

## Effect of maize variety harvested at different maturity stages on feeding value and performance of dairy cows

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**Abstract** — Maize silage was produced from two different varieties (SG: “stay-green” and DD: “dry down”) at two different stages of maturity (target: 30–32 and 38–42% DM). Dry matter and nutrients of plant fractions and silages, fermentation parameters of silages and digestibility in sheep were determined. Furthermore a feeding trial was conducted in which the effect of the maize silage on feed intake and performance of dairy cows was studied. This trial series (TS 1) was replicated in the following year (TS 2). In both years, variety SG had higher ear (dehusked) dry matter content and lower residual plant dry matter content (58.9% and 23.7%) than variety DD (54.9% and 26.7%) and a slightly lower ear (dehusked) proportion. The constituents of the ear (dehusked) and residual plants were affected by maturity stage but not by variety. The maize silages of variety DD had slightly lower crude ash, crude fat and crude fibre contents and a higher starch content than SG. In TS 1, the digestibility of the organic matter averaged about 77% for variety SG and 80% for variety DD; in TS 2 this value was uniform at about 77%. While the maize variety had little effect on the average daily feed intake over both feeding trials (SG 17.2 kg DM per cow and DD 16.9 kg DM per cow), the stage of maturity had a significant effect. Maturity stage 2 increased the total daily feed intake from 16.4 to 17.8 kg DM per cow relative to maturity stage 1. The daily milk yield, which averaged 24.9 kg (TS 1) and 25.2 kg per cow (TS 2) was not significantly affected either by the variety or the maturity status, although there was a slight quantitative advantage of 1.1 kg (TS 1) and 0.7 kg (TS 2) milk per cow and day in favour of variety SG over variety DD.

**dairy cow / maize silage / variety / maturity / feeding value / stay-green**

**Résumé** — **Influence de la variété du maïs, récoltée à différents stades de maturité, sur la valeur alimentaire de la plante et sur les performances des vaches laitières.** Le maïs à ensiler était issu de deux variétés distinctes (SG : aptitude à rester vert « stay green » et DD : dessèchement rapide « dry down ») à deux stades de maturité différents (30–32 et 38–42 % de MS). La matière sèche et la composition chimique des fractions végétales et des ensilages ainsi que les paramètres de fermentation des ensilages et la digestibilité mesurés sur mouton ont été déterminés. Un essai d'alimentation, dans

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lequel ont été étudiées la prise alimentaire et les performances des vaches laitières, a également été mis en place. Cette série d'essais a été réalisée sur deux années consécutives, respectivement, TS 1 et TS 2. Les résultats ont montré que, sur les deux années, les épis (sans spathes) de la variété SG ont eu une teneur en matière sèche plus élevée, et les fractions végétales résiduelles une teneur en matière sèche plus faible (58,9 % et 23,7 %) que celles de la variété DD (54,9 % et 26,7 %). La proportion d'épis (sans spathes) a été légèrement inférieure pour la variété SG. La composition des fractions végétales a été affectée par le stade de maturité mais pas par la variété. Pour les ensilages, ceux de la variété DD ont eu une teneur en matières minérales, en matière grasse et en fibres brutes légèrement plus faible et une teneur en amidon plus élevée que les ensilages de la variété SG. Lors de la première année (TS 1), la digestibilité de la matière organique a été en moyenne de 77 % pour la variété SG et de 80% pour la variété DD ; l'année suivante (TS 2), cette valeur a été en moyenne de 77 % pour les deux variétés. La consommation moyenne quotidienne des aliments a été plus affectée par le stade de maturité que par la variété du maïs (SG : 17,2 kg MS par vache et DD : 16,9 kg MS par vache). Par rapport au stade de maturité 1 (30–32 % de MS), le stade de maturité 2 (38–42 % de MS) a engendré une augmentation de la consommation moyenne quotidienne d'aliments de 16,4 à 17,8 kg MS par vache. La production journalière du lait, quant à elle, a été en moyenne de 24,9 kg pour TS 1 et 25,2 kg pour TS 2. Elle n'a pas été significativement affectée par la variété ou le stade de maturité du maïs, bien qu'il y ait eu un léger avantage quantitatif de 1,1 kg (TS 1) et 0,7 kg (TS 2) de lait produit par vache et par jour en faveur de la variété SG.

**vache laitière / ensilage de maïs / variété / maturité / valeur alimentaire / stay green**

## 1. INTRODUCTION

Maize silage is an important forage and a major energy source in dairy cattle rations both in Europe and North America. The feeding value and energy content of maize silage are determined by the chemical composition and the relative proportions of the different plant fractions (stalks, leaves, ear) and their digestibility. The feeding value of maize silage can also be enhanced by mechanical processing of the grain and the residual plant [14, 25, 32]. But one of the most important factors affecting the nutritive value of maize silage is the choice of harvest time and the physiological maturity of the crop at harvest [17]. With advancing maturity and increasing DM content, the content of total sugar in the residual plant decreases [6] and simultaneously the ADF and NDF content of the residual plant increases [35], thus reducing its digestibility [26, 29]. As long as living conductive tissues exist, the soluble carbohydrates migrate from the residual plant to the ears, where they are transformed to starch during the progress of maturity [6]. As a result, the

starch content of the ear and the ear proportion of the whole plant increase with higher dry matter contents, and ear digestibility is improved [29] while the ruminal starch degradability of the maize kernel declines [10]. A reduced rate of ruminal starch degradation could, however, have a positive impact on the dairy cow's glucose supply due to the increased intestinal starch flow [11]. These at times contradictory effects of the maturity status on the feeding value of maize silage demonstrate the difficulty of determining an optimal harvest time. Moreover, technical aspects of silage production will also have to be considered when selecting a harvest time, such as field and harvest losses, the effect of the DM content on the suitability of the crop for silage production and on fermentation parameters [16].

In addition to the harvest time, feeding value and digestibility of maize silage are also significantly affected by the variety [1, 4, 7, 8]. A possible higher digestibility of a relatively immature residual plant has in recent years been discussed together with stay-green genotypes, which have a mature kernel while the residual plant is still green

[29]. There have also been several studies of brown midrib varieties [3, 20, 34], which lead to improved digestibility due to their lower lignin content. Furthermore, it has been suggested that the variety has an effect on ruminal degradability of starch in maize [22, 23].

This paper is concerned with the effect of maturity stage and variety on the constituents and digestibility of maize silage and feed intake and milk yield of dairy cows. Up to now, there have been no clear reports of a specific interest of stay-green hybrids for cattle feeding. Moreover, such hybrids are often harvested late, because farmers underestimate the maturity of plants. Therefore, we compared a variety with a stay-green residual plant and a variety with a fast maturing residual plant. In order to determine the effect of the maturity, maize silages with a lower and higher dry matter content were produced from both varieties. Furthermore, all investigations of trial series 1 (TS 1, harvest year 1999) were repeated in the following year (TS 2, harvest year 2000).

## 2. MATERIALS AND METHODS

### 2.1. Cultivation data and silage production

In this study we investigated the varieties Achat (SG) from the intermediate maturity group (S 240, grain type: simple hybrid, flint × dent maize) and Mondeo (DD) from the early maturity group (S 210, grain type: simple hybrid, flint × dent maize) (breeder: KWS). SG is a variety with a stay-green residual plant and DD a variety with a fast maturing residual plant ("dry down"). The maize crops were grown in 1999 (TS 1) and 2000 (TS 2) under comparable conditions on identical plots at the Hirschau experimental station. Seeding dates were the 28th of April 1999 and 27th of April 2000. The seeding density was 10 seeds·m<sup>-2</sup> with a

distance between rows of 75 cm and a distance between seeds of 13 cm.

From the 23rd of August 1999 and the 29th of August 2000, representative samples of whole plants (30 plants per variety and date of sampling) were drawn from the standing crop at about 10–14-day intervals. The degree of maturity at the chosen harvest date was estimated by determining the dry matter content of the ear (dehusked), residual plant and whole plant of a pooled sample for each variety and date of sampling.

In TS 1, variety SG was harvested on the 6th and 21st of September, variety DD on the 6th and 20th of September. In TS 2, harvest dates for variety SG were the 8th and the 29th of September and for variety DD the 8th and the 26th of September. The crop was harvested with a Claas forage harvester; a uniform chopping length of 6 mm and the use of a corn cracker were specified. The ensiling was done in identical bunker silos (a capacity of about 60–70 m<sup>3</sup> each) under usual agronomic conditions.

### 2.2. Digestion experiments

The digestion experiments were conducted with 20 wethers (Merino Land Sheep) (n = 5 per treatment) in TS 1 and 16 wethers (n = 4 per treatment) in TS 2; the sheep had a mean bodyweight of 68.8 ± 4.3 kg (TS 1) and 80.2 ± 7.5 kg (TS 2). In TS 1 and TS 2 the sheep were fed 0.96 and 1.05 kg DM maize silage, respectively, 0.13 kg soya bean meal and 0.02 kg mineral feed per day. The energy intake was about 1.2 times the maintenance requirement. The digestion experiments were divided into an 11-day preliminary period and a 10-day faecal collection period. Bulk faeces were collected daily from each sheep, kept in the chill room during the collection period, mixed at the end of the collection period and an aliquot was then removed for freeze-drying and subsequent analysis. Aliquot feed samples were also taken and

frozen for analysis. Digestibilities were calculated for maize silages by consideration and deduction of supplemented soya bean meal.

### 2.3. Dairy cattle feeding trials

Feeding trial 1 was carried out over an 8-week period in July and August 2000, feeding trial 2 over 7 weeks in January and February 2001. A total of 44 (TS 1) and 48 (TS 2) dairy cows (Red Holstein Friesian  $\times$  Fleckvieh) were used. Cows were randomly allotted to the 4 treatment groups considering milk yield, body weight and number of finished lactations at the start of the trial. At the beginning of the experiments, the cows were on average 136 (TS 1) and 112 (TS 2) days in milk. In TS 1 and TS 2, 12 and 11 cows were in their first lactation, respectively, while the remaining cows were in their second or subsequent lactation. The same numbers of primiparous and multiparous cows with a comparable milk yield, dry matter intake and live weight were allotted to each treatment. The animals were housed in a loose barn with pens without straw,

milking parlour and outdoor feeding area with transponder-controlled weigh troughs (6 feeding spaces per treatment) and concentrate stations.

The dairy cows were fed a forage diet consisting of maize silage mixed with 17.0% soya bean meal (relative to maize silage DM) ad libitum, and hay given restrictedly to a maximum of 1.0 kg per animal and day. Concentrate (27% soya bean meal, 29% dried sugar beet pulps, 25% wheat, 17% maize grains and 2% vitaminised mineral feed) was offered in both trial series to the cows with a milk yield more than 19 kg·d<sup>-1</sup> at an amount of 1 kg per 2 kg of milk. Mineral feed of 120 g per cow daily was provided. The DM and nutrient concentrations of the concentrates and the hay are shown in Table I.

Feed intake and milk yield of each individual cow was recorded automatically each day. On two milking days per week, samples were drawn from the evening and morning milk for analysis of the milk constituents (lactose, protein, fat, urea) by the Bavarian LKV (state control agency). All cows were weighed once a week. Maize

**Table I.** Mean DM (%), crude nutrient (g·kg<sup>-1</sup> DM), RNB (g·kg<sup>-1</sup> DM), nXP (g·kg<sup>-1</sup> DM) and energy levels (MJ NEL·kg<sup>-1</sup> DM) of the concentrates and the hay.

|                                       | Hay            | Soya bean meal | Concentrate    |
|---------------------------------------|----------------|----------------|----------------|
| Dry matter (%)                        | 86.0 $\pm$ 0.0 | 88.0 $\pm$ 0.0 | 88.0 $\pm$ 0.0 |
| Crude ash (g·kg <sup>-1</sup> DM)     | 56 $\pm$ 8     | 77 $\pm$ 4     | 68 $\pm$ 4     |
| Crude protein (g·kg <sup>-1</sup> DM) | 104 $\pm$ 13   | 478 $\pm$ 15   | 219 $\pm$ 5    |
| Starch (g·kg <sup>-1</sup> DM)        | 0 $\pm$ 0      | 69 $\pm$ 0     | 289 $\pm$ 0    |
| Crude fibre (g·kg <sup>-1</sup> DM)   | 318 $\pm$ 13   | 68 $\pm$ 5     | 79 $\pm$ 1     |
| NfE (g·kg <sup>-1</sup> DM)           | 505 $\pm$ 15   | 366 $\pm$ 21   | 621 $\pm$ 5    |
| Ether extract (g·kg <sup>-1</sup> DM) | 18 $\pm$ 2     | 11 $\pm$ 5     | 14 $\pm$ 4     |
| RNB (g·kg <sup>-1</sup> DM)           | -2 $\pm$ 1     | 29 $\pm$ 1     | 4 $\pm$ 1      |
| nXP (g·kg <sup>-1</sup> DM)           | 120 $\pm$ 4    | 296 $\pm$ 6    | 195 $\pm$ 0    |
| Energy (MJ NEL·kg <sup>-1</sup> DM)   | 5.2 $\pm$ 0.1  | 8.5 $\pm$ 0.1  | 7.9 $\pm$ 0.0  |

NfE: N-free extract; RNB: ruminal nitrogen balance; nXP: utilisable crude protein at the duodenum; NEL: net energy for lactation.

silage samples were drawn twice weekly, samples of hay and soybean meal once weekly and concentrate samples from each mixture.

#### 2.4. Analysis and statistical evaluation

The DM concentrations of the maize silage and the residual maize plant were determined after drying for 24 hours at 60 °C, the DM content of the uncrushed ear (dehusked) after drying for 72 h at 60 °C, followed by grinding and further drying for 3 hours at 105 °C. Crude nutrients in all feed samples were measured using the Weende analytical technique [19]. Nitrogen content of feed was analysed using a Macro N nitrogen analyser. Crude fat was analysed by ether extraction in a Soxhlet apparatus. In the digestibility experiments, fat was measured as total fat after HCl hydrolysis. The starch content of the maize silage and the maize ear (dehusked) was recorded polarimetrically. For determination of the ensiling quality, the pH was measured in 14-day mixed samples of the maize silages and the fermentation acids were measured by gas chromatography.

The nXP and RNB values of feedstuffs were calculated by means of regression equations as suggested by the German Nutrition Society [13] in conjunction with the results of the feed analysis. The energy concentration of feedstuffs was calculated according to the regression equations of GfE [12], using the crude nutrient concentrations and digestibilities of feedstuffs. Table values for the digestibilities of organic matter, crude fat and crude fibre [9] were used for concentrates and hay, whereas for maize silages, the digestibilities determined in the digestion experiments were used.

The statistical evaluation of the data was done by analysis of variance with a PC version of the software package Statistical Analysis System (Release 8.2, SAS Institute Inc., Cary North Carolina, USA 2001 [27]) using the GLM procedure with the

factors variety, stage of maturity, year and interactions between variety, stage of maturity and year.

In TS 1 two animals (SG, maturity stage 1 and DD, maturity stage 2) and in trial series 2 three animals (SG, maturity stage 1 and two animals DD, maturity stage 2) were excluded from the analysis because of poor performance due to mastitis. In the digestibility experiment one animal in trial series 1 (treatment SG, maturity stage 1) had to be excluded from the statistical analysis.

### 3. RESULTS

#### 3.1. Composition and crude nutrient concentrations of maize

In both harvest years and across both varieties, the average DM content of an ear (dehusked) and residual plant rose at the later harvest date from 53.6% and 21.8% to 60.2% and 28.6% ( $P < 0.05$ ), respectively (Tab. II). At the same time, the starch content of the ear (dehusked) and the crude fibre content of the residual plant increased from 53.3% and 32.0% to 60.8% and 36.1% ( $P < 0.05$ ), respectively, whereas the crude fibre content of the ear (dehusked) decreased numerically from 9.7% to 7.9%. Across both trial series, variety SG had a higher ear (dehusked) DM content ( $P < 0.05$ ) than variety DD (58.9% vs. 54.9%), and a numerically lower residual plant DM content (23.7% vs. 26.7%). Overall, variety DD had a higher ear proportion ( $P < 0.05$ ) than variety SG in both trial series at both stages of maturity.

#### 3.2. Nutrient and energy concentrations, digestibilities and fermentation parameters of the maize silages

The dry matter content of the maize silages was comfortably within the target range of about 30–32% for maturity stage 1

**Table II.** Mean DM and crude nutrient concentrations (% of DM) in ear (dehusked) and residual plant and ear proportion (%) of the whole plant.

|                    | Maturity stage 1 |      | Maturity stage 2 |      | SE   | Significance |       |         |
|--------------------|------------------|------|------------------|------|------|--------------|-------|---------|
|                    | SG               | DD   | SG               | DD   |      | Var          | S     | S × Var |
| Ear (dehusked)     |                  |      |                  |      |      |              |       |         |
| Dry matter (%)     | 55.8             | 51.4 | 61.9             | 58.4 | 0.5  | <0.01        | <0.01 | 0.56    |
| Crude ash (%)      | 1.60             | 1.48 | 1.60             | 1.44 | 0.09 | 0.22         | 0.85  | 0.85    |
| Crude protein (%)  | 8.50             | 8.30 | 8.49             | 9.44 | 0.28 | 0.16         | 0.32  | 0.16    |
| Starch (%)         | 54.3             | 52.3 | 59.6             | 61.9 | 1.6  | 0.94         | 0.01  | 0.27    |
| Crude fibre (%)    | 9.57             | 9.90 | 8.28             | 7.54 | 0.62 | 0.79         | 0.06  | 0.50    |
| NfE (%)            | 75.7             | 76.7 | 76.7             | 77.4 | 0.79 | 0.42         | 0.43  | 0.86    |
| Ether extract (%)  | 4.62             | 3.64 | 4.92             | 4.24 | 0.17 | 0.11         | 0.02  | 0.52    |
| Residual plant     |                  |      |                  |      |      |              |       |         |
| Dry matter (%)     | 21.3             | 22.3 | 26.1             | 31.0 | 0.14 | 0.17         | 0.02  | 0.32    |
| Crude ash (%)      | 5.72             | 5.45 | 5.50             | 5.46 | 0.04 | 0.74         | 0.83  | 0.81    |
| Crude protein (%)  | 6.48             | 7.06 | 5.19             | 5.57 | 0.06 | 0.13         | 0.55  | 0.90    |
| Crude fibre (%)    | 32.3             | 31.7 | 35.9             | 36.4 | 0.9  | 0.96         | 0.02  | 0.63    |
| NfE (%)            | 54.4             | 54.3 | 52.4             | 51.6 | 1.68 | 0.31         | 0.81  | 0.88    |
| Ether extract (%)  | 1.07             | 1.58 | 1.05             | 1.09 | 0.08 | 0.08         | 0.06  | 0.10    |
| Ear proportion (%) | 52.1             | 57.5 | 59.3             | 62.1 | 1.2  | 0.04         | 0.01  | 0.38    |

Maturity stage 1: 30–32% DM; Maturity stage 2: 38–42% DM; SG: maize variety “Achat” (Stay Green); DD: maize variety “Mondeo” (Dry Down); SE: standard error; Var: variety, S: stage of maturity; S × Var = interaction between variety and stage of maturity; NfE: N-free extract.

and 38–40% for maturity stage 2 (Tab. III). Only the maize silage from variety DD, late maturity, in TS 1 had an excessive DM content of 48.7% and therefore DM content of variety DD as a mean of both stages of maturity was 2.3% higher than in variety SG ( $P < 0.05$ ). Variety DD had lower average crude fibre concentrations ( $P < 0.05$ ) across both trial series than variety SG (195 g·kg<sup>-1</sup> DM vs. 217 g·kg<sup>-1</sup> DM). Starch and crude protein levels were higher in variety DD compared to variety SG. But these parameters showed a significant interaction between variety and stage of maturity. Maturity stage 2 resulted in a reduction of the crude fibre content from 21.3 to 19.9% ( $P < 0.05$ ) and an increase in the starch content from 28.0 to

34.0% compared with maturity stage 1. From the nutrient concentrations and digestibilities of the maize silages we calculated high energy levels of 6.9–7.2 MJ NEL·kg<sup>-1</sup> DM.

The pH of all silages was in the range 3.8–4.1. With the exception of TS 2, maturity stage 1, variety SG, where the lactic acid content was very low at 0.78% of the fresh matter and the acetic acid content very high at 1.49% of the fresh matter, the values recorded for lactic acid and acetic acid were very uniform at about 1.6–1.9% and 0.3–0.9% of the fresh matter, respectively. Maturity stage 1 led to higher acetic acid levels than maturity stage 2, whereas the lactic acid concentrations showed no directional change. The mentioned fermentation

**Table III.** Mean DM (%), crude nutrient ( $\text{g}\cdot\text{kg}^{-1}$  DM), RNB ( $\text{g}\cdot\text{kg}^{-1}$  DM), nXP ( $\text{g}\cdot\text{kg}^{-1}$  DM) and energy levels (MJ NEL $\cdot\text{kg}^{-1}$  DM) and fermentation parameters of the maize silages.

|   | Maturity stage 1 |      |      |      | Maturity stage 2 |              |       |       | Significance |       |         |       |             |
|---|------------------|------|------|------|------------------|--------------|-------|-------|--------------|-------|---------|-------|-------------|
|   | SG               | DD   | SG   | DD   | DD               | pooled<br>SE | Var   | S     | S × Var      | Y     | Var × Y | S × Y | S × Var × Y |
| Dry matter (%)                                    | 30.9             | 32.1 | 40.2 | 43.6 | 43.6             | 0.96         | <0.01 | <0.01 | 0.06         | <0.01 | <0.01   | 0.037 | <0.01       |
| Crude ash ( $\text{g}\cdot\text{kg}^{-1}$ DM)     | 36.9             | 34.8 | 34.7 | 33.0 | 33.0             | 0.5          | <0.01 | <0.01 | 0.68         | 0.16  | 0.10    | <0.01 | 0.87        |
| Crude protein ( $\text{g}\cdot\text{kg}^{-1}$ DM) | 78.4             | 82.7 | 78.4 | 77.6 | 77.6             | 1.33         | <0.01 | <0.01 | <0.01        | <0.01 | <0.01   | <0.01 | <0.01       |
| Starch ( $\text{g}\cdot\text{kg}^{-1}$ DM)        | 268              | 293  | 324  | 356  | 356              | 9.5          | <0.01 | <0.01 | 0.01         | <0.01 | 0.87    | 0.21  | <0.01       |
| Crude fibre ( $\text{g}\cdot\text{kg}^{-1}$ DM)   | 226              | 200  | 208  | 189  | 189              | 3.8          | <0.01 | <0.01 | 0.36         | 0.54  | 0.49    | 0.07  | 0.80        |
| NfE ( $\text{g}\cdot\text{kg}^{-1}$ DM)           | 621              | 648  | 640  | 668  | 668              | 5            | <0.01 | <0.01 | 0.833        | 0.672 | 0.717   | 0.031 | 0.264       |
| Ether extract ( $\text{g}\cdot\text{kg}^{-1}$ DM) | 36.9             | 34.6 | 38.8 | 32.1 | 32.1             | 1.3          | <0.01 | 0.81  | 0.11         | 0.03  | 0.58    | 0.29  | 0.65        |
| RNB ( $\text{g}\cdot\text{kg}^{-1}$ DM)           | -9.3             | -9.3 | -9.6 | -9.7 | -9.7             | 0.07         | <0.01 | <0.01 | 0.21         | 0.06  | <0.01   | 0.09  | <0.01       |
| nXP ( $\text{g}\cdot\text{kg}^{-1}$ DM)           | 136              | 141  | 138  | 138  | 138              | 0.9          | <0.01 | 0.01  | <0.01        | <0.01 | <0.01   | <0.01 | <0.01       |
| Energy (MJ NEL $\cdot\text{kg}^{-1}$ DM)          | 6.9              | 7.2  | 7.1  | 7.1  | 7.1              | 0.05         | <0.01 | 0.02  | <0.01        | <0.01 | <0.01   | <0.01 | <0.01       |
| Fermentation parameters                           |                  |      |      |      |                  |              |       |       |              |       |         |       |             |
| pH  | 3.90             | 3.80 | 3.98 | 4.04 | 4.04             | 0.05         | 0.26  | <0.01 | 0.03         | 0.18  | 0.01    | 0.02  | 0.64        |
| Lactic acid (% fresh matter)                      | 1.32             | 1.95 | 1.66 | 1.67 | 1.67             | 0.11         | <0.01 | 0.43  | <0.01        | <0.01 | <0.01   | 0.06  | 0.06        |
| Acetic acid (% fresh matter)                      | 1.09             | 0.70 | 0.52 | 0.46 | 0.46             | 0.12         | <0.01 | <0.01 | 0.01         | <0.01 | 0.61    | 0.04  | 0.25        |
| Butyric acid (% fresh matter)                     | 0.08             | 0.04 | 0.07 | 0.07 | 0.07             | 0.02         | 0.32  | 0.15  | 0.30         | 0.22  | 0.04    | 0.01  | <0.01       |

Maturity stage 1: 30–32% DM; Maturity stage 2: 38–42% DM; SG: maize variety “Achat” (Stay Green); DD: maize variety “Mondeo” (Dry Down); SE: standard error; Var: variety; S: stage of maturity; Y: year; S × Var: interaction between variety and stage of maturity; Var × Y: interaction between variety and year; S × Y: interaction between stage of maturity and year; S × Var × Y = interaction between stage of maturity, variety and year; NfE: N-free extract; RNB: ruminal nitrogen balance; nXP: utilisable crude protein at the duodenum; NEL: net energy for lactation.

**Table IV.** Mean digestibilities (%) of the maize silages.

|                | Maturity stage 1 |      |      | Maturity stage 2 |      |      | Significance |      |      |         |       |         |       |             |
|----------------|------------------|------|------|------------------|------|------|--------------|------|------|---------|-------|---------|-------|-------------|
|                | SG               | DD   | DD   | SG               | DD   | DD   | pooled SE    | Var  | S    | S × Var | Y     | Var × Y | S × Y | S × Var × Y |
| Organic matter | 76.8             | 79.6 | 78.4 | 77.7             | 78.4 | 78.4 | 0.60         | 0.02 | 0.82 | 0.14    | 0.02  | 0.05    | 0.82  | 0.43        |
| Crude fibre    | 66.1             | 70.6 | 66.0 | 66.0             | 66.0 | 66.0 | 1.36         | 0.17 | 0.07 | 0.13    | 0.27  | 0.33    | 0.18  | 0.55        |
| NfE            | 81.2             | 83.3 | 82.8 | 81.7             | 82.8 | 82.8 | 0.63         | 0.01 | 0.75 | 0.39    | <0.01 | 0.08    | 0.15  | 0.40        |

Maturity stage 1: 30–32% DM; Maturity stage 2: 38–42% DM; SG: maize variety “Achat” (Stay Green); DD: maize variety “Mondeo” (Dry Down); SE: standard error; Var: variety; S: stage of maturity; Y: year; S × Var: interaction between variety and stage of maturity; Var × Y: interaction between variety and year; S × Y: interaction between stage of maturity and year; S × Var × Y: interaction between stage of maturity, variety and year; NfE: N-free extract.

Table V. Feed intake, nutrient intake and performance criteria.

|                                 | Maturity stage 1 |      |       | Maturity stage 2 |      |           | Significance |      |         |      |         |       |             |
|---------------------------------|------------------|------|-------|------------------|------|-----------|--------------|------|---------|------|---------|-------|-------------|
|                                 | SG               | DD   | SG    | DD               | DD   | pooled SE | Var          | S    | S × Var | Y    | Var × Y | S × Y | S × Var × Y |
| Daily feed intake (kg DM)       |                  |      |       |                  |      |           |              |      |         |      |         |       |             |
| Total feed                      | 16.6             | 16.3 | 18.0  | 17.5             | 0.42 | 0.45      | <0.01        | 0.88 | 0.03    | 0.47 | 0.81    | 0.70  |             |
| Maize silage                    | 10.4             | 10.5 | 12.0  | 11.6             | 0.34 | 0.63      | <0.01        | 0.58 | <0.01   | 0.27 | 0.49    | 0.93  |             |
| Concentrate                     | 5.8              | 5.5  | 5.6   | 5.7              | 0.41 | 0.74      | 0.88         | 0.72 | 0.17    | 0.91 | 0.76    | 0.90  |             |
| Daily nutrient intake           |                  |      |       |                  |      |           |              |      |         |      |         |       |             |
| Energy (MJ NEL)                 | 121              | 121  | 132   | 129              | 3    | 0.83      | <0.01        | 0.66 | 0.22    | 0.26 | 0.95    | 0.90  |             |
| Crude protein (g)               | 2588             | 2550 | 2720  | 2682             | 84   | 0.68      | 0.14         | 0.99 | 0.93    | 0.31 | 0.76    | 0.91  |             |
| nXP (g)                         | 2772             | 2759 | 2997  | 2937             | 77   | 0.68      | 0.01         | 0.80 | 0.35    | 0.32 | 0.97    | 0.91  |             |
| RNB (g)                         | -29.6            | 34.2 | -44.6 | -41.7            | 2.9  | 0.69      | <0.01        | 0.28 | <0.01   | 0.71 | 0.19    | 0.33  |             |
| Crude fibre (g)                 | 2910             | 2640 | 3021  | 2698             | 66   | <0.01     | 0.15         | 0.86 | <0.01   | 0.36 | 0.42    | 0.68  |             |
| Starch (g)                      | 4062             | 4301 | 5128  | 5332             | 141  | 0.06      | <0.01        | 0.81 | <0.01   | 0.62 | 0.35    | 0.05  |             |
| Performance criteria            |                  |      |       |                  |      |           |              |      |         |      |         |       |             |
| Milk yield (kg)                 | 25.8             | 24.5 | 25.3  | 24.8             | 1.4  | 0.54      | 0.95         | 0.78 | 0.81    | 0.88 | 0.85    | 0.92  |             |
| FPCM (kg)                       | 25.6             | 24.8 | 24.9  | 24.0             | 1.1  | 0.46      | 0.54         | 0.99 | 0.33    | 0.72 | 0.93    | 0.98  |             |
| Protein (%)                     | 3.42             | 3.57 | 3.52  | 3.58             | 0.08 | 0.19      | 0.45         | 0.67 | 0.03    | 0.43 | 0.81    | 0.75  |             |
| Fat (%)                         | 3.89             | 4.04 | 3.82  | 3.78             | 0.14 | 0.74      | 0.30         | 0.58 | 0.17    | 0.57 | 0.92    | 0.59  |             |
| Lactose (%)                     | 4.74             | 4.67 | 4.71  | 4.71             | 0.04 | 0.25      | 0.86         | 0.27 | 0.69    | 0.17 | 0.02    | 0.24  |             |
| Urea (mg·100 mL <sup>-1</sup> ) | 28.1             | 25.1 | 25.7  | 25.1             | 0.9  | 0.04      | 0.17         | 0.20 | 0.86    | 0.20 | 0.16    | 0.03  |             |
| Liveweight change (kg)          | 32.0             | 31.6 | 24.6  | 26.9             | 4.7  | 0.85      | 0.76         | 0.30 | 0.01    | 0.88 | 0.45    | 0.26  |             |

Maturity stage 1: 30–32% DM; Maturity stage 2: 38–42% DM; SG: maize variety “Achat” (Stay Green); DD: maize variety “Mondeo” (Dry Down); SE: standard error; Var: variety; S: stage of maturity; Y: year; S × Var: interaction between variety and stage of maturity; Var × Y: interaction between variety and year; S × Y: interaction between stage of maturity and year; S × Var × Y: interaction between stage of maturity, variety and year; NEL: net energy for lactation; nXP: utilisable crude protein at the duodenum; RNB: ruminal nitrogen balance; FPCM: fat and protein corrected milk.

parameters showed a significant interaction between variety and stage of maturity.

The digestibility (Tab. IV) of organic matter, crude fibre and N-free extract (NfE) of variety DD in TS 1 was 2.9, 3.4 and 2.6% higher, than in variety SG, whereas in TS 2 differences in digestibility relative to variety were small. Across both harvest years, these differences in TS 1 resulted in a significantly higher ( $P < 0.05$ ) digestibility of organic matter and NfE of variety DD compared to variety SG. The stage of maturity had no directional effect on digestibilities. The observed values for digestibility of organic matter and NfE in TS 1 were 1.5% and 2.7% higher than in TS 2 ( $P < 0.05$ ).

### 3.3. Dairy cattle feeding trials

While the maize silage variety had no effect on feed intake, the maturity stage had a significant effect: total daily feed intake and the daily intake of maize silage for maturity stage 1 (16.5 and 10.5 kg DM per cow) were considerably lower ( $P < 0.05$ ) than the corresponding intakes for maturity stage 2 (17.8 and 11.8 kg DM per cow) (Tab. V). These differences in feed intake were observed in both harvest years: In TS 1 a higher DM content of maize silages resulted in an increase in daily total feed intake and maize silage intake of 1.2 and 1.1 kg DM, respectively, and in TS 2 of 1.4 and 1.5 kg. In TS 2 total feed and maize silage intake were significantly higher (1.0 and 1.4 kg DM per animal and day) compared to TS 1. The daily intake of hay averaged 0.34 kg DM. The average daily energy, CP and starch supply was 126 MJ NEL per cow, 2635 g per cow and 4706 g per cow, respectively, whereas these parameters were significantly higher for maturity stage 2 compared to maturity stage 1. The daily intake of crude fibre was considerably less for variety DD (2669 g per cow) than for variety SG (2966 g per cow).

Milk yield was not significantly affected by variety or maturity stage (Tab. V), but in

each trial series the animals of group SG showed a numerically higher milk yield than the animals of group DD. In TS 1 the animals of group SG had a mean milk yield of 25.5 kg per cow and day across both maturity stages, 1.2 kg more than group DD. In TS 2, feeding silage SG or DD resulted in a daily milk yield of 25.6 kg per cow and 24.9 kg per cow, respectively. The average fat, protein and lactose content of the milk from all cows was 3.88, 3.52 and 4.71% respectively. The milk urea content was 26.9 mg·100 mL<sup>-1</sup> in group SG and 25.1 mg·100 mL<sup>-1</sup> in group DD. The higher value for group SG originates from a relatively high milk urea content of 30.0 mg·100 mL<sup>-1</sup> of animals of group SG, maturity stage 1 in TS 1. In the course of TS 1 and 2 the cows of all treatment groups gained an average of 35 and 23 kg in weight, respectively. There was no evidence of a marked effect of maturity stage or variety on liveweight change.

## 4. DISCUSSION

### 4.1. Composition and digestibility of the maize silage

In this study, maize silages with an identical dry matter content were produced from maize varieties of different genotypes (stay-green – dry down), with little variation in the harvest time between varieties. Variety SG had a lower dry matter content in the residual plant and a higher ear (dehusked) DM content. Variety DD had a slight advantage with regards to digestibility of organic matter and crude fibre of the maize silage. Elsewhere, Schlagheck et al. [28] and Schwarz and Ettle [29] showed in a wide spectrum of varieties that the in-vitro digestibility of residual plant and whole plant is not necessarily better for stay-green types even if the residual plants of the compared varieties (conventional genotypes) have matured more. The higher ear (dehusked) proportion of variety DD in the

present study might also have positively affected its digestibility since the ear is more digestible than the residual plant [29] and rising ear proportions consequently increase whole plant digestibility.

The higher maturity status led to an average reduction in the crude fibre content of 1.5 percentage points and an increase in the starch content of 6 percentage points, which correlates well with previous data for a DM range of 30–40% [29]. In agreement with earlier results [21, 29], crude fibre digestibility declined by 2.7 percentage points between the first and the second stage of maturity whereas the digestibility of NfE rose slightly. These shifts in the carbohydrate fractions and their digestibilities during the ripening process explain the fact that the digestibility of the organic matter of the maize silages was largely unaffected by the maturity stage.

#### 4.2. Feed intake

The total digestibility of the ration [30] and the digestibility of the organic matter in the forage [18, 31] are important variables in regulating feed intake. Yet, when we compared varieties at identical stages of maturity in the present study, a higher digestibility in sheep of the maize silages did not always lead to a higher feed intake by the cows. By contrast, the later harvest time, despite a reduction in crude fibre digestibility and unchanged digestibility of the organic matter, resulted in a significant increase in total feed intake and maize silage intake by 1.2 kg DM and 1.1 kg DM in experiment 1 and 1.4 kg DM and 1.5 kg DM in experiment 2. Older studies [5, 15] showed a marked increase in the feed intake of up to 0.5 kg DM for maize silages with a DM content of up to about 30% when the DM content of the maize silage was increased by 1 percentage point. It emerged, however, that at a silage DM in excess of 30%, the increase in the feed intake becomes smaller with increasing maturity of the silages.

Several recent studies [2, 24, 33] also indicate a plateau formation in the feed intake at silage DM levels above 30%. In the present study, an increase in the DM content of the silage by 1% resulted in a slightly lower average increase in the maize silage DM intake by 125 g. It should be noted that an increase in feed intake can only be expected if, as in the present study, the fermentation parameters were not deteriorated as a result of the increasing maturity stage.

#### 4.3. Milk yield

Feed intake and nutrient concentrations had little effect on the average energy and protein supply in our comparison of the two varieties. In both trial series and at both stages of maturity, the crude fibre intake was distinctly higher in group SG. In a few cases (TS 1, maturity stage 1; TS 2, maturity stage 2), there was also a marginal or distinct reduction in the starch supply of group SG, but this had no adverse effects on the milk production criteria of that group. On the contrary, the milk yield, at least in quantitative terms, was higher than that of group DD in both sets of experiments. But, since we did not measure the degradability of the carbohydrate fractions, we do not know whether the supply of starch at the duodenum, which might have an impact on the milk yield by improving the energy supply, was affected by the different silages.

The later maturity greatly improved the energy and starch supply. We can also presume that ruminal starch degradability is much reduced at a higher DM content of the grain [10], so that a greater flow of starch to the duodenum might be expected. However, the later harvest time did not result in a higher milk yield. Bal et al. [2] observed a non-significant increase in the milk yield by 0.8 and 0.7 kg after feeding maize silage with 35.1% DM compared with silages containing 32.4 and 42.0% DM. Phipps et al. [24] recorded significantly higher milk yields of 32.7 and 33.0 kg, respectively,

when feeding maize silage with DM concentrations of 29% and 30% than when feeding maize silage with a DM content of 39% (30.8 kg milk). The absence of effects of the higher energy and starch supply at increased silage DM levels on performance criteria in the present study suggests that the energy supply did not limit the milk yield, even at a low DM content.

Neither the DM content of the silages nor the maize variety had significant effects on milk constituents, although it was noted in both sets of experiments that the protein content was increased at least numerically by variety DD. The minimal variation in the nutrient supply between the two varieties provided no explanation for the higher protein content.

## 5. CONCLUSIONS

A comparison of the two trial series (harvest years) in the present study showed equivalent effects for almost all measured criteria in relation to variety and maturity stage. Variety DD had lower concentrations of crude fibre and higher concentrations of starch than variety SG, and a later harvest time shifted the carbohydrate fractions of both varieties towards a higher starch content. The determination of digestibility and energy content revealed relatively minor differences depending on variety and harvest time, which suggests a high harvest elasticity of maize in these parameters. Variety DD was, however, marginally more digestible than variety SG. But further criteria like the conservation technique or the ruminal degradability of starch or fibre should be considered. The variety (stay-green vs. dry down type) had no effect on the intake of maize silage, but a higher DM content (here about 38–40% vs. 30–32%) significantly increased the intake (+1.0–1.5 kg DM per cow and day). The higher intake of maize silage did not, however, translate into a higher milk yield.

It was noticed that in both sets of experiments variety SG was insignificantly superior to variety DD with regards to milk yield, at least in quantitative terms, which was not expected based on the data for feed ingredients, digestibility and feed intake.

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