slightly higher DM content.

At the early maturity stage, the coarse silage contained more particles larger than 8 mm compared with the fine silage (22 vs. 16%), but less particles between 2 and 4 mm in size (from 11 to 19%) (Tab. II). Consequently, the LP2 proportion was not affected (61% on a DM basis) by chopping length. At the late maturity stage, coarse chopping induced a marked increase in the proportion of particles larger than 8 mm (from 9 to 45%) that was only partly offset by a lower proportion of particles between 2 and 8 mm in size (from 51 to 30%). Coarse chopping thus resulted in an increase in the LP2 proportion (from 58 to 73%) and in the extent of dispersion, which rose from 3 to 14 mm, showing the high heterogeneity of the silage.

3.2. Maturity stage and particle size reduction

Because the cows were limited-fed, DM intake per day or per meal did not vary with the maturity stage. The intake during the morning meal accounted for nearly half of the daily intake, on average 7 kg DM (Tab. III). Maturity stage did not affect the time spent eating per day or per unit of feed. The time spent chewing was higher for the

Table III. Influence of maturity stage and chopping length of maize silage on DM intake and chewing activity of dairy cows.

Maturity stage	Early		Late		SE
Chopping length	Fine	Coarse	Fine	Coarse	
Dry matter intake (DMI)					
Total DMI ($kg \cdot d^{-1}$)	14.57[a]	14.89[a]	14.56[a]	14.45[a]	0.99
a.m. meal DMI (kg)	6.86[a]	6.98[a]	6.97[a]	6.81[a]	0.46
Time spent eating					
$min \cdot d^{-1}$	297[a]	273[a]	261[a]	304[a]	15
$min \cdot kg^{-1}$ DMI	21.70[a]	19.51[a]	19.84[a]	21.28[a]	2.19
a.m. meal (min)	124[a]	114[ab]	103[b]	121[a]	4
a.m. meal ($min \cdot kg^{-1}$ DMI)	19.28[a]	17.08[a]	16.74[a]	18.30[a]	1.87
Time spent ruminating					
$min \cdot d^{-1}$	538[a]	550[a]	491[a]	444[b]	29
$min \cdot kg^{-1}$ DMI	37.50[a]	37.83[a]	34.48[a]	31.72[a]	2.90
Time spent chewing					
$min \cdot d^{-1}$	835[a]	836[a]	752[b]	749[b]	24
$min \cdot kg^{-1}$ DMI	59.17[a]	57.41[a]	54.25[a]	52.86[a]	4.45

[a, b] Within the same line, means with different letters are significantly different ($P < 0.05$); SE: standard error.

early than for the late maturity stage, 836 vs. 751 min. This difference persisted when the results were expressed per unit of feed intake, but was no longer significant. In lactating cows, De Boever et al. [8] reported a higher chewing time per unit of feed intake for the less mature maize, which they attributed to the lower grain content of this silage.

The LP2 proportions, being on average comparable for the early and late stage (respectively 61 and 65% on DM basis) (Tab. IV), were similar in the corresponding boluses, respectively 44.2 and 46.1% on a DM basis. By mastication overall, mean particle size and LP2 proportion for the 4 silages decreased from 1.19 to 0.25 mm and from 63 to 45.1% on a DM basis. Ingestive mastication strongly reduced mean particle size by 79%. With hay, mastication during consumption reduced the large particle proportion on average by 44% in sheep [6] and by 51% in cattle [19]. Ingestive mastication increased the proportion of small particles, particularly those smaller than 0.05 mm (on average with 11% units).

Rumen fill expressed as fresh matter was significantly higher with the early than with the late maturity stage, and the rumen fill expressed in dry matter followed the same trend (Tab. V). Neither the solid phase proportion, nor DM content, nor DM particle size distribution varied with the maturity stage. The higher rumen fill with the early silage was not accompanied by any modification to the structure of the rumen contents. A higher NDF content as in the early stage silage, may induce a higher rumen fill [1]. This did not depress DMI, because the cows were limited-fed. Ruminal mean retention was not affected by the maturity stage.

3.3. Chopping length and particle size reduction

At the early maturity stage there was little difference in particle size characteristics between fine and coarse chopped silages, so we focused on late maize silages.

Table IV. Influence of maturity stage and chopping length of maize silage on particle size in digesta.

Maturity stage	Early		Late		SE
Chopping length	Fine	Coarse	Fine	Coarse	
Particle size distribution in bolus (% DM retained on sieve)					
8.0 mm	9.8^{a}	12.2^{ab}	7.7^{a}	16.5^{b}	1.8
4.0 mm	17.0^{a}	22.7^{b}	20.3^{ab}	19.7^{ab}	1.8
2.0 mm	14.8^{a}	11.9^{a}	17.7^{a}	10.3^{b}	1.1
0.4 mm	14.6^{a}	10.9^{a}	14.6^{a}	11.8^{a}	1.3
0.1 mm	5.5^{a}	4.4^{a}	4.4^{a}	4.9^{a}	0.6
0.05 mm	1.6^{a}	1.2^{a}	1.3^{a}	1.5^{a}	0.2
< 0.05 mm	36.6^{a}	38.6^{a}	33.8^{a}	35.6^{a}	2.6
Mean particle size (mm)	0.21^{a}	0.21^{a}	0.27^{a}	0.30^{a}	0.06
d75-d25 (mm)*	1.67^{a}	2.09^{a}	1.96^{a}	2.54^{a}	0.25
LP2 (% on DM basis)	41.6^{a}	46.7^{a}	45.7^{a}	46.5^{a}	2.9
Change in					
Mean particle size (mm)	0.59^{a}	0.55^{a}	0.28^{a}	2.35^{b}	0.06
LP2 (% on DM basis)	21.0^{a}	14.3^{b}	12.3^{b}	26.6^{a}	2.4
Particle size distribution in rumen (% DM retained on sieve)					
8.0 mm	5.1^{a}	10.7^{b}	6.5^{a}	13.5^{b}	1.9
4.0 mm	13.3^{a}	14.5^{a}	11.1^{a}	12.8^{a}	1.3
2.0 mm	19.3^{a}	14.3^{b}	19.5^{a}	11.5^{b}	1.4
0.4 mm	27.3^{a}	24.6^{a}	26.7^{a}	28.1^{a}	2.7
0.1 mm	14.4^{a}	14.2^{a}	12.6^{a}	13.7^{a}	1.6
0.05 mm	2.9^{a}	2.5^{a}	2.5^{a}	2.6^{a}	0.4
< 0.05 mm	18.2^{a}	19.2^{a}	21.2^{a}	18.7^{a}	5.6
Mean particle size (mm)	0.57^{a}	0.55^{a}	0.46^{a}	0.62^{a}	0.20
d75-d25 (mm)*	1.61^{a}	1.87^{a}	1.65^{a}	1.93^{a}	0.19
LP2 (% on DM basis)	37.7^{a}	39.5^{a}	37.1^{a}	37.8^{a}	2.8
Change in					
Mean particle size (mm)	-0.36^{a}	-0.32^{a}	-0.19^{a}	-0.32^{a}	0.11
LP2 (% on DM basis)	2.3^{a}	7.2^{a}	8.6^{a}	8.6^{a}	2.9

* Extent of dispersion.
[a, b] Within the same line, means with different letters are significantly different ($P < 0.05$).
SE: standard error; DM: dry matter; LP2 = sum of the particle proportions retained on 8, 4, and 2 mm sieve aperture.

Chewing behaviour of cows receiving the two late maize silages did not vary with chopping length (Tab. III). The time spent eating per day or per unit of feed intake tended to increase with the coarse silage, but the differences were not significant. In contrast, the time spent ruminating per day decreased significantly with the coarse silage, but this decrease was no longer significant when expressed per unit of feed intake. Thus, the time spent chewing was similar for the two late silages at both chopping lengths. In a recent review, Beauchemin [5] established a relationship between feed particle size and eating and ruminating times. Fine chopping reduced chewing time, but the extent of this reduction was variable and depended on the particle size distribution. With maize silages, either no effect of chopping length on chewing behaviour [3, 18, 25], or an increase in chewing time with higher chopping length was observed [8]. All these data were obtained with animals fed ad libitum, but DMI did not vary between silages.

At the late maturity stage, the LP2 proportions in the boluses from the fine and coarse silages were similar, on average 46.1% on a DM basis (Tab. IV). Coarse silage contained more particles larger than 8 mm than fine silage (17 vs. 8%), but this was compensated by a lower proportion of particles between 2 and 4 mm in size (10 vs. 18%). Ingestive mastication particularly increased the proportion of particles retained on the 0.4 mm sieve and also of particles smaller than 0.05 mm, and decreased particles larger than 4 mm. Mean particle size and LP2 proportion markedly decreased, this drop being greater for the coarse than for the fine silage, respectively from 2.35 to 0.28 mm and from 27 to 12% on a DM basis. With hays and straws, Lee and Pearce [19] also reported differences in the extent to which roughages were reduced by ingestive mastication. More recently, Bailey et al. [4], Bernard et al. [6], studied comminution during ingestive mastication with hays with different initial particle sizes. A reduction in particle size was greater with the long than with the short form, 22 vs. 15% [4], 50 vs. 32% [6]. To our knowledge, only one trial on particle size reduction during mastication has been conducted with silages, haylage and maize silage [4]; initial particle size distribution of the silages was similar and so the authors could not draw any firm conclusion from their trial. Our result on maize silage supports the results obtained previously with hay; large particles were reduced more than small ones during ingestive mastication. These differences were not accompanied by significant changes in time spent eating or chewing. Our results suggest that ingestive mastication expressed per unit of feed intake was more efficient for coarse than for fine silage.

To assess the role of ingestive mastication in total comminution, particle size distribution in boluses and ruminal content was compared. Few studies have made this comparison [14, 26]. The particle size distribution in the ruminal contents corresponded to the ingestion of a mixed ration (79% maize silage and 21% concentrate) and was compared with boluses made up of only maize silage (Tab. IV).

At the late maturity stage, the ruminal particle size distribution was similar and the LP2 fraction represented 37.5% on a DM basis for the two silages. Just like the modifications of particle size distribution between the silage and bolus, the particles retained on the 0.4 mm screen increased from the bolus to rumen content. However, in contrast to the variation observed during ingestive mastication, the proportion of the smallest particles (0.05 mm) decreased on average from 35 to 20% for the two silages. The LP2 proportion decreased from the bolus to rumen content (from 46 to 37% on DM basis), but this decrease was smaller than the drop observed from the silage to the bolus (from 65 to 46% on a DM basis). Ingestive mastication was more efficient in

Table V. Influence of maturity stage and chopping length on ruminal pool size and retention time.

Maturity stage	Early		Late		SE
Chopping length	Fine	Coarse	Fine	Coarse	
Ruminal pool size					
Fresh matter (kg)	99.1[a]	98.5[a]	89.8[b]	87.2[b]	4.0
Dry matter (kg)	14.2[a]	13.7[a]	12.9[a]	12.7[a]	0.9
DM content (%)	14.3[a]	13.8[a]	14.5[a]	14.4[a]	0.5
Solid phase proportion (% fresh matter)	49.0[a]	45.6[a]	47.4[a]	44.3[b]	1.3
Ruminal mean retention time (h)	42.0[a]	40.3[a]	43.7[a]	41.0[a]	5.4

[a, b] Within the same line, means with different letters are significantly different ($P < 0.05$).
DM: dry matter.

reducing particle size than the combined action of ruminative mastication and microbial digestion. This increase in mean particle size from the bolus to rumen content agreed with the decrease in the proportion of the smallest particles (0.05 mm), which reflected the selective movement of these particles through the reticulo-omasal orifice.

Ruminal particle size was somewhat higher for the coarse than for the fine maize silage, but these differences were not significant for any of the parameters taken. For the two late silages, the LP2 proportion was similar in the bolus and rumen contents, and the modifications from the bolus to rumen contents were identical: a 9% unit decrease.

Rumen fill was not affected by chopping length of the maize silage (Tab. V). At the late maturity stage, rumen fill expressed in fresh or dry matter was on average respectively 88.5 and 12.8 kg. This lack of response in the rumen fill may be related to the NDF content, which was similar in the silages. Mean retention time did not vary with chopping length, because the cows were limited-fed. Bal et al. [3] reported no effect of chopping length of maize silages on ruminal mean retention time with animals fed ad libitum. The after ingestive mastication particle size in the boluses was similar for coarse and fine silages, which could also explain the lack of an effect on rumen fill and ruminal mean retention time.

4. CONCLUSION

With maize silages, the LP2 proportion and particle size markedly decreased after ingestive mastication in comparison with total comminution, and this decrease was more pronounced for coarsely chopped than for finely chopped silage. Concurrently, chewing behaviour by limited-fed cows did not vary significantly between diets. Thus the comminution from chewing during eating did not depend on eating time, but rather on the initial particle size of the feed; the greater the size, the greater the reduction.

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