Turkish Journal of Veterinary & Animal Sciences

Volume 30 | Number 3 Article 9

1-1-2006

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Turk. J. Vet. Anim. Sci.
30 (2006) 331-336


Research Article

# Effects of Hybrid Type, Stage of Maturity, and Fermentation Length on Whole Plant Corn Silage Quality

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Received: 14.10.2005

**Abstract:** Two corn hybrids (conventional: CON; silage: SIL) were harvested at early dent (ED), $^1/_2$ milkline ($^1/_2$ ML), and black layer (BL) stages of maturity for testing the effects of hybrid, stage of maturity, and length of fermentation on corn silage quality. Tested parameters were pH, DM, CP, and ruminal in situ DM disappearance (ISDMD), respectively. Longer fermentation length caused lower silage pH at 8 (3.97) and 16 (3.93) weeks. While CP content tended to increase with longer fermentation length, it tended to decrease with increasing maturity stage (ED: 8.0%; BL: 7.2%). In situ DM disappearance was 4% higher for the SIL hybrid compared to CON hybrid (40.1% vs. 36.2%). Higher ISDMD was observed for ED (48.4%) and $^1/_2$ ML (42.8%) maturity stages compared to the BL maturity stage (23.5%). In conclusion, similar chemical composition, but higher ISDMD favored the SIL hybrid over CON hybrid. Based on chemical composition and ISDMD, the optimum harvesting stage in whole plant corn silage should be between ED and $^1/_2$ ML. In addition, for optimal pH, fermentation length should be between 8 and 16 weeks in whole plant corn silage.

Key Words: Hybrid, corn silage, stage of maturity, digestibility

## Hibrit Çeşidi, Olgunluk Derecesi ve Fermantasyon Uzunluğunun Mısır Silajı Kalitesi Üzerine Etkileri

**Özet:** İki farklı mısır silajı hibriti (Tane; T, Silajlık; S) erken sütlenme (ES), $^1/_2$ sütlenme ($^1/_2$ S) ve siyah katman (SK) olgunluk derecelerinde hasat edilmiştir. Her bir hibrit ve olgunluk derecesindeki mısır silajları sırasıyla 0, 1, 2, 4, 8, ve 16 haftalık sürelerde fermantasyona tabi tutulmuştur. Silaj kalite parametreleri sırasıyla pH, kuru madde (KM), ham protein (HP) ve ruminal in situ KM sindirilebilirliği olarak ölçülmüştür. Uzayan fermantasyon süresi optimum silaj pH değerini sağlamıştır (8 hafta = 3,97, 16 hafta = 3,93). Optimum silaj KM düzeyi her iki hibritte de ortalama olarak $^1/_2$ S olgunluk derecesinde oluşmuştur (% 36,4). In situ KM sindirilebilirliği S hibritinde T hibritine göre % 4 daha yüksek gözlemlenmiştir. Mısır silajlarında, fermantasyon uzunluğu ile in situ KM sindirilebilirliği arasında bir ilişki gözlemlenmezken (r = 0,15), ES (% 48,4) ve $^1/_2$ S (% 42,8) olgunluk derecelerinde, SK (% 23,5) olgunluk derecesine göre daha yüksek ruminal in situ KM sindirilebilirliği gözlemlenmiştir. Optimum pH ve HP içerikleri mısır silajlarında en az 8 haftalık bir fermantasyon uzunluğunun olması gerektiğini göstermiştir. Kimyasal kompozisyon ve in situ KM sindirilebilirliği, optimum hasat olgunluğunun ES ve $^1/_2$ S arasında olması gerektiğini göstermiştir.

Anahtar Sözcükler: Hibrit, mısır silajı, olgunluk derecesi, sindirilebilirlik

## Introduction

Corn silage has been used as one of the main roughage sources for lactating dairy cattle rations. Since whole plant corn consists of both grain and leafy portions, it contributes more digestible energy portions from starch and fiber than just the grain itself (1). In addition, corn silage exceeds other traditional forages (alfalfa and wheat straw) in terms of its digestible energy content. Previous research showed that the nutritive value of corn silage can be affected by genetic, agronomic, harvest, and preservation practices (2). These practices can also include hybrid selection, planting date, stage of maturity, and length of fermentation. All these factors can influence the digestibility of corn silage and, as a result, animal performance (3). Corn silage management starts with hybrid selection. Recently, the hybrid corn market has become specialized for specific agronomic response parameters rather than selecting

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hybrids for better animal performance. However, whole plant corn silage utilization is determined by the digestibility of its grain and stover fractions. Hunt et al. (4) reported that there was a 6.9 percentage unit in situ DM degradation difference within 6 different whole plant corn silage hybrids. Another important factor for corn silage quality is related to harvesting whole plant corn at the proper stage of maturity. This can affect whole plant and stover digestibility (5), as well as digestibility and milk production of dairy cows (3). Corn silage quality can also be affected by fermentation length. This is an important factor for lactic acid accumulation via substrate (soluble plant carbohydrates) utilization. Fisher and Burns (6) indicated that higher soluble plant carbohydrates result in higher lactic acid production and lower silage pH. This can be achieved with whole plant moisture as well as silage fermentation length.

The objectives of this study were to test the effects of corn hybrid type, maturity stage at harvest, and fermentation length on corn silage quality, in terms of pH, DM, CP, and ISDMD, using a macro in situ bag technique.

## Materials and Methods

Two commercially available corn hybrids (CON: Pioneer 3563, relative maturity of 105 d; SIL: Mycogen TMF 106, relative maturity of 106 d) were harvested as whole plant corn silage at ED, $^{1}/_{2}$ ML, and BL stages of maturity using a corn silage chopper set for a 0.93 cm theoretical length of cut. Each corn silage hybrid at each maturity stage was stored in duplicate 5-l capacity plastic jars. Treatment corn silages were stored for 1-, 2-, 4-, 8- and 16-week periods (except harvesting day treatment). Duplicate samples were analyzed for each treatment and results were averaged for analyzed treatment silages. Tested silage quality parameters were pH, DM, CP, and ISDMD.

Silage pH was measured by macerating 50 g of a sample with distilled water, filtering through 2 layers of cheese cloth, and then measuring with a pH meter. Treatment corn silages were analyzed for DM and CP (7) for each fermentation length. Ruminal ISDMD was conducted with 2 ruminally cannulated multiparous Holstein cows in mid-lactation. Cows were fed a total mixed ration containing 50% forage ($^{1}/_{3}$ alfalfa silage + $^{2}/_{3}$ corn silage; DM basis) and 50% concentrate mix comprised of ground corn and soybean meal (DM basis). Dacron polyester cloth (25 x 35 cm; 52 ± 5 µ pore size) was used as in situ bag material. Twenty-five grams of DM (approximately 65-85 g as fed) for respective corn silages were incubated in duplicate bags within each cow for 24 h. Bags were placed in a nylon laundry bag (30 x 40 cm) and placed in the ventral rumen. Six sample bags (2 hybrids at 3 maturity stages) for each fermentation length were placed into the laundry bag. Two blank bags were also incubated in each laundry bag for correcting any DM infiltration into the sample bags. After 24 h incubation, the laundry bag was removed and soaked in cold water and then washed twice with cold water to resume further DM degradation (8). Bags were dried at 60 °C for 48 h to determine DM disappearance.

Data were analyzed using GLM procedure of SAS (9) with cow by treatment interaction as the error term. Hybrid type, maturity stage, and fermentation length were used as main effects. Their interactions were also included in the model to test possible combined effects on silage quality parameters. Treatment comparisons were made by the least significant difference method (9).

## Results

Hybrid effect on whole plant corn silage quality is presented in Table 1. Dry matter content was higher ($P < 0.01$) for the CON hybrid than for the SIL hybrid. Both hybrids had lower and higher DM content at ED and BL stages of maturity, respectively (hybrid x maturity interaction). Crude protein content was higher for the CON hybrid than for the SIL hybrid ($P < 0.01$). Neither hybrid nor hybrid x length and hybrid x maturity interactions were significant for silage pH, and averaged 4.39 for both hybrids. Higher ISDMD was observed for the SIL hybrid than for the CON hybrid ($P < 0.01$).

The effect of stage of maturity on corn silage quality is presented in Table 2. There was an increasing trend for DM as the whole plant corn silage matured. Crude protein content decreased linearly ($P < 0.01$) as whole plant corn silage maturity increased from ED to BL. Lower pH content was observed for ED and $^{1}/_{2}$ ML maturity stages compared to BL maturity stage ($P < 0.01$). There was a maturity x length interaction ($P = 0.02$) for pH, with pH content decreasing as fermentation length increased from 1 week to 2, 4, 8, and 16 weeks for each maturity stage (data not shown). There was a linear decrease for ISDMD

Table 1. Chemical composition and in situ DM disappearance of whole plant corn silage according to hybrid type[1].

| Parameter | Hybrid Type | | | Effect (P-value) | | |
|---|---|---|---|---|---|---|
| | CON[2] | SIL[3] | SEM[4] | H[5] | HxL[6] | HxM[7] |
| DM | 39.3[a] | 38.7[b] | 0.1 | < 0.01 | NS[8] | < 0.01 |
| CP | 7.82[a] | 7.32[b] | 0.05 | < 0.01 | NS | NS |
| pH | 4.38[a] | 4.40[a] | 0.01 | NS | NS | NS |
| ISDMD[9] | 36.2[b] | 40.1[a] | 0.7 | < 0.01 | NS | NS |

[1]Means in same row with different letters differ
[2]CON: Conventional hybrid
[3]SIL: Silage hybrid
[4]SEM: Standard error of mean
[5]H: Hybrid
[6]HxL: Hybrid fermentation length interaction
[7]HxM: Hybrid maturity stage interaction
[8]P > 0.05
[9]ISDMD: In situ DM disappearance

Table 2. Chemical composition and in situ DM disappearance of whole plant corn silage at 3 different stages of maturity[1].

| Parameter | Stage of Maturity | | | | Effect (P-value) | | |
|---|---|---|---|---|---|---|---|
| | ED[2] | 1/2 ML[3] | BL[4] | SEM[5] | M[6] | MxH[7] | MxL[8] |
| DM | 30.8[c] | 36.4[b] | 49.8[a] | 0.2 | < 0.01 | < 0.01 | < 0.01 |
| CP | 8.04[a] | 7.44[b] | 7.24[c] | 0.06 | < 0.01 | NS[9] | NS |
| pH | 4.15[b] | 4.20[b] | 4.82[a] | 0.02 | < 0.01 | NS | 0.02 |
| ISDMD[10] | 48.4[a] | 42.8[b] | 23.5[c] | 0.9 | < 0.01 | NS | NS |

[1]Means in same row with different letters differ
[2]ED: Early dent
[3]1/2 ML: 1/2 milkline
[4]BL: Black layer
[5]SEM: Standard error of mean
[6]M: Maturity
[7]MxH: Maturity x hybrid interaction
[8]MxL: Maturity x fermentation length interaction
[9]P > 0.05
[10]ISDMD: In situ DM disappearance

as maturity progressed (P < 0.01). This was more pronounced between 1/2 ML and BL stages of maturity.

The effect of fermentation length on whole plant corn silage quality parameters is presented in Table 3. There was no significant difference for DM content across the all fermentation lengths; however, whole plant corn DM content was 1 percentage unit higher before fermentation when compared to all fermentation lengths (P = 0.05). There was a linear increase in CP content as fermentation length progressed from 0 to 16 weeks (P < 0.01). This trend was more evident at 16 weeks. Extending the fermentation length caused a linear

Table 3. Chemical composition and in situ DM disappearance of whole plant corn silage fermented for various fermentation lengths[1].

| Parameter | Fermentation Length (week) | | | | | | Effect (P-value) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 4 | 8 | 16 | SEM[2] | L[3] | LxH[4] | LxM[5] |
| DM | 39.7$^{a}$ | 38.9$^{b}$ | 39.2$^{ab}$ | 38.9$^{b}$ | 38.7$^{b}$ | 38.6$^{b}$ | 0.2 | 0.05 | NS[6] | < 0.01 |
| CP | 7.20$^{c}$ | 7.40$^{bc}$ | 7.54$^{b}$ | 7.76$^{ab}$ | 7.70$^{ab}$ | 7.82$^{a}$ | 0.08 | < 0.01 | NS | NS |
| pH | 6.05$^{a}$ | 4.23$^{b}$ | 4.08$^{c}$ | 4.09$^{c}$ | 3.97$^{d}$ | 3.93$^{d}$ | 0.02 | < 0.01 | NS | 0.02 |
| ISDMD[7] | 38.1$^{b}$ | 34.5$^{c}$ | 40.2$^{ab}$ | 36.8$^{bc}$ | 36.2$^{bc}$ | 43.0$^{a}$ | 1.3 | < 0.01 | NS | NS |

[1]Means in same row with different letters differ
[2]SEM: Standard error of mean
[3]L: Fermentation length
[4]LxH: Fermentation length x hybrid interaction
[5]LxM: Fermentation length x maturity interaction
[6]P > 0.05
[7]ISDMD: In situ DM disappearance

decrease in pH (P < 0.01). This was more evident within the first week of fermentation (6.05 vs. 4.23). Although variable ISDMD results were observed across all fermentation lengths, the lowest and highest values were observed for 1- and 16-week fermentation lengths (34.5% vs. 43.0%), respectively.

## Discussion

The higher DM content of CON whole plant corn silage was also observed by others (2,10). Bal et al. (10) tested CON (35.9%) and SIL (37.4%) hybrids for their chemical composition and found 3.5% DM difference at ½ ML maturity stage. In the present study, this difference was much lower than the previous results at the same maturity stage (36.9% vs. 35.8% for CON and SIL, respectively). There was an increased trend for DM content of treatment corn silages for both hybrids as maturity progressed from ED to BL (hybrid x maturity interaction). Previous research (2,11) showed that the hybrid of corn silage had an impact on DM concentration of various plant parts and that the DM content of leaves, ear, husk, stalk, and stover are affected by hybrid and maturity interactions. Johnson et al. (2) compared the DM content of CON and SIL hybrid silages and found 8.7% higher DM in CON (41.8%) compared to SIL (33.1%) at ½ ML stage of maturity. Although there was a higher CP content for CON compared to the SIL hybrid in the present study, others (10,12) did not find any difference between CON and SIL hybrids. This was true only at ½ ML and BL maturity stages, but there was higher CP content for CON (8.7%) compared to the SIL hybrid (8.0%) at ED maturity stage. It was clear that higher ISDMD for SIL compared to CON was also confirmed by others using different digestibility methods (10,13). Kuehn et al. (13) found 2.4% higher in vitro DM digestibility difference between SIL (69.2%) and CON (66.2%) hybrids. In addition, Bal et al. (10) found 1.9% higher ISDMD for SIL (58.8%) compared to CON (56.9%). The higher ISDMD for SIL could be related to more readily available nutrients for this hybrid such as starch. Dwyer et al. (14) indicated that increased nutrient digestibility for the SIL hybrid may be related to increased whole plant moisture or reduced kernel hardness compared to the CON hybrid. It is evident that as whole plant corn matures DM content becomes significantly higher (Table 2). There was a 19% difference as maturity progressed from ED to BL. This trend has been reported by others (15,16) and is possibly due to kernel development resulting from the remobilization of soluble carbohydrate reserves from the stover. Although DM content of treatment corn silages did not change for ½ ML and BL maturity stages as the fermentation length progressed, there was a declining DM trend for ED maturity stage as fermentation length progressed (maturity x length interaction; data not shown). Declining CP content as maturity stage progresses for both hybrid corn silages could be related to the photosynthesis rate of whole plant and being lower as the plant matures (17). Lower pH for ED and $^{1}/_{2}$ ML corn silages was possibly due to high concentrations of water soluble carbohydrates and more extensive fermentation (6). Extensive fermentation was more evident as fermentation length progressed from 0 to 16 weeks for ED, $^{1}/_{2}$ ML, and BL maturity stages (maturity x length interaction). Lower ISDMD for BL maturity stage of whole plant corn silage was also observed by others for in situ (10), in vitro (5), and in vivo (3) studies. This reduction in DM disappearance for BL compared to both ED and $^{1}/_{2}$ ML could be explained by lower digestibility of CP, fiber, and starch for this treatment. As the whole plant corn matures, it is affected by a more mature stover portion (low fiber digestibility) and whole kernel passage (low starch digestibility) for its nutritive value.

As fermentation is started by harvesting whole plant corn, DM content of silage is reduced due to active plant enzymes and aerobic bacteria on the surface of the material. Harvesting whole plant corn at early maturity stages causes a higher rate of respiration, which lowers the content of water-soluble carbohydrates. In the present study, this was more pronounced for ED maturity stage (length x maturity interaction) in which DM content was 33.3% and 29.2% at 0 and 16 weeks of fermentation, respectively (data not shown). Due to the rapid growth of lactic acid bacteria after the plant material is harvested, a rapid drop in pH occurs during ensiling periods (18). Interestingly, the rapid drop in pH occurred right after the plant material was harvested, due to the release of plant juices and enzymes, which allowed the rapid growth of lactic acid bacteria. Although there are no available data for showing the relationship between fermentation length and nutrient degradability of whole plant corn silage, our data indicated that longer fermentation periods may result in greater ISDMD. This could be related to higher availability of other nutrients that are more digestible with acidic fermentation, especially starch in the grain portion of whole plant.

In conclusion, higher ISDMD results for SIL hybrid over the CON hybrid should be considered when selecting alternative corn hybrids for silage production. The appropriate maturity stage for harvesting whole plant corn silage should be between ED (30% DM) and $^{1}/_{2}$ ML (35% DM) for optimal silage chemical composition. In addition, the suggested maturity should be $^{1}/_{2}$ ML if silage is not mechanically processed. Based on the appropriate pH of corn silages, fermentation length should be between 8 and 16 weeks.

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