The potential of forage–maize intercrops in ruminant nutrition

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Abstract

Studies at the University of Reading (UK) compared silage quality, feed intake and digestibility of maize silage with maize–sunflower (MS), maize–kale (MK) and maize–runner bean (MRB) silage, when sunflowers, kale and runner beans represented 26, 7 and 16% of total silage dry matter (DM). All intercrop silages had higher crude protein values (MS, 137 g kg\(^{-1}\), MRB, 120 g kg\(^{-1}\), MK, 105 g kg\(^{-1}\)) than maize (81 g kg\(^{-1}\)). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were higher and the neutral cellulase gamminase digestibility (NCGD) values lower for MRB and MS compared with maize and MS silage. All silages fermented well with pH ranging from 3.9 to 4.2 and ammonia-N content of less than 100 g kg\(^{-1}\) total nitrogen (TN). An in vivo digestibility study with sheep showed no significant difference in voluntary feed intake between the four silages, with the highest and lowest values of 68 and 62 g DM (kg BW\(^{0.75}\))\(^{-1}\) per day being recorded for MK and MS silage. The highest and lowest values for in vivo DM digestibility (DMD) and organic matter digestibility (OMD) were recorded for MK and MS silages, with intermediate values for maize and MRB silage. The inclusion of all three intercrops significantly increased nitrogen digestibility when compared with maize silage. The metabolisable energy values for maize and MK silage were both substantially higher than those recorded for MRB and MS silage.

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1. Introduction

Although grass remains the primary forage crop in the UK, forage maize has become a major constituent of ruminant rations in recent years. Studies have shown that its inclusion in dairy cow diets can improve forage intake, increase animal performance and
has the potential to reduce production costs (Phipps, 1994). Although cereal-based forages have a high energy content they are low in crude protein (CP), when compared with grass silage which they often replace, and therefore require additional protein supplementation for milk or meat production. Legumes have long been recognised as a good source of CP and other protein-rich forages such as kale (Brassica oleracea) are gaining popularity. Protein-rich forages can be ensiled and used to complement high-energy maize silage. The existing practice is to grow these crops separately and mix them at the time of feeding. Instead of growing these crops separately, the possibility exists to grow them together in intercrops.

Intercropping may offer one way of increasing forage protein, the principle being improvement of forage quality through the complementary effects of two or more crops grown simultaneously on the same area of land. Intercropping of cereals with legumes or any other protein-rich fodder may increase overall protein content even though the additional biomass from such intercropping may be small. Other advantages of intercropping for forage production have been reviewed by Anil et al. (1998). Moreover, the use of cereal–legume combinations may be attractive to organic meat or milk producers. This paper evaluates the silage quality, feed intake and in vivo digestibility of maize–sunflower (MS), maize–kale (MK) and maize–runner bean (MRB) silage combinations in comparison to maize silage.

2. Materials and methods

2.1. Silage preparation and experimental design

The seed rates (seeds ha⁻¹) were: maize 100,000, MK 100,000 + 200,000, MRB 100,000 + 50,000 and MS 100,000 + 25,000. Prior to harvesting the field plots (220 m × 27 m) with a self-propelled maize harvester in late September 1997, six samples (1 m × two rows) were taken randomly from within each plot to estimate the contribution of the intercrop. Kale, runner beans and sunflowers represented 7, 16 and 27% of total dry matter (DM) yield. Approximately 900 kg of fresh forage from each treatment were ensiled in nine plastic barrels. Following a minimum of 90 days fermentation, two 300 g samples of silage were taken prior to feeding, from each barrel, bulked and subsequently analysed for DM, pH, volatile fatty acids (VFA), lactic acid, ethanol and ammonia-N (NH₃-N g/kg total nitrogen (TN)). Oven-dried samples were hammer milled through a 1 mm screen and analysed for total ash (TA), CP, neutral detergent fibre (NDF), acid detergent fibre (ADF), oil, and neutral cellulase plus gamanase digestibility (NCGD). Standard ‘wet chemistry’ procedures previously described by Sutton et al. (1997) were used for analysis.

A 4 × 4 Latin square design trial with four periods using eight mule wether sheep was conducted to determine the intake, digestibility and metabolisable energy (ME) values of the four silages (maize, MK, MRB, MS). Each period consisted of 23 days: a 9-day acclimatisation period followed by 7 days to measure voluntary feed intake (VFI) and 7 days of restricted feeding to measure digestibility. The initial liveweight of the sheep was between 38 and 43 kg. The animals were individually housed in slatted floor
pens. Two days prior to the digestibility collection period animals were transferred to metabolism crates and subsequently returned to the slatted pens at the end of the collection period.

2.2. Measurement of VFI, digestibility and ME

In addition to a daily silage ration all sheep received 30 g of mineral mixture and 50 g of soyabean meal to ensure an adequate supply of nitrogen for rumen digestion. During the acclimatisation and VFI measurement periods feed was offered once daily at 08.30 h. Animals were offered 15% more feed than their previous days intake. During this period, feed refusals were collected and weighed. On day 16, animals were fed at an estimated maintenance ME level (AFRC, 1995). These rations were offered twice daily, at 08.45 h and 19.00 h in metabolism crates. From day 17 until the trial ended, all feed refusals, faeces and urine were collected and weighed. Feed samples, faeces and urine were analysed for gross energy (GE) and methane GE output was predicted using the equation of Blaxter and Clapperton (1965). Animals were weighed at the beginning, at the end of VFI measurement and at the end of each period. The results were examined using an analysis of variance using the General Linear Model Procedure of Statistical Analysis System (SAS, 1996).

3. Results

3.1. Chemical composition of maize and intercrop silages

Maize was relatively mature with an oven DM content of 330 g DM kg\(^{-1}\) and 364 g starch kg\(^{-1}\) DM (Table 1). Intercropping maize with kale, runner bean and sunflower reduced silage DM and starch content, while CP content increased from 81 g kg\(^{-1}\) DM for maize to 137 g kg\(^{-1}\) DM in MS silages. Maize silage had the lowest ash content (34 g kg\(^{-1}\) DM) while MS silage had the highest value (92 g kg\(^{-1}\) DM) with the intermediate values recorded for MK and MRB silage. It should also be noted that the NDF and ADF content of maize and MK tended to be lower than those recorded for MRB and MS silage. Among the intercrop silages, only MRB had a lower GE content than maize, a difference that is difficult to explain. MS silage contained substantially more oil than the other three silages. The NCGD value was highest for maize and the lowest for MS silage with intermediate values for MK and MRB silage.

The lactic and VFA content of intercrop silages was in all cases higher when compared with maize silage. The pH and NH\(_3\)-N content of all silages indicated a well-fermented silage.

3.2. Animal performance

The VFI of intercrop silages and maize silage did not differ significantly (Table 2). However, the highest value was recorded with MK silage and the lowest for MRB and
Table 1  
Chemical composition of maize silage and intercrop silages

<table>
<thead>
<tr>
<th>Composition (g kg⁻¹ DM unless otherwise stated)</th>
<th>Maize</th>
<th>Intercrop silages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MK</td>
<td>MRB</td>
</tr>
<tr>
<td>Oven dry matter (g kg⁻¹)</td>
<td>330</td>
<td>270</td>
</tr>
<tr>
<td>Crude protein</td>
<td>81</td>
<td>105</td>
</tr>
<tr>
<td>Neutral detergent fibre</td>
<td>469</td>
<td>440</td>
</tr>
<tr>
<td>Acid detergent fibre</td>
<td>217</td>
<td>210</td>
</tr>
<tr>
<td>Ash</td>
<td>34</td>
<td>49</td>
</tr>
<tr>
<td>Water soluble carbohydrates</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Starch</td>
<td>364</td>
<td>231</td>
</tr>
<tr>
<td>Oil-B</td>
<td>34</td>
<td>38</td>
</tr>
<tr>
<td>Neutral cellulase + ganase digestibility</td>
<td>831</td>
<td>799</td>
</tr>
<tr>
<td>Gross energy (MJ kg⁻¹)</td>
<td>19.8</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Fermentation characteristics

<table>
<thead>
<tr>
<th></th>
<th>Maize</th>
<th>Intercrop silages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MK</td>
<td>MRB</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Propionic acid</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Butyric acid</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Ethanol</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Ammonia-N (g kg⁻¹ TN)</td>
<td>87</td>
<td>75</td>
</tr>
<tr>
<td>pH</td>
<td>3.9</td>
<td>3.9</td>
</tr>
</tbody>
</table>

MS. The digestibility values are expressed on a corrected DM (CDM) basis (Porter et al., 1984).

There were significant (P < 0.001) differences between maize silage and intercrop silages in DMD, DOMD and OMD. When compared with maize silage, the inclusion of sunflowers as an intercrop significantly (P < 0.001) reduced DMD, DOMD, OMD, NDF

Table 2  
VFI (g DM (kg BW⁰.⁷⁵)⁻¹ per day), digestibility (g kg⁻¹) and ME calculation (MJ kg⁻¹ DM) of maize and intercrop silages

<table>
<thead>
<tr>
<th>Digestibility coefficientsᵃ and voluntary feed intake</th>
<th>Maize silage</th>
<th>Intercrop silage</th>
<th>S.E.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFI [g DM (kg BW⁰.⁷⁵)⁻¹ per day]</td>
<td>65</td>
<td>68</td>
<td>62</td>
</tr>
<tr>
<td>DMD</td>
<td>688</td>
<td>710</td>
<td>675</td>
</tr>
<tr>
<td>DOMD</td>
<td>665</td>
<td>673</td>
<td>628</td>
</tr>
<tr>
<td>OMD</td>
<td>709</td>
<td>730</td>
<td>694</td>
</tr>
<tr>
<td>NDF digestibility</td>
<td>562</td>
<td>560</td>
<td>548</td>
</tr>
<tr>
<td>ADF digestibility</td>
<td>516</td>
<td>514</td>
<td>517</td>
</tr>
<tr>
<td>N digestibility</td>
<td>575</td>
<td>687</td>
<td>667</td>
</tr>
<tr>
<td>Starch digestibility</td>
<td>990</td>
<td>984</td>
<td>965</td>
</tr>
<tr>
<td>ME (MJ kg⁻¹ DM)</td>
<td>11.3</td>
<td>11.2</td>
<td>9.9</td>
</tr>
</tbody>
</table>

a Calculated on CODM.

b Not statistically analysed.

NS, not significant; ***P < 0.001.
and ADF coefficients, but resulted in a marked increase in N digestibility. In contrast the
inclusion of kale increased DMD, DOMD, OMD and N digestibility coefficients with
significant differences recorded for DMD, OMD and N when compared with maize
silage, but NDF and ADF coefficients were similar.

Values for MRB tended to be higher than MS but lower than maize and MK silage. The
exception was N digestibility, which was similar to the other intercrop silages. While
starch digestibility for maize and MK silage was similar they were both higher when
compared with MRB and MS.

Maize and MK silage had similar ME values, whilst those for MS and MRB were
markedly lower. This may be attributed, in the case of MS, to the lower ADF and NDF
digestibility values, but this could not be the case for MRB as the fibre digestibility
coefficients were similar to those of maize and MK silage.

4. Discussion

When discussing the results of intercropping studies it is important to be able to relate
the current study to those found in the literature. In order to do this, it is important to
know the contribution of the intercrop to total DM yield. It is unfortunate that few papers
provide this information. In addition, silage chemical composition is markedly effected
by a range of management and environmental factors, which are also likely to vary
between studies. However, some discussion of the effect of intercrops on silage
characteristics is important in the current study to establish if intercrops can be
successfully ensiled and also because there is little information relating to the UK, where
intercropping is not widely practised.

4.1. Silage chemical composition and fermentation characteristics

In the current study maize silage had the highest DM content. The value of 270 g kg\(^{-1}\)
noted for MK silage was markedly higher than the values of 128 and 170 g kg\(^{-1}\) reported
by Mazaheri (1979) and Fulkerson and Tossell (1972), and may have been due to a
number of unspecified factors including cultivar, climatic and management differences. In
contrast the DM content of MS silage was similar to that reported by Fisher et al. (1993)
and Valdez et al. (1988a).

The CP content of all the intercrop silage was higher than that of maize silage. Although these values are in some cases higher (Fisher et al., 1993) and in other cases
lower (Mazaheri, 1979) than those noted in the literature they clearly point to the fact that
intercrop silage has the potential to reduce the requirement for purchased protein sources
in livestock production systems. The markedly higher CP content noted by Mazaheri
(1979) may be due to a higher proportion of kale than that which was achieved in the
current study.

The higher NDF content in MS and MRB silages is associated with the lower NCGD
values for these silages when compared with maize.

During the growing season field observations indicated, that at the density used in the
current study, sunflowers dominated the maize crop producing water stress. It is
suggested that this adversely affected ear and grain development and was responsible for the low starch content when compared maize silage. This effect was less pronounced in the other intercrop plots. These results demonstrate the need to determine the appropriate plant density for sunflowers when grown as an intercrop with maize.

While the inclusion of sunflowers resulted in the highest CP and oil content it also produced the lowest NCGD value. These effects are attributed to sunflowers representing 26% of total MS silage DM. The high CP and oil content are associated with the whole-oil seed and the low NCGD with poor stem digestibility. If MS silage is fed as a basal forage to lactating dairy cows care should be taken to ensure that the total dietary oil content does not exceed 8% of the ration DM. Higher levels might reduce both DM intake and fibre digestion (Coppock and Wilks, 1991).

The higher concentration of fermentation products in the intercrop silage is attributed to a more intense fermentation resulting from their lower DM content when compared with maize silage. All the intercrop silages were well fermented which supports earlier studies by Mazaheri (1979) and Valdez et al. (1988a).

5. Animal performance

5.1. Voluntary feed intake

There was no significant difference in VFI between maize and intercrop silages. However, it should be noted that the highest value of 68 g DM (kg BW$^{0.75}$)$^{-1}$ per day was noted for MK silage while the lowest value of 62 g DM (kg BW$^{0.75}$)$^{-1}$ per day was noted for MRB and MS silage. The reduced intake is probably due to the lower ME value and NDF digestibility of these forages when compared with maize. These results, however, tend to conflict with those of Fisher et al. (1993) using lactating cows and Mir et al. (1992) using steers who reported similar DM intakes for maize and MS silage. This difference is again attributed to a number of possible management and environmental differences, which are not possible to quantify.

5.2. In vivo digestibility and metabolisable energy

The current study has demonstrated that intercropping maize with kale significantly improved forage quality in terms of OMD and DMD coefficients when compared with maize MRB and MS silage, while differences between maize and MRB silage were not significant. The reduction in OMD and DMD values that occurred when comparing MS with the other three silages is mainly attributed to the higher content and lower digestibility coefficients for NDF and ADF. These effects may be ameliorated by careful choice of sunflower cultivar and plant density. The use of dwarf varieties may reduce the proportion of highly indigestible sunflower stem, and an appropriate plant density will not allow the sunflowers to dominate the maize crop and depress ear and grain development. Further studies should be conducted to examine the effect of plant density of sunflower intercrops on ear development and subsequent digestibility of the resultant silage.
Although the NDF and ADF content of MRB and MS silage were similar, the NDF and ADF digestibility values for MRB silage were markedly higher than MS silage, and similar to those for maize alone. These results indicate that the fibre content of runner bean is more digestible than that of sunflowers and similar to that of maize.

Valdez et al. (1988a,b) did not observe any difference in DMD, NDF and ADF digestibility between maize and MS silage in a digestion trial with non-lactating dairy cows. They reported DMD, NDF and ADF digestibility values of 682, 615 and 660 g kg\(^{-1}\), respectively for MS silage, which were higher than the present digestion trial (615, 485 and 425 g kg\(^{-1}\), respectively) in wether sheep. A number of factors including species of experimental animal, proportion of intercrop in the silage and environmental and management factors may well have contributed to these differences.

The starch and N digestibility and the ME content are based on single pooled sample analysis and were not statistically analysed. However, these values are discussed below since there are no other literature on these parameters for these intercrop silages.

Starch is an important source of energy for ruminants. In the present experiment, with wether sheep, starch digestibility, which ranged from 965 (MRB) to 990 g kg\(^{-1}\) DM of maize silage and was much higher than the value of 635 g kg\(^{-1}\) DM reported by Valdez et al. (1988b) for cattle. The reason for the high starch digestibility in the current study might be due to the higher grain digestibility noted in sheep compared with cattle.

Maize and MK silage had similar ME values, which reflects their similar digestibility coefficients. The lower ME content of MS silage is attributed to the significant depression in fibre digestibility.

6. Conclusions

Intercropping maize with a variety of protein rich forages can increase silage CP content by 3–5% units and improve N digestibility, indicating a potential to reduce the requirement for purchased protein supplements. The degree of uptake of intercropping will depend on the cost and reliability of other sources of protein. Farmers may still prefer to grow ‘energy’ and ‘protein’ forages separately and then mix crops pre or post ensiling.

While VFI was similar for all silages the digestibility study indicated lower values for MS silage which reflected its lower digestibility coefficients. Further studies are required to determine the optimal sunflower cultivar and plant density to ensure that both crops fulfil their potential, with maize providing a high starch content and the sunflowers providing a protein and energy rich seed with the least amount of indigestible stem.

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References


