Chemical composition and in vitro digestibility of stalks, leaves and cobs of four corn hybrids at different phenological stages

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ABSTRACT

Four hybrids of class FAO 700: EA6601 and Simeto (Monsanto), Eleonora (Pioneer), Pampero (Syngenta), grown under identical conditions, underwent analysis to determine their analytical and botanical composition and DM (IVDMD) and NDF (IVNDFD) in vitro digestibility.

The content of fibrous fractions increased with maturity. For stalks there was an increase from an average value of 47.72% (V8) up to over 61% during the dough stage of the grain (R4) reaching over 73% during the phase of physiological maturation (R6). At the eighth-leaf vegetative stage in hybrids the stalk represented 61.59% of the DM of the plant and reached 40.35% in the dough stage, while the leaf apparatus fall from 38.41% of the eighth-leaf stage DM to 18.19% during the dough stage of the grain and only 9.17% during physiological maturation.

The ear, which represented only 12.93% of DM plant at the silking stage, increased to 41.47% and 53.01 respectively at the dough and physiological phases. At the dough stage (R4) the hybrids Simeto and Pampero, had a stalk percentage significantly higher (41.67% and 42.34% respectively; P< 0.01) compared with Eleonora (38.97%) and EA6601 (38.44%).

Eleonora hybrid had a leaf proportion of 19.80% - higher than Pampero (17.93%), Simeto (17.60%), EA6601 (17.43%). This greater leafiness occurred with a lower incidence of the stalk, which has the highest loss of digestibility during maturing.

The grain percentage of EA6601 was significantly higher than Pampero (26.46%), Simeto (27.33%) and Eleonora (27.88%). In the R4 phase the hybrid EA6601 had a higher stalk fibre content (ADF 41.38%; P< 0.05) compared to Pampero (37.61%) Simeto (38.14%) and Eleonora (39.16%).

The effect of the phenological stage on the fiber content of the leaves was less evident, only the ADL increased from values of about 5% in the first period, to 8% and more in the final three stages.

Even here, in dough stage, EA6601 differed (P< 0.01) from the others for its higher levels of ADL (9.35%) and ADF (35.05%), while the hybrids Eleonora and Pampero presented lower values of ADL (P 0.01) and ADF (7.90%).

Simeto had the lowest ADF content (31.39%; P< 0.01). In the dough stage there was no significant differences for in vitro digestibility of DM and NDF between the hybrids - for all the botanical parts.

In the whole plant, as maturity advanced, the differences of in vitro digestibility of stalks, were counterbalanced by the increasing proportion of grain.

Key Words: Corn silage, Hybrids, Digestibility, Plant composition.
Introduction

Corn silage, and alfalfa, are the most important and economical forage resources for today's dairy farmers in all temperate irrigated areas.

There are many corn silage hybrids on the market that producers can choose among, but there is little data which compares plant composition or the digestibility of stalks and leaves.

In recent years there has been increasing interest by seed companies in selecting specialized corn hybrids for corn silage production (Johnson et al., 1997; Kuehn et al., 1999).

An important aspect of high yield dairy farming is maximising dry matter intake (DMI), particularly during early lactation when the negative energy balance limits productive and reproductive performance.

Physical fill is regarded as one of the factors that regulates feed intake of dairy cows (Mertens 1987, 1992) and the fermentation rate of NDF of forages, in particular regulates the retention time of DM in the rumen. According to Obra and Allen (1999) a one unit increase of forage NDF digestibility in vitro is associated with a 0.17 increase of DMI in a dairy cow.

Studies by Weiss et al. (1992) and Weiss...
Table 1. Dry matter content of corn plant at different vegetative stage (n. = 8 for each hybrid).

| Hybrid     | Vegetative stage |
|------------|------------------|
|            | V8   | VT    | R2   | R4   | R6   |
| Simeto     | 15.60\(^{Bb}\) | 20.15\(^{a}\) | 24.00\(^{bc}\) | 32.03\(^{a}\) | 50.28\(^{Aa}\) |
| Eleonora   | 14.73\(^{Aa}\) | 20.03\(^{b}\) | 21.43\(^{a}\) | 34.98\(^{ab}\) | 54.80\(^{ABb}\) |
| EA6601     | 17.38\(^{Cd}\) | 19.78\(^{B}\) | 25.45\(^{C}\) | 35.60\(^{b}\) | 55.68\(^{AAb}\) |
| Pampero    | 16.20\(^{Bc}\) | 17.93\(^{A}\) | 22.70\(^{ab}\) | 33.63\(^{ab}\) | 59.23\(^{Bc}\) |
| SE         | 0.155 | 0.376 | 0.512 | 1.105 | 1.319 |

A, B, C: P < 0.01; a, b, c: P < 0.05.

V8: 8° Leaf; VT: Tasseling; R2: Blister; R4: Dough; R6: Physiological maturity.

(1998), adopted by the NRC (2001) show the effect of the contents in ADF and ADL on the digestibility of the NDF and therefore its effect on the nutritional value of the forage.

Studies by many authors (Johnson et al., 1997; Kuehn et al., 1999) on fibre digestibility with leafiness or brown midrib (BMR) mutants (Cherney et al., 1991; Allen et al., 1997; Johnson et al., 1999; Obi and Allen 2000a, 2000b; Balland et al., 2001; Thomas et al., 2001; Tine et al., 2001) have indicated the importance of differentiating the selection of grain hybrids with respect to those for silage.

In these studies the corn hybrids were compared in vivo and in vitro, evaluating the digestibility of the organic substance of the whole plant without separating the effect of the grain quota on the digestibility of the plant.

During the maturation phase there is a progressive lignification of the vegetative part (stalk + leaves) which tends to reduce digestibility, which is counterbalanced, however, by the progressive accumulation of starch in the grain, as shown by Russell (1986), Russell et al. (1992) and by Hunt et al. (1998).

The identification of corn hybrids, which maintain a high digestibility during maturing, represent therefore the best strategy to increase the quality of ensiled corn (Xu et al., 1995).

The aim of this study was to compare the evolution of the digestibility in vitro of the DM (IVDMD) and the NDF (IVNDFD) of stalks, leaves and cobs of 4 corn hybrids (class FAO 700) during the different phases of their growth cycle.

Material and methods

The research was undertaken at the Research Centre of Zootechnics and the Environment (San Bonico, Piacenza), using four FAO 700 (131-140 d) corn hybrids: Simeto (Monsanto, St. Louis, MO, USA), Eleonora (Pioneer, Johnston, IA, USA), EA6601 (Monsanto, St. Louis, MO, USA), Pampero (Syngenta, Wilmington, DE, USA) recommended by the suppliers as hybrids for the production of corn silage.

Planting and establishment

The four hybrids were seeded in a field of 4.6 hectares alternatively in groups of three rows with a total of 56 rows per hybrid, on April 15\(^{th}\) 2003 and harvested on August 22\(^{nd}\) 2003 after 129 days of growth.

Manuring was undertaken with 54 - 54 -
### Table 2. Plant composition (on DM basis) in different period of life cycle. (n.= 8 for each hybrid).

| Vegetative stage | Hybrid  | Stalk (%) | Leaf (%) | Cob (%) | Husk (%) | Grain (%) |
|------------------|---------|-----------|----------|---------|----------|-----------|
| **V8**           | Simeto  | 63.04b    | 36.96a   | -       | -        | -         |
|                  | Eleonora| 61.36ab   | 38.64ab  | -       | -        | -         |
|                  | EA6601  | 59.40a    | 40.60b   | -       | -        | -         |
|                  | Pampero | 62.54b    | 37.46a   | -       | -        | -         |
|                  | SE      | 0.866     | 0.866    | -       | -        | -         |
| **VT**           | Simeto  | 64.00Bb   | 25.40ab  | 10.60a  | -        | -         |
|                  | Eleonora| 58.30Aa   | 27.09b   | 14.62ab | -        | -         |
|                  | EA6601  | 59.35ABa  | 24.86a   | 15.80b  | -        | -         |
|                  | Pampero | 63.97Bb   | 25.31ab  | 10.72a  | -        | -         |
|                  | SE      | 1.124     | 0.619    | 1.441   | -        | -         |
| **R2**           | Simeto  | 43.01Bc   | 20.18ab  | 10.47ab | 9.29     | 17.04ab   |
|                  | Eleonora| 39.95ABab | 21.09b   | 12.54b  | 9.24     | 16.19Ab   |
|                  | EA6601  | 39.15Aa   | 18.77a   | 9.90    | 9.64     | 22.55Ab   |
|                  | Pampero | 41.87Bbc  | 20.95b   | 11.91ab | 9.05     | 16.22Ab   |
|                  | SE      | 0.853     | 0.561    | 0.850   | 0.669    | 1.343     |
| **R4**           | Simeto  | 41.67a    | 17.60a   | 7.64a   | 5.85     | 27.33a    |
|                  | Eleonora| 38.97A    | 19.80a   | 7.68    | 5.67     | 27.88a    |
|                  | EA6601  | 38.44A    | 17.43A   | 6.54a   | 5.71     | 31.89a    |
|                  | Pampero | 42.34A    | 17.93A   | 7.08ab  | 6.19     | 26.46A    |
|                  | SE      | 0.531     | 0.312    | 0.337   | 0.310    | 0.569     |
| **R6**           | Simeto  | 41.15b    | 9.48ab   | 8.66ab  | 5.37     | 35.36a    |
|                  | Eleonora| 36.72a    | 10.34b   | 8.78ab  | 6.57     | 38.60ab   |
|                  | EA6601  | 36.47a    | 8.30a    | 9.04    | 5.91     | 40.23a    |
|                  | Pampero | 37.91ab   | 8.57ab   | 8.24    | 6.10     | 39.18ab   |
|                  | SE      | 1.342     | 0.576    | 0.214   | 0.591    | 1.283     |

A, B: P< 0.01; a, b, c: P< 0.05.

**V8**: 8° Leaf; **VT**: Tasseling; **R2**: Blister; **R4**: Dough; **R6**: Physiological maturity.

109 kg/ha (N, P$_2$O$_5$, K$_2$O respectively) as dairy manure in October 2002. Starter fertilizer was applied at a rate of 40-36-50 kg/ha (N, P$_2$O$_5$, K$_2$O respectively) during planting and 200 kg/ha of N as urea was distributed as a top dressing at the eighth leaf stage.

The hybrids were irrigated four times by rainfall (104.6 mm), but because of particularly hot temperatures the plants presented signs of hydric stress in the final phases of the study.

In order to evaluate the development of
the composition of the plants during the growth phase samples of each corn hybrid were taken at each phonological stage: eighth leaf (V8), emergence of tassel (VT), blister (R2), dough stage (R4) physiological ripening (R6).

During each sampling and for each type of hybrid, 8 plants were randomly selected from the central rows of the field, 2 plants for every 4 longitudinally, cutting the stalk at a height of 25 cm from the ground. Every plant collected was separated into its components: stalk, leaves and cobs; the cobs were split into their three components:
grain, cob and husk. For all the botanical fractions the moisture was determined with cuttings at 2 cm and essication at 60° in a ventilated oven to a constant weight.

Chemical analysis
Pre dried samples were ground to pass through a 1 mm screen using a Wiley mill (model 3: Arthur H. Thomas Co. Philadelphia, PA) for chemical analysis. Ground samples were analysed for DM, ash, CP (AOAC, 1995), NDF, ADF, and ADL (Van Soest et al., 1991), using the ANKOM Fiber Analyser, ANKOM Technology Corporation, Fairport.

Table 4. Chemical composition of corn leaves (% on DM basis) coming from four hybrids harvested in different vegetative stages.

| Vegetative stage | Hybrid       | SS   | CP   | NDF  | ADF  | ADFip | ADL  |
|------------------|--------------|------|------|------|------|-------|------|
| V8               | Simeto       | 22.65 | 13.67 | 52.10 | 27.92 | 0.80  | 5.34  |
|                  | Eleonora     | 28.82 | 13.76 | 58.33 | 29.40 | 0.65  | 4.73  |
|                  | EA6601       | 23.90 | 13.96 | 59.91 | 30.01 | 1.37  | 5.41  |
|                  | Pampero      | 23.06 | 14.32 | 57.31 | 29.54 | 1.01  | 5.57  |
|                  | SE           | 0.208 | 0.508 | 2.589 | 0.268 | 0.152 | 0.180 |
| VT               | Simeto       | 26.91 | 15.26 | 56.68 | 28.61 | 0.74  | 6.42  |
|                  | Eleonora     | 26.55 | 14.58 | 56.67 | 28.41 | 1.03  | 5.64  |
|                  | EA6601       | 25.77 | 14.64 | 58.94 | 31.46 | 1.05  | 6.70  |
|                  | Pampero      | 25.29 | 15.94 | 56.98 | 30.15 | 0.86  | 6.25  |
|                  | SE           | 0.588 | 0.286 | 0.304 | 0.256 | 0.268 | 0.180 |
| R2               | Simeto       | 26.53 | 13.29 | 57.54 | 30.50 | 0.87  | 7.80  |
|                  | Eleonora     | 24.37 | 13.73 | 59.15 | 30.45 | 0.81  | 6.83  |
|                  | EA6601       | 26.50 | 13.17 | 59.47 | 33.08 | 1.30  | 8.98  |
|                  | Pampero      | 26.41 | 13.58 | 57.01 | 31.43 | 1.00  | 8.08  |
|                  | SE           | 0.392 | 0.497 | 0.295 | 0.364 | 0.123 | 0.323 |
| R4               | Simeto       | 32.37 | 11.34 | 56.46 | 31.39 | 0.68  | 7.61  |
|                  | Eleonora     | 30.49 | 10.38 | 59.93 | 32.50 | 0.58  | 6.85  |
|                  | EA6601       | 29.23 | 11.62 | 59.77 | 35.05 | 1.09  | 9.35  |
|                  | Pampero      | 33.88 | 12.20 | 57.91 | 32.75 | 0.67  | 7.90  |
|                  | SE           | 1.878 | 0.351 | 0.535 | 0.380 | 0.080 | 0.257 |
| R6               | Simeto       | 80.45 | 7.63  | 61.08 | 34.17 | 0.64  | 6.67  |
|                  | Eleonora     | 79.52 | 6.98  | 62.39 | 36.48 | 0.78  | 7.18  |
|                  | EA6601       | 85.90 | 6.68  | 61.73 | 38.56 | 0.24  | 8.55  |
|                  | Pampero      | 92.79 | 7.99  | 60.41 | 38.56 | 0.24  | 8.59  |
|                  | SE           | 4.491 | 0.321 | 0.551 | 0.622 | 0.158 | 0.274 |

A, B, C: P< 0.01; a, b, c: P< 0.05.
V8: 8° Leaf; VT: Tasseling; R2: Blister; R4: Dough; R6: Physiological maturity.
The ADF residues were analysed for their CP content (AOAC, 1995) to determine ADFIP.

In vitro true disappearance and IVNDFD were determined with the Daisy incubator (ANKOM technology Corporation, Fairport, NY) as described by Holden (1999) using approximately 0.5 g sample incubated for 48 hours. Rumen fluid came from one donor cows fed a diet made of grass hay (8 kg as fed), corn silage (10 kg as fed), concentrate (2 kg as fed); the DMI was 12.1 kg and the CP content was 12% on DM.

For each hybrid, botanical part and vegetative stage Y replicates were obtained.

Statistical Analysis
Normal distribution of data was assessed using the Wilcoxon test. The analysis of variance was performed with the PROC GLM of the software statistic SAS using the following experimental model:

\[ y = \mu + \alpha + \varepsilon \]

where:
- \( y \) = dependent variable
- \( \mu \) = general mean
- \( \alpha \) = effect of the hybrid
- \( \varepsilon \) = experimental error

The regressions were carried out using the PROC REG of the software statistic SAS with the phonological stage as variation factor.

Table 5. Chemical composition of corn cob (% on DM basis) coming from four hybrids harvested in different vegetative stages.

| Vegetative stage | Hybrid  | SS    | CP    | NDF  | ADF  | ADFIp | ADL  |
|------------------|---------|-------|-------|------|------|-------|------|
| R2               | Simeto  | 23.93a | 5.24b | 71.82bc | 36.66b | 0.92  | 6.35a |
|                  | Eleonora| 20.51a | 6.42ab| 69.91abc| 33.11ab| 0.57  | 4.29a |
|                  | EA6601  | 29.09a | 4.77a | 67.57abc| 35.10ab| 0.36  | 4.65a |
|                  | Pampero | 22.52a | 5.01a | 64.77ab| 33.39a | 0.70  | 4.66a |
|                  | SE      | 1.368  | 0.412 | 1.182 | 0.935 | 0.227 | 0.223 |
| R4               | Simeto  | 45.42  | 3.00a | 67.69  | 33.20abc| 0.15b | 4.77a |
|                  | Eleonora| 45.11a | 3.88a | 65.96  | 30.71abc| 1.09b | 3.54a |
|                  | EA6601  | 50.21a | 3.25a | 68.25  | 34.30abc| 0.41a | 4.31a |
|                  | Pampero | 45.16a | 3.41a | 66.18  | 32.52abc| 0.41a | 4.34a |
|                  | SE      | 0.651  | 0.207 | 1.279  | 0.626 | 0.228 | 0.177 |
| R6               | Simeto  | 58.43a | 3.00a | 73.65a | 35.71a | 0.23  | 6.98a |
|                  | Eleonora| 62.58a | 3.29a | 75.17abc| 36.40a | 0.43  | 4.43a |
|                  | EA6601  | 63.17abc| 3.00a | 77.60abc| 39.26a | 2.10  | 5.54ab|
|                  | Pampero | 68.14a | 2.80a | 77.77abc| 39.34a | 0.12  | 5.62ab|
|                  | SE      | 1.250  | 0.211 | 0.845  | 0.564 | 0.680 | 0.695 |

A, B: P< 0.01; a, b, c: P< 0.05.
R2: Blister; R4: Dough; R6: Physiological maturity.

Results and discussion
There were no differences in plant popula-
Plant composition
The average DM content of plants of the 4 hybrids increased from 16.0% in the eight leaf stage to 34.0% in the dough stage, as reported in table 1.

At the eighth leaf vegetative stage, in the 4 hybrids the stalk represented 61.59% of the DM of the plant and decreased to 40.35% at the dough stage (Table 2) while the leaf apparatus decreased from 38.41% of the DM at the eighth leaf stage to 18.19% at the dough stage.

Table 6. *In vitro* digestibility of DM and NDF in different botanical parts of corn plant at different stage of maturity.

| Vegetative stage | Hybrid | Stalks | | Leaves | Cobs |
|------------------|--------|--------|------------------|--------|------------------|
|                  |        | IVDMD  | IVNDFD | IVDMD  | IVNDFD | IVDMD  | IVNDFD |
| V8               | Simeto | 78.43a | 55.04  | 79.81b | 57.96a | -      | -      |
|                  | Eleonora | 81.05a | 58.95  | 76.97a | 60.52ab | -      | -      |
|                  | EA6601 | 78.94a | 57.33  | 77.86ab | 63.05a | -      | -      |
|                  | Pampero | 79.74a | 57.23  | 76.41a | 58.82ab | -      | -      |
|                  | SE     | 0.622  | 1.299  | 0.874  | 1.567  | -      | -      |
| VT               | Simeto | 68.25a | 44.38  | 77.17  | 59.73  | -      | -      |
|                  | Eleonora | 71.73a | 48.68  | 77.27  | 59.88  | -      | -      |
|                  | EA6601 | 67.81a | 44.29  | 77.96  | 62.60  | -      | -      |
|                  | Pampero | 69.99a | 46.20  | 76.24  | 58.31  | -      | -      |
|                  | SE     | 1.045  | 1.864  | 1.412  | 2.523  | -      | -      |
| R2               | Simeto | 66.17a | 39.23  | 74.61  | 55.87  | 61.10ab | 45.84a |
|                  | Eleonora | 68.05a | 42.21  | 74.38  | 56.69  | 67.82ab | 53.97a |
|                  | EA6601 | 66.51a | 40.33  | 72.94  | 54.51  | 67.07ab | 51.26a |
|                  | Pampero | 70.70a | 41.77  | 74.57  | 55.39  | 68.20ab | 50.90a |
|                  | SE     | 1.094  | 2.067  | 1.132  | 1.940  | 1.522  | 2.211  |
| R4               | Simeto | 62.73a | 39.21  | 73.59  | 53.21  | 64.37  | 47.36  |
|                  | Eleonora | 61.63a | 39.14  | 73.12  | 55.14  | 68.23  | 51.83  |
|                  | EA6601 | 59.37a | 37.63  | 71.86  | 52.91  | 64.88  | 48.59  |
|                  | Pampero | 64.34a | 38.83  | 72.31  | 52.18  | 66.32  | 49.08  |
|                  | SE     | 1.736  | 2.853  | 0.680  | 1.180  | 1.280  | 1.911  |
| R6               | Simeto | 52.20a | 33.02  | 69.62  | 50.27  | 55.78a | 39.95  |
|                  | Eleonora | 52.51a | 35.09  | 69.06  | 50.40  | 54.58a | 39.57  |
|                  | EA6601 | 52.52a | 36.20  | 69.00  | 49.78  | 54.78a | 41.73  |
|                  | Pampero | 51.77a | 35.68  | 69.07  | 48.80  | 50.66a | 36.55  |
|                  | SE     | 1.328  | 1.806  | 1.060  | 1.741  | 1.530  | 2.017  |

A, B: *P* < 0.01; a, b: *P* < 0.05.

V8: 8° Leaf; VT: Tasseling; R2: Blister; R4: Dough; R6: Physiological maturity.

infection, infected ears, barren ears or broken plants. During the growing season a total of 104.6 mm of rain fall and there were 10.71 growing degree days or heat units.

The average DM content of plants of the 4 hybrids increased from 16.0% in the eight leaf stage to 34.0% in the dough stage, as reported in table 1.
stage of the cob and only 9.17\% in the physiological maturation stage (Table 2).

The sum of cob, husk and grain represented only 12.93\% of the DM of the plant at the tasseling and this raised to 41.47\% and 53.01\% respectively at the dough and physiological maturation stages.

The most interest comparison among the hybrids can be done at the dough stage (R4) is the most interesting. At this phenological stage 2 hybrids, Simeto and Pampero, presented a significantly higher stalk percentage (41.67\%, Simeto and 42.34\% Pampero P< 0.01) than for Eleonora (38.97\%) and EA6601 (38.44\%) (Table 2).

Eleonora hybrid had a higher leaf quota of (19.80\%) than the the other 3 hybrids (17.93\% Pampero, 17.60\% Simeto, 17.43\% EA6601).

The grain percentage in the EA6601 hybrid (31.89\%) was significantly higher than that of Pampero (26.46\%), Simeto (27.33\%) and Eleonora (27.88\%).

Greater leafiness of the plant results in a reduction of the stalk percentage which, as reported by Johnson et al. (1999) represents the fraction of the plant whose nutritional characteristics progressively worsen during the ripening phase.

**Chemical composition**

**Stalks**

The effect of the phenological stage on the content in fibrous components of stalks is very clear (Table 3). The average NDF value increases from 47.72\% (V8) to over 61\% at the dough stage of the corn (R4), going over 73.0\% at the physiological maturation stage (R6) (Table 3).

ADL levels, while low, double from 3\% DM at the herbaceous stage to 6.31\% DM at the dough stage (Table 3) in accordance with the normal values reported in the bibliography.

As reported by Johnson et al. (1999) this increase of levels of NDF and lignification corresponds with a progressive and exponential decrease in digestibility. In phase R4 the hybrid EA6601 is characterised by a higher ADF content (41.38\%; P<0.05) than Pampero (37.61\%) and Simeto (38.14\%) but not Eleonora (39.16\%); the NDF content (65.15\%) was different (P< 0.05) only from Pampero (58.31\%) which represents the lowest value (Table 3).

Low levels of ADL are observed for Eleonora (5.59\%), while EA6601 has the highest values (6.88\% DM) (Table 3).

For stalks there is no observable difference for ADF protein levels, while only Pampero is significantly different (P< 0.01) with a raw protein content of 4.91\% compared with the other hybrids which have values around 3\% (Table 3).

**Leaves**

The effect of the vegetative state on the content in fibrous fractions of leaves is much less evident than for stalks (Table 4). Only the ADL in leaves increases from values around 5\% in the first phase to around 8\% in the final three phases (Table 4).

In this case too, in period R4 (dough stage), EA6601 differs from the others hybrid (P<0.01) for its higher levels of ADL (9.35\%) and ADF (35.05\%), while the hybrids Eleonora and Pampero are characterised by lower values of ADL (P< 0.01) and ADF (7.90\%). Simeto presents the lowest value of ADF (31.39\%, P<0.01).

The effect of the phenological phase can also be observed in the protein content. In fact, in the first 3 vegetative states the protein value varies from values over 13.5\%, with peaks of 15.94\% in the second phase, falling in the dough stage (11.0\%) to reach a minimum of 7\% at physiological maturity (Table 4). There is no statistical difference observable between the hybrids. In the blister stage (R2) and after the dough stage, the Pampero hybrid presents higher proteic levels than the others, while at the dough stage these difference is true only for Simeto and EA6601 but not for the Eleonora hybrid. ADF values are low and in the dough stage the hybrid EA6601 has the highest values.
The particularly low values regarding ADF protein would suggest there is good availability of leaf proteins (Table 4).

Cobs
As observed in table 2 the cob percentage in the plant reaches 7.24% in the dough stage. The hybrid Eleonora had the lowest ADL content (3.54% P< 0.05) and ADF (30.71%) (Table 5) compared to the other hybrids. The cob is particularly fibrous, with an ADL content greater than that of the stalk. In the dough stage Eleonora shows the lower ADF and ADL content, and this lower fibre content is also observed at physiological maturity.

In vitro digestibility

IVDMD: effect of the phenological stage
As with all forages, the digestibility of the stalk portion of the corn silage declines rapidly with progressive maturity (Table 6). As reported by Russell (1986), the NSC and IVDMD of the corn stalk of a corn hybrid harvested at three maturity stages ranging from 3 week pre to 5 week post physiological maturity; decreased and was highly correlated to the ADF and ADL content.

For stalks an IVDMD average value of 79.54% was observed at the silking stage with a fall to 62.02% at the dough stage and 52.25% at physiological maturity (Table 6). Less evident is the effect of the stage of maturity in the leaves for which the IVDMD falls from 77.76% at the silking stage to 69.19% at physiological maturity (Table 4). For cobs, at the dough stage there is an IVDMD superior to that of stalks (65.95 % vs 62.02%).

At the dough stage statistical analysis of IVDMD data does not indicate significant differences between the hybrids for either stalks, leaves or cobs.

Digestibility of the DM in leaves and stalks is conditioned in a way substantially different from the stage of maturation, as can be saw in table 6.

Decline is stronger for the stalk (-34.3%) than for leaves (-11.03%) as also shown by the work of Xu et al. (1995), and this supports the choice, in the case of non BMR hybrids, of looking for the greatest leafiness of a plant. For both stalks and leaves there is a lack of statistical differences between the values of the 4 hybrids which is not surprising as they are not hybrids characterised by radically different genetic factors like the BMR.

The selective objectives for the production of corn silage are analogous and therefore represented by high stay-green of the plant, excellent corn production and slow dry-down of the ear.

Table 7. Average DM digestibility (%) estimated on the basis of IVDMD of individual botanical parts.

| Hybrid   | Vegetative stage |
|----------|------------------|
|          | V8   | VT   | R2    | R4    | R6    |
| Simeto   | 78.93 | 71.48 | 72.46a | 74.59 | 70.56 |
| Eleonora | 79.45 | 74.03 | 73.46a | 74.96 | 72.71 |
| EA6601   | 78.49 | 71.95 | 74.91b | 74.53 | 72.65 |
| Pampero  | 78.49 | 72.24 | 75.46c | 74.95 | 71.20 |
| SE       | 0.639 | 0.927 | 0.701  | 0.854 | 0.717 |

a, b: P< 0.05.
V8: 8° Leaf; VT: Tasseling; R2: Blister; R4: Dough; R6: Physiological maturity.
IVNDFD: effect of the phenological stage
At the dough stage values for stalks and leaves are rather different, oscillating around 38% for the former and a little above 50% for the latter (Table 6).

Cobs digestibility at phenological stages 3 and 4, with the plant still green, have a value of 50%, only slightly lower than that for leaves (Table 6).

For digestibility of the NDF too, there was no significant difference observable between the hybrids for this parameter, indicating a strong homogeneity among hybrids of analogous class and typology.

These results do not apparently concur with the observations of Kuehn et al. (1997), who reported an IVNDFD difference of around 10% in favour of “leafy” hybrids compared to “grain” hybrids in the stalks and around 8% in the leaves.

On this point it should be pointed out that the hybrids tested by this author are quite obsolete today (over ten years old) and very different from a commercial point of view.

The hybrids used in our study are of more recent constitution and are highly specialised for silage production, therefore it is not possible to divide them in two distinct groups “leafy” or “grain”.

Effect of botanical composition on in vitro digestibility
The data presented in table 6 are in accord with those reported by Kuehn et al. (1997) who reported a difference of around 10% in favour of “leafy” hybrids compared to “grain” hybrids in the stalks and around 8% in the leaves.

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The progressive increase of the quota of grain after the emergence of the ear completely invalidates the evaluation of the loss of nutritional value of the vegetative parts. In fact, in many studies that have compared different corn hybrids, significant differences in the digestibility of the DM or the NDF have been observed, which then do not correspond to real variations in milk production or ingestion (Kuehn et al., 1997).

These data highlight the conflict between grain development and stover quality associated with maturity of the corn plant.

These results are perfectly in accordance with the observations of Xu et al., (1995) which indicated that the percentage of grain determines an increase in the overall digestibility of the plant, even if in parallel with a reduction in the digestibility of the vegetative part. A similar finding was reported also by Johnson et al. (1999). Identification of corn hybrids that maintain stover quality while increasing grain content at advances stages of maturity could be a suitable strategy to improve corn silage quality.

The quantity of corn produced being equal it would therefore be recommended to select hybrids with maximum leafiness, as confirmed by the experiments of Thomas et al. (2001) and Ballard et al. (2001) who demonstrated that these hybrids, characterised by being larger, with greater leafiness and having stalks with thinner rinds, had a higher in vivo DM digestibility than traditional hybrids.

Theoretical IVDMD of the whole plant
Using the data obtained from the individual botanical parts, and hypothesizing a DM digestibility of grain of 98%, the theoretical digestibility of the whole plant was calculated and reported in Table 7. The only significant differences observed concern the R2 period and show a greater digestibility of the hybrids EA6601 and Pampero compared to Simeto, which in this phase is the genotype with the greatest stalk percentage.
Conclusions

The experiment has highlighted, quite clearly, the effects of maturation of the plant on the digestibility of DM and the NDF in the leaves and stalks of corn.

Although the 4 hybrids had different botanical composition, with difference in DM and NDF in vitro digestibility, no significant difference between the 4 hybrids has been detected in the theoretical whole plant digestibility. It can therefore be assumed that inside homogeneous FAO classes the selection objectives of different breeders has led to choosing very similar plants which can be mainly characterized by their potential for grain production.

It seems, therefore, that this parameter is the principal indicator of the quality of a hybrid to be used for silage, apart from physiological characteristics, such as stay-green and dry-down of the ear, which are the real difference between a silage-specialized hybrid and a grain hybrid.

The relationships between plant composition, digestibility and feed intake are complicated. As maturity advances, the lignification of the stalk increases and its digestibility declines, however proportion of grain and consequently of starch, increases with advancing maturity and this lead to a higher digestibility of whole plant and to an improvement of dry matter intake. The development of corn hybrids with high leafiness and low stalk lignification will be an important goal.

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