Comparison of yield, nutritive value, and in vitro digestibility of monocrop and intercropped corn-soybean silages cut at two maturity stages

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Abstract

Limited information on nutrient composition and in vitro digestibility of corn-soybean intercropped silage is available. The objective of this study was to compare corn (Zea mays L.) or soybean (Glycine max L. Yesilsoy) monocrop silage with corn-soybean intercropped silages in terms of yield, nutritive value, and in vitro digestibility. Intercropping was as follows: 1 row corn to 1 row soybean (1M1S), 1 row corn to 2 rows soybean (1M2S) and 2 rows corn to 1 row soybean (2M1S). The crops were harvested when the corn reached 3/5 or 1/4 milk line. The silage samples were analysed for pH, dry matter (DM), crude protein (CP), ether extract (EE), neutral (NDF) and acid detergent fibre (ADF), calcium, potassium, magnesium and phosphorus. Also, in vitro true digestibility (IVTD) and in vitro NDF digestibility were determined in the silages samples. The DM, EE, and NDF values were higher in silage harvested at 1/4 than 3/5 milk line. All intercropped silages had higher CP values (1M1S, 8.3%; 1M2S, 10.1%; 2M1S, 8.0%) than the monocrop corn (SM, 6.8%) silage. The NDF and ADF levels were higher for 1M1S, 2M1S and SM compared with 1M2S and monocrop soybean (SS) silage. In vitro true DM digestibility of all silages increased with maturity stage; it was higher for the 1M2S than other silages. It is concluded that corn-soybean intercropped silage has better nutrient composition and digestibility than SM or SS silage.

Introduction

Because of high yield in a single harvest, simplicity for ensiling and high energy value (net energy for lactation=1.45 Mcal/kg) corn silage is a major forage source for dairy cows throughout the world (National Research Council, 2001; Guadarrama-Estradal et al., 2007). Comparing with legume silage (Anil et al., 2000), it is poor in protein content (8.8%) (National Research Council, 2001). On the other hand, legume material is highly difficult to ensile because of its high buffering capacity and low level of water soluble carbohydrate (Maasdorp and Titterton, 1997). Therefore, protein-rich legume and high-energy corn silage can be ensiled to form better nutrient composition (Anil et al., 2000). As a cultivation system, intercropping involves the planting of two or more crop species on the same field (Kipkemoi et al., 2010; Costa et al., 2012). Intercropping has several advantages such as higher total yield and improved soil conservation, better utilisation of water and light (Akinlade et al., 2003; Costa et al., 2012). Moreover, intercropping with legumes for silage is a feasible strategy to improve crude protein (CP) level (Prasad and Brook, 2005; Costa et al., 2012; Contreras-Govea et al., 2009; Zhu et al., 2011). Compared with the ensilage of monocrop corn (SM), intercrops of corn and legumes for silage have higher CP, fibre and lactic acid concentrations (Contreras-Govea et al., 2009; Zhu et al., 2011).

Because of optimum nutritive composition, predicting the best harvest time of intercropping is an important issue in intercropped silage (Salawu et al., 2001). Salawu et al. (2001) reported that level of potentially digestible nutrients is an appropriate measure of forage quality. However, limited information on nutrient composition and in vitro digestibility of corn-soybean intercrop silage is available. Therefore, the objective of this study was to evaluate the yield, nutritient composition and in vitro digestibility of corn intercropped with soybean in comparison with SM or monocrop soybean (SS) silages.

Materials and methods

Crop production and silage preparation

The crops were produced during the second crop growing season in summer 2010 at the Eastern Mediterranean Agricultural Research Institute (36°51’18” latitude N, 35°20’49” longitude E) in Adana, Turkey. The crop production was a split plot design in a randomised complete block design replicated four times. The main plots represented intercropped and monocrop silages, whereas, maturity was assigned to the sub plots. It was determined that soil contained 7.7 pH, 20% lime, 2% organic matter, 28% sand particle, 31% clay, and 41% silt. Fields were fertilised according to the soil test results and were cultivated before planting. Corn (Zea mays L. Pioneer 31Y43) and soybean (Glycine max L Yesilsoy) were seeded as monocrop (SM and soybean (SS) or intercropped as follows: 1 row corn to 1 row soybean (1M1S), 1 row corn to 2 rows soybean (1M2S) and 2 rows corn to 1 row soybean (2M1S). The SM and SS were spaced at 70 cm×15 cm and 70 cm×5 cm with population of about 95,240 and 285,710 plants per hectare, respectively. The crops were planted at the end of June and harvested (FX40 New Holland) when the corn reached 3/5 kernel milk line (in early September) or 1/4 kernel milk line (mid September) of maturity according to Aflakwa and Crookston (1984). Mean, maximum and minimum daily air temperatures were 28, 33, and 22°C respectively, and precipitation was 776 mm during the crop production.

Botanical composition of the intercrops was estimated by hand-clipping six different areas (1.0 m×0.5 m) per field before each harvest,
Forage and dry matter yields of monocrop and intercropped corn-soybean silages.

Table 2. Botanical composition in the intercropped corn-soybean silages (values expressed as fresh).

| Silages   | Maturity | Corn, % | Soybean, % |
|-----------|----------|---------|------------|
| 1M1S      | 1        | 68.2    | 31.8       |
| 2         | 66.3     | 33.7    |
| 1M2S      | 1        | 60.1    | 39.9       |
| 2         | 51.8     | 48.2    |
| 2M1S      | 1        | 82.2    | 17.8       |
| 2         | 79.2     | 20.8    |

1M1S, 1 row corn to 1 row soybean; 1M2S, 1 row corn to 2 rows soybean; 2M1S, 2 rows corn to 1 row soybean; 1, at 3/5 kernel milk line; 2, at 1/4 kernel milk line.

In vitro digestibility

The ground samples were exposed to in vitro digestion using ANKOM DAISY II incubator (Ankom Technology Corporation, Fairport, NY, USA) using the method outlined by Goering and Van Soest (1970). Briefly, approximately 0.50 g of each silage was weighed into separate Ankom F57 filter bags. The bags were placed in digestion jars. Two buffer solutions were warmed to 39°C before setting up each in vitro digestion. The solutions were mixed in a 5:1 ratio, and 1800 mL of the mixed buffer solution was added to digestion jars. Digestion jars were sealed and placed in the preheated incubator for 24 min, allowing the temperatures of the incubator and vessels to equilibrate to 39°C.

Rumen liquor was collected from two ruminally cannulated infertile Holstein heifers (approximately 350-400 kg live weight) 2 h after morning feeding. The heifers were fed a corn silage-based diet at maintenance level [dry matter (DM) basis; 2.1 Mcal/kg metabolizable energy, 10% CP, 32% NDF]. The rumen liquor was strained through four layers of cheesecloth before mixing with the buffer solution. After 48 h, the bags were removed from the digestion jars, rinsed and, then placed in an ANKOM 200/220 Fibre Analyzer (Ankom Technology Corporation). Digesta samples were exposed to NDF extraction. In vitro true DM digestibility and in vitro NDF digestibility (IVNFD) were calculated as described by Thomas et al. (2001).

Statistical analysis

Data were analysed using the PROC MIXED procedure of SAS (2000). The statistical model included maturity, silages and the maturity x silages interaction. Excepting K and ash values for nutritional composition of monocup and intercropped silages, nonsignificant interactions were found for all variables. Therefore the interactions were removed from the model. Kenward-Rogers adjustment was used for calculation of denominator degrees of freedom. Pre-planned contrasts were used to compare yield, nutritive value, and in vitro digestibility of silages. The contrast were as follows: SM vs SS (C1), SM vs intercropped silages (C2), SS vs intercropped silages (C3), 1M1S vs 1M2S (C4), 1M1S vs 2M1S (C5), 1M2S vs 2M1S (C6). All results are reported as least squares means. In statistical analyses, P≤0.05 was taken as the level of significance and P>0.10 was considered to indicate a tendency.

Results and discussion

In the intercropped silages, the proportion of corn declined while soybean proportion increased (Table 1). The lowest percentage of corn (51.8%) was observed in 1M2S silage at 1/4 milk line. On the other hand, the highest percentage of corn (82.2%) was observed in 2M1S silage at 3/5 milk line. Soybean proportion was lowest (17.8%) for 2M1S silage and increased as the maturity progressed.

The maturity stage did not (P>0.05) affect fresh forage, and DM yields ranged from 29.9

Table 2. Forage and dry matter yields of monocrop and intercropped corn-soybean silages.

| Yield        | Maturity | Silages     | SEM | Maturity | C1   | C2   | C3   | C4   | C5   | C6   |
|--------------|----------|-------------|-----|----------|------|------|------|------|------|------|
| Forage, t/ha | 1        | 46.9        | 29.9| 41.1     | 39.3 | 40.8 | 2.71 | ns   | ***  | **   |
|              | 2        | 42.7        | 32.5| 36.3     | 38.3 | 40.0 |     |      |      |      |
| DM, t/ha     | 1        | 11.4        | 5.8 | 10.0     | 10.2 | 9.6  | 0.89 | ns   | **   | ***  |
|              | 2        | 12.0        | 7.8 | 10.1     | 10.9 | 11.4 |     |      |      |      |

SM, monocrop corn; SS, monocrop soybean; 1M1S, 1 row corn to 1 row soybean; 1M2S, 1 row corn to 2 rows soybean; 2M1S, 2 rows corn to 1 row soybean; C1, at 3/5 kernel milk line; 2, at 1/4 kernel milk line; DM, dry matter. **P<0.01; ***P<0.001; ns, not significant.
to 46.9 t/ha and 5.9 to 12.0 t/ha (Table 2). Monocrop corn had a higher forage yield (average of harvesting times: 44.8 t/ha) than SS (average of harvesting times: 31.2 kg/ha; contrast C1; P<0.01) and of all intercropped silages (average of harvesting time: 39.3 kg/ha; contrast C2; P<0.05). Similar response was observed in DM yield except for comparison SM with intercropped silages (contrast C2; P<0.10).

Fresh forage and DM yields were higher in SM silages, followed by three intercropped silages and the SS silage. Several researchers have reported variable results of intercropping systems. Geren et al. (2008) indicated that intercropped corn with cowpea (Vigna unguiculata) and bean (Phaseolus vulgaris) produced higher DM yield than SM. On the other hand, Maasdorp and Titterton (1997) reported that because of tall and leafy structure, corn in row intercropping had a marked depressing effect on legume growth. Competition and unequal use of environmental or underground resources, such as light and water, seem to account for problems experienced on intercropped communities. These imbalances may have negative effects (for example reduced leaves or leaf area index) on crop yield (Chui and Shibles, 1984; Esmail, 1991).

Nutrient value of silages is given in Table 3. The maturity stage did not affect pH and CP content of silages. Silages harvested at 1/4 milk line had higher DM, EE, and NSC (P<0.01 for all). Also, there was a trend for increased P in association with maturity (P<0.10). On the other hand, NDF, ADF, ash, Ca, K, and Mg contents were decreased with maturity (P<0.05).

There were significant differences between monocrop silages (SM and SS) and intercrop silages in pH (P<0.01), SM having the lowest pH (3.8). The DM contents differed (P<0.01) between the silages and the 1M2S silage had the highest DM value (27.1%). The highest CP (13.3%) and EE (2.2%) contents were determined in the SS. When compared to SM, the inclusion of soybean as an intercrop increased CP and EE contents (P<0.01), whereas decreased NDF (P<0.01), ADF (P<0.05), and ash (P<0.01) contents. Also, Ca, K, and Mg in the intercrop silage were higher (P<0.01) than SM. The P concentration was similar (P>0.10) between all silages with the one exception being monocrop SM and SS (P<0.10).

The high pH of SS and 1M2S silages may be due to the buffering effect of soybean (Mugweni et al., 2000). Legumes may result in relatively high pH values in the silages. The pH values achieved in this study seem to suggest that when the soybean is mixed with corn, which has high levels of fermentable carbohydrates (Bal et al., 1997), the buffering effect is reduced and desirable pH levels are achieved. Also, these findings confirm the technical feasibility of intercropped corn-soybean silages.

The DM contents of the silages were between 20 and 29%. McDonald et al. (1987) suggested that optimum DM range of ideal corn silage is between 28 and 32%. Especially, the silages harvested at 1/4 milk line presented higher DM levels than the silages harvested at 3/5 milk line. Costa et al. (2012) reported that the DM level was related to the fermentation conditions of the material and to the levels of loss in the systems.

One of the main objectives of intercropped silage is to obtain a complementary effect of the desirable nutrient characteristics of two or more crops. In the present study it was deter-

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Table 3. Nutrient composition of monocrop and intercropped corn-soybean silages (dry matter basis).

| Nutrient composition | Maturity | Silages | SEM | Maturity | C1 | C2 | C3 | C4 | C5 | C6 |
|----------------------|----------|---------|-----|----------|----|----|----|----|----|----|
|                      | SM       | SS      | 1M1S | 1M2S     | 2M1S |     |     |    |     |     |
| pH                   | 1        | 3.8     | 5.5  | 4.0       | 4.1  | 3.9 |     | 0.08 | ns  | *** | *** | *** | ns      | ns  | **     |
| DM, %                | 1        | 24.4    | 19.7 | 24.4      | 25.8 | 23.6 |     | 1.05 | *** | *** | ns  | *** | ns      | ns  | ns     |
| CP, %                | 1        | 6.7     | 11.3 | 8.2       | 10.3 | 8.3 |     | 0.48 | ns  | *** | *** | *** | ***      | *** | NS     |
| EE, %                | 1        | 1.1     | 1.9  | 1.3       | 1.5  | 1.2 |     | 0.14 | *** | *** | *** | *** | **       | ns  | ns     |
| NDF, %               | 1        | 53.9    | 43.4 | 49.7      | 45.0 | 49.5 |     | 1.25 | *** | *** | *** | *** | ns      | ns  | ns     |
| ADF, %               | 1        | 30.6    | 29.9 | 28.1      | 25.5 | 27.9 |     | 2.34 | *** | ns  | *** | *** | ***      | *** | ns     |
| NSC, %               | 1        | 31.2    | 31.6 | 34.1      | 36.5 | 34.0 |     | 0.55 | *** | ns  | ns  | ns  | ns      | ns  | ns     |
| Ash, %               | 1        | 7.2     | 11.9 | 6.6       | 6.6  | 7.0 |     | 0.23 | *** | *** | *** | *** | ns      | ns  | ns     |
| Ca, %                | 1        | 0.31    | 0.65 | 0.35      | 0.39 | 0.35 |     | 0.02 | *** | *** | *** | *** | ns      | ns  | ns     |
| K, %                 | 1        | 2.4     | 3.4  | 2.5       | 2.5  | 2.4 |     | 0.05 | *** | *** | *** | *** | ns      | ns  | ns     |
| Mg, %                | 1        | 0.18    | 0.24 | 0.20      | 0.23 | 0.20 |     | 0.01 | ** | *** | *** | *** | ns      | ns  | ns     |
| P, %                 | 1        | 0.30    | 0.32 | 0.31      | 0.32 | 0.31 |     | 0.01 | ns  | ns  | ns  | ns  | ns      | ns  | ns     |

SM, monocrop corn; SS, monocrop soybean; 1M1S, 1 row corn to 1 row soybean; 1M2S, 1 row corn to 2 rows soybean; 2M1S, 2 rows corn to 1 row soybean; C1, SM vs SS; C2, SM vs 1M1S+1M2S+2M1S; C3, SS vs 1M1S+1M2S+2M1S; C4, 1M1S vs 1M2S; C5, 1M2S vs 2M1S; C6, at 3/5 kernel milk line; 2, at 1/4 kernel milk line; DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; ADF, acid detergent fibre; NSC, non structural carbohydrates [calculated as 100-(CP+EE+NDF+ash)]; ***P<0.01; **P<0.05; ns, not significant.
mained that average protein value of intercropped silages was higher (29%) than SM silage. Legumes are rich in protein. Anil et al. (2000) reported that intercropping corn with a variety of protein-rich forages could increase silage CP level by 3-5% and improve N digestibility, indicating a potential to reduce the requirement for purchased protein supplements. In addition, previous researches have shown that CP concentration increases when the proportion of corn decreases or legumes increase in the mixture (Maasdorp and Titterton, 1997; Contreras-Govea et al., 2009). However, it should be noted that CP levels of corn and soybean grown as monocrop were low because of second crop production and high environmental temperature during growing months.

The NDF contents of the silages varied from 39 to 54% and decreased with the percentage of soybean increased in the mixture. The presence of leguminous plants in the ensiled mass affected NDF and ADF levels in the present study. There is usually lower concentration of fibres in the DM of legumes in relation to grasses (Costa et al., 2012). In addition, NDF level is related to the maturity stage of the forage sources, because of levels of cell wall components, chiefly the cellulose, hemicellulose, and lignin (Mugweni et al., 2000). However, such an effect had not been observed in other experiments and found no effect of intercropping on the NDF and ADF level (Costa et al., 2012).

When comparing SM and intercropped silages, it is evident how these last had higher content of Ca and Mg. Paulson et al. (2008) reported that legumes had more total macro and micro minerals and ash than grasses. For example, legumes contain 2 to 3 times Ca than in grasses (Paulson et al., 2008). This result is in agreement with the current study.

Table 4 summarises the in vitro true digestibility (IVTD) of all silages increased (P<0.01) with maturity and value for the 1M2S was the highest (68.1%) at 1/4 milk line. However, NDF digestibility of the silages was decreased (P<0.01) by the stage of maturity. At the 3/5 milk line stage, NDF digestibility of silages was 42.8% while that value was 35.4 at 1/4 milk line stage. There was a trend for increased IVTD in association with intercropping (P<0.10).

Also, increased proportion of soybean in the intercrop silage increased (P<0.05) IVTD. No significant difference in NDF digestibility was observed between corn and intercropped silage. The lowest NDF digestibility (35.5%) was observed in SS. In addition, intercropped silages had higher NDF digestibility (P<0.01) than monosil DPs.

True DM of the silages were improved with maturity. This effect may result in increased soybean ration in mixture. Murphy et al. (1984) reported a more adequate protein for rumen bacteria when sheep are fed corn-faba bean silage rather than corn silage. On the other hand, no significant differences in these parameters were observed between SM and intercropped silages. Zhu et al. (2011) reported that in vitro DM and NDF digestibility were similar among silages made from the vine peas, corn, and mixtures.

Conclusions

Intercropped corn with soybean increased CP, and decreased NDF and ADF concentration in silages. The optimum time for harvesting intercropped silage could be at 1/4 kernel milk line stage of corn. However, for high yield, SM silage is recommended. Finally, among all intercropped silages the 1M2S (1 row corn to 2 rows soybean) was preferable according to nutrient composition than other intercropped silage. Therefore it may be an alternative to SM silage in nutrition of ruminants. In vivo studies are needed for further confirmation.

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