MAIZE SILAGE IN THE DRY SEASON FOR GRAZING DAIRY COWS IN SMALL-SCALE PRODUCTION SYSTEMS IN MEXICO’S HIGHLANDS

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ABSTRACT

The aim was to determine the productive and economic response to feeding maize silage (MS) at 3, 6 and 9 kg DM/cow/d, to continuous grazing cows with a high stocking rate and low herbage allowance during the dry season. Six Holstein cows were used in a repeated 3 x 3 latin square design. Cows received 2.5 kg/d of DM of commercial concentrate. Treatments consisted of 3, 6 and 9 kg of DM/cow/d of MS. There were no differences on response variables (P > 0.05), milk yields (19.0 kg/cow/d), fat and protein content (33.5 and 32.8 g/kg, respectively), live weight (473.6 kg), body condition score (1.75), and total DMI (13.86 kg/cow/d). Total feeding cost/kg of milk was $0.06, $0.07 and $0.08 (USD), for treatments 3, 6 and 9 kg/DM of MS, respectively. Increasing MS to either 6 or 9 kg/cow/d did not increase milk yields compare to 3 kg/cow/d, but it does reduce profits.

Key words: Conserved forages, Continuous grazing, Milk production, Supplementation.

INTRODUCTION

Small-scale dairy production systems contribute between 35 and 40% of the national milk supply (Val-Arreola et al., 2006), and are an important option for small-scale farmers in the central highlands of Mexico not only for their contribution to the national supply, but rather for their role as a rural development option (Espinoza-Ortega et al., 2007). A problem faced by these systems is the low availability of forage in the winter and spring dry season (November through May); so that farmers identify the need for low cost feeding strategies as a priority. Intensive grazing of ryegrass-white clover pastures is an option for these systems where there is access to irrigation (Arriaga-Jordán et al., 2002). However, herbage growth on pastures is greatly reduced during the dry season given the limited irrigation available plus low ambient temperatures.

Maize (Zea mays) is the traditional crop in these systems, and maize silage (MS) is characterized by its high concentration of soluble carbohydrates that enable a good fermentation, good energy supply and high rumen degradability (NRC, 2001). The good fermentation characteristics of maize forage without additives (Mosquera and González, 1998) even under difficult conditions, and reasonable yields make it attractive for small-scale dairy production systems in the highlands of central Mexico, where farmers do not have a tradition of forage conservation having relied mostly on maize straw and high amounts of concentrate to feed their herds in the dry season (Arriaga-Jordán et al., 2002, García-Martínez et al., 2009).

The integration of MS in a feeding system based on the intensive grazing of cultivated pastures has proven adequate (Arriaga-Jordán et al., 2002), but there is no indication on the amounts that make the optimal use of available resources. Therefore, the objective of this work was to determine the production and economic response to feeding maize silage at levels between 3 and 9 kg DM/cow/d offered to lactating Holstein cows based on intensive continuous grazing of cultivated pastures with a high stocking rate in the winter – spring dry season.

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MATERIALS AND METHODS

The study was undertaken in the dry spring season in the village of Ejido San Cristóbal, in the central highlands of Mexico at 19º 24’ N and 99º 51’ W, an altitude of 2,650 m.a.s.l., with a mean annual temperature of 13°C, summer rains (May – October) and annual rainfall between 800 and 1,000 mm; where a demonstration module in feeding strategies for small dairy herds has been established.

Pastures and maize silage

Cows continuously grazed on two 0.75 ha plots that were established in mid May of 1999 for pasture with a mixture of perennial and short cycle ryegrass (Lolium perenne cv. Nui and L. perenne X L. multiflorum cv. Tama) and white clover (Trifolium repens cv. Pitau) fertilised at sowing with 100 kg/ha each of urea, potassium chloride, and triple superphosphate. Nitrogen levels in the soil were low so that pastures were fertilised with 100 kg/ha of urea every month (46 % of N), as well as irrigated after fertilising.

A crop of 1.5 ha of a local landrace white maize variety cultivated following traditional practice (sown in late April and harvested on 20 October 1999) was destined for silage using a trench silo dug in the ground, compacting forage with a tractor and covered with a black 600 caliber plastic sheet with soil on top. Silage feeding was initiated after 50 days of ensiling.

Grazing management

A set stocking grazing system was followed with a high stocking rate (4 cows/ha) and 9 h access to pastures (7:00 to 16:00 h). Water in troughs was available at all times at pastures.

Net herbage accumulation (NHA) was estimated every 21 days using five exclusion cages following the procedures described by Heredia-Nava et al. (2007). Pasture height was recorded on three days every week with a rising plate grass meter (Hodgson, 1990) taking 20 recordings each time. The experiment started on April 10th ending on June 11th (9 weeks).

Animals and measurements

Six lactating Holstein cows with a mean live-weight of 473 kg were used in the experiment and grouped in trios according to calving date. Cows in the first group were in mid-lactation with 164 days in milk on average, and cows in Group 2 were in early lactation with a mean of 48 days in milk at the beginning of the experiment.

Milk yields were weighted on a 20 kg spring-scale and recorded daily using the mean daily yield on the last week of each period for analysis, and cows were weighed at the beginning and the end of each experimental period on a portable an electronic weighbridge with a 1500 kg capacity; when body condition score (BCS) was determined on a 1 (under condition) to 5 (over condition) scale (Wildman et al., 1982). Live-weight and BCS during the last week of each period were used in the analysis. Milk samples were taken in two consecutive milkings and milk fat and protein contents (g/kg) were determined using an automatic ultrasound analyser (Ekomilk-M).

Milking was undertaken by hand twice a day at 5:00 and 16:30 h. Cows had access to silage and concentrate only during each milking, with half the concentrate and half the silage allocations given in the morning (5:00 to 7:00 h) and the other half in the afternoon milking (16:30 to 18:30 h). The milking time was sufficient for the cows to consume their silage and concentrate allocations, recording any refusal. Commercial mineral compound, for dairy cattle was sprinkled daily over the concentrate (approximately 50 g/cow/d), with a minimum guarantee composition of: Ca 120.0, P 120.0, Fe 15.0, Mg 10.0, Mn 3.0, Zn 2.0, Cu 0.5, Co 0.1 and NaCl 100 g/kg. Cows were kept when not at grass in a tie barn with concrete troughs.

Treatments

Treatments were continuous grazing for 9 h/d plus 3 kg fresh weight/cow/d of a 16% CP commercial compound concentrate supplementation plus: Treatment MS-3: 3.0 kg DM of maize silage/cow/d; treatment MS-6: 6.0 kg DM maize silage/cow/d; and treatment MS-9: 9.0 kg DM of maize silage/cow/d.

Chemical analysis

Samples of concentrate and MS were taken daily on the last week of each experimental period dried at 65°C, bulked over the week and a composite sample taken for each experimental period. Pasture samples were hand plucked simulating grazing on the last week of each period and dried at 65°C to constant weight to determine DM. Feed samples were also analysed for ash by 56 incinerating at 600°C in
a muffle furnace, Crude Protein (CP) by the micro Kjeldahl method, Neutral Detergent Fibre (NDF) and Acid Detergent Fibre (ADF) through the ANKOM method (ANKOM, 2005), and in-vitro Organic Matter digestibility (IVOMD) by the procedure of Tilley and Terry (1963).

Silage DM intake was determined during the measurement week by difference between offered and refused silage. Grazed herbage DM intake was estimated indirectly from animal performance results (Pulido and Leaver, 2003) taking calculations for energy requirements of milking dairy cows from AFRC (1993) and estimated ME content of feeds from chemical analysis using equations from Menke and Steingass (1988).

Experimental design

Cows in each group (squares) of three were randomly assigned to a treatment sequence according to a 3 X 3 replicated Latin Square Design following the model (Arriaga-Jordán and Holmes, 1986):

\[ Y_{ijkl} = \mu + S_i + C_{j(i)} + P_k + t_l + e_{ijkl} \]

Where:
- \( \mu \) = General mean
- \( S_i \) = Effect due to squares (i = 1 and 2)
- \( C_{j(i)} \) = Effect due to cows within squares (j = 1, 2 and 3)
- \( P_k \) = Effect due to experimental periods (k = 1, 2 and 3)
- \( t_l \) = Effect due to silage treatment (l = 3, 6 and 9 kg DM)
- \( e \) = Residual error term

Significant differences between means were compared with the Tukey test (P < 0.05).

Economic analysis

Partial budgets were used to compare feeding costs between the three silage treatments, considering only those costs and returns specific for the silage treatments, commercial compound concentrate and pasture (kg/cow/treatment) (Espinoza-Ortega et al., 2007).

Costs of maize silage treatments were calculated as if the cows would have been eating the total amount offered, since the refusals (mainly from treatment MS-6 and MS-9) went to waste. Cows consumed the total amount of commercial concentrate compound offered. Whereas pasture intake (kg/DM/cow), was estimated by subtracting concentrate and maize silage intake from total intake, calculated from AFRC (1993).

Costs of feedstuffs ($/kg/DM) were as follows: commercial compound concentrate = 0.20, maize silage = 0.09, and pasture = 0.03. Finally, milk selling price was 0.29 ($/kg).

RESULTS AND DISCUSSION

Environmental conditions

Mean maximal temperature was 24.3°C, mean minimal of 6.2°C, and an overall mean temperature of 15.3°C. Total precipitation was 151.0 mm during the experiment, of which 75% fell in Period 3 and the other 25% in Period 2. There was no rain during Period 1.

Chemical composition of feeds

Table 1 shows the chemical composition of MS, pasture herbage and concentrates. In general, low nutritive values of MS and pastures were a result of the difficult conditions at harvest and during the development of the experiment, respectively.

Net herbage accumulation and sward height

Total net herbage accumulation (NHA) for the experiment was 2,470 kg OM/ha during the experiment, of which cows consumed 1,702 kg OM, which gives an herbage utilization of 69%.

Environmental conditions, severely limited NHA at only 8.3 kg OM/ha/d during period 1, raising to 67.8 kg OM/ha/d in period 2 and 41.6 kg OM/ha/d for Period 3. Average herbage availability per cow was 9.8 kg OM/cow/d, within 3.3 cm grass height measure with rising plate meter.

<table>
<thead>
<tr>
<th>TABLE 1: Chemical composition of feeds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize Silage (MS)</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Dry matter (g/kg)</td>
</tr>
<tr>
<td>Organic matter (g/kg DM)</td>
</tr>
<tr>
<td>Crude protein (g/kg DM)</td>
</tr>
<tr>
<td>Neutral detergent fibre (g/kg DM)</td>
</tr>
<tr>
<td>Acid detergent fibre (g/kg DM)</td>
</tr>
<tr>
<td>In vitro OM digestibility (g/kg OM)</td>
</tr>
<tr>
<td>Estimated metabolizable energy (MJ/kg DM)</td>
</tr>
</tbody>
</table>
Grazing heights (GH) at the beginning and at the end of the experiment were 4.0 and 4.1 cm for both pastures. The average height was 3.3 and 3.4 cm for pasture I and II, respectively (rising plate grass meter). Due to drought conditions height descended to 1.5 and 1.8 cm during EP 1 and 2, respectively limiting grazing conditions.

**Intake**

Total organic matter intake was not affected by treatments (P > 0.05) with an average of 13.9 kg/cow/d, whereas herbage intake decreased (P < 0.05) (8.3, 6.9 and 5.1 kg OM/cow/d), as intake of MS increased (2.5, 4.8 and 6.5 kg OM/d) (P < 0.05) (Table 2), giving a substitution rate of 0.83 kg of herbage OM per kg of MS.

Total organic matter intake was different over periods (P < 0.05), having the lowest intake on EP2 and EP3 with 13.0 and 13.9 kg OM/d, respectively; whereas EP1 recorded the highest intake with 14.6 kg OM/cow/d (Table 2).

**Animal measurements**

Table 3 shows results for milk yields (kg/cow/d), milk fat and protein contents (g kg⁻¹), live weight (kg) and body condition score, with no differences (P > 0.05) for any of the measured variables, due to treatments. To the respect of EP there were no differences (P > 0.05) for any response variables, with the exception of EP2 where fat content was lower (30.0 g/kg) (P > 0.05).

**Economic analysis**

Increasing levels of MS from 3 to 6 and 9 kg/DM of MS, resulted in 15 and 26% increase in total feeding cost, without any effect on milk yields or its components (Table 4), as well as any other response variable. Feeding milk production cost was 0.06, 0.07 and 0.08 $/kg, for treatments 3, 6 and 9 kg/DM/cow/d of maize silage. Giving a margin of 0.23, 0.22 and 0.21 $/kg of milk produced.

Table 1 shows the chemical composition of feeds (MS, pasture herbage and concentrates). There was variation (P < 0.05) in NDF and ADF contents between periods for MS, being higher compared with the MS used by Phipps et al. (1992). Values were also higher for NDF and ADF than those reported by Hernandez-Mendo and Leaver (2006), but nearer to NDF and ADF values reported by Anaya-Ortega et al. (2009), Garduño-Castro (2009), and Ramirez-Mella et al. (2010) from work undertaken in the same region. Protein content in maize silage was in line with reports in the literature.

**In vitro OM digestibility of maize silage was on average 692.2 g/kg OM with an estimated mean**

### TABLE 2: Estimated mean daily intake of feeds (kg OM/cow/d).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate</td>
<td>2.5</td>
</tr>
<tr>
<td>Maize silage</td>
<td>2.5a</td>
</tr>
<tr>
<td>Maize silage refusal</td>
<td>0.5</td>
</tr>
<tr>
<td>Pasture herbage</td>
<td>8.3a</td>
</tr>
<tr>
<td>Total intake</td>
<td>13.3</td>
</tr>
</tbody>
</table>

a,b,c (P < 0.05). MS-3 = Maize silage 3 kg OM cow/d; MS-6 = Maize silage 6 kg OM cow/d; MS-9 = Maize silage 9 kg OM cow/d. EP 1, 2 and 3 = experimental periods, respectively. Pasture herbage was estimated by subtracting concentrate and maize silage intake from total intake, calculated from AFRC (1993).

### TABLE 3: Milk yields, milk composition, live weight and body condition score.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (kg/d)</td>
<td>18.8</td>
</tr>
<tr>
<td>Milk fat (g/kg)</td>
<td>32.6</td>
</tr>
<tr>
<td>Protein (g/kg)</td>
<td>32.6</td>
</tr>
<tr>
<td>Live weight (kg)</td>
<td>474.9</td>
</tr>
<tr>
<td>Body condition score</td>
<td>1.75</td>
</tr>
</tbody>
</table>

MS-3 = Maize silage 3 kg DM cow/d; MS-6 = Maize silage 6 kg DM cow/d; MS-9 = Maize silage 9 kg DM cow/d; NS (P > 0.05); EP 1, 2 and 3 = experimental periods, respectively.
TABLE 4: Feeding Costs and cash returns per treatment of grazing cows with different levels of maize silages supplementation (in US Dollars).

<table>
<thead>
<tr>
<th>Feeding cost</th>
<th>Maize silage 3 kg DM cow/d</th>
<th>Maize silage 6 kg DM cow/d</th>
<th>Maize silage 9 kg DM cow/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial compound concentrate</td>
<td>$74.8</td>
<td>$74.8</td>
<td>$74.8</td>
</tr>
<tr>
<td>Maize silage</td>
<td>$35.3</td>
<td>$70.5</td>
<td>$105.8</td>
</tr>
<tr>
<td>Pasture</td>
<td>$36.2</td>
<td>$25.9</td>
<td>$17.4</td>
</tr>
<tr>
<td>Total feeding costs</td>
<td>$146.3</td>
<td>$171.2</td>
<td>$198.0</td>
</tr>
<tr>
<td>Milk yields (kg)</td>
<td>2,386.3</td>
<td>2,397.0</td>
<td>2,446.3</td>
</tr>
<tr>
<td>Selling price / kg of milk</td>
<td>$0.29</td>
<td>$0.29</td>
<td>$0.29</td>
</tr>
<tr>
<td>Cash returns from milk’s sale</td>
<td>$692.4</td>
<td>$695.5</td>
<td>$709.8</td>
</tr>
<tr>
<td>Margin over feeding costs</td>
<td>$546.1</td>
<td>$524.3</td>
<td>$511.8</td>
</tr>
<tr>
<td>Returns / cash expenditure ratio</td>
<td>4.7</td>
<td>4.06</td>
<td>3.6</td>
</tr>
<tr>
<td>Feeding cost / kg of milk</td>
<td>$0.06</td>
<td>$0.07</td>
<td>$0.08</td>
</tr>
<tr>
<td>Margin /kg of milk</td>
<td>$0.23</td>
<td>$0.22</td>
<td>$0.21</td>
</tr>
</tbody>
</table>

Cost of feed per unit ($/kg/DM): commercial compound concentrate = 0.198, maize silage = 0.093, and pasture = 0.030.

Total kg of feed’s intake per treatment:
- Commercial compound concentrate = 378 kg (2 cows x 3 kg x 63 days)
- Maize silage. MS-3, MS-6 and MS-9 = 378, 756 and 1,134 kg/OM, respectively (2 cows x treatment x 63 days)
- Pasture = 1,045.8, 869.4 and 642.6 kg of DM, MS-3, MS-6 and MS-9, respectively. (2 cows x treatment x 63 days)

Returns / cash expenditure ratio = Cash returns from milk’s sale / Total feeding cost
Feeding cost / kg of milk = Total Feeding cost / Milk yields (kg) per treatment
Margin / kg of milk = Margin over feeding cost / Milk yields (kg).

ME content of 10.2 MJ ME/kg OM, considered acceptable taking into account that late rains usually impede optimal harvest dates for ensiling, which results in high fibre contents in the maize silage; coupled with a large particle size (> 20 mm) that limits good compaction of the forage. This is shown in the digestibility values that are lower to international reports from Hameleers (1998), O´Mara et al. (1998), and Hernandez-Mendo and Leaver (2006); but similar to Anaya-Ortega et al. (2009), and higher than those reported by Ramírez-Mella et al. (2010), corresponding to a fresh chopped maize supplemented to dairy cows.

Plucked samples of herbage had a mean NDF content similar to that reported by Hernandez-Mendo and Leaver (2006) in their Experiment 2; but over 50% higher in ADF. This resulted in a mean ME content of 10.06 MJ ME/kg DM compared to 11.7 MJ ME/kg DM in the plucked herbage samples reported by these authors. Differences may be attributed to dryer conditions experienced during the work herein reported. IVOMD was 718.0 g/kg being 10% lower to those reported by Kennedy et al. (2006).

Crude protein content (164.0 g/kg OM) was equal to that reported by Anaya-Ortega et al. (2009) on similar perennial ryegrass pastures in the study area, but lower than reports from Garduño-Castro et al. (2009).

There was a high efficiency in the utilization of the pastures, where cows ate 94% of available herbage, similar to that reported by Mayne et al. (2000), under conditions of low herbage availability (HA) (16 kg DM/cow/d). In this study the average HA was even lower (9.8 kg OM/cow/d) than that reported by Mayne et al. (2000). According to this, high efficiency of herbage utilisation was achieved in this study. However, environmental conditions such as drought in experimental period (EP) 1 and excess of rain fall in 3, had a detrimental effect on herbage mass production, together with the high stocking rate, resulted in low grazing heights (average 3.3 cm), that could have limited herbage intake by the cows as reported by Dale et al. (2008); as well as, reduced sward heights might limit herbage mass production (Fulkerson and Slack, 1994), compromising future pasture yields.

Types of supplements determine the extent of substitution rate. Concentrate supplementation results on reduced substitution rates; whereas forage supplements (e.g. silages) cause high substitution rates (Phillips and Leaver, 1985, Mayne et al., 2000). In this study the substitution rate was 0.83 kg of herbage OM per kg of MS, being greater than 0.67
of herbage dry matter per kg of fresh cut maize reported by Ramírez-Mella et al. (2010), but within the range reported as normal by Phillips and Leaver (1985). On the other hand, herbage availability is a factor that influences intake and milk production (Pulido and Leaver, 2003).

In this study HA was 9.8 kg OM/cow/d, which is even lower to 16 kg DM/cow/d considered as low by Mayne et al. (2000). So, restricted sward conditions in this study such as low HA and low average pasture height of 3.3 cm limited cow’s dry matter intake, and consequently milk yields. Under such restrictive pasture conditions, the use of maize silage supplemented at levels of 6 or 9 kg could have increased milk yields per hectare by way of increasing stocking rate despite the reductions on individual cow’s milk yields as well as reductions on herbage production. The use of MS proved to be an important complement for the grazed pastures representing 36% of average total DMI per cow, allowing sustaining adequate milk yields per cow under high stocking rate (4 cows/ha). This result is similar to Hernández-Mendo and Leaver (2006), where high MS intakes resulted in higher milk yields; where MS represented 54% of total dry matter intake.

Average milk production per treatment (19.03 kg/cow/d), was similar (19.0 kg/cow/d) to the one reported by Bargo et al. (2002), of grazing cows receiving no supplementation whatsoever; and way below milk yields (33.2 kg/cow/d) reported by Burke et al. (2007), from grazing cows supplemented with a mixture of “grass silage and corn silage” (12.1 kg/DMI/cow/d), and concentrate (6.2 kg/DMI/cow/d).

Milk yields of this study were higher than the average 10.53 kg/cow/d reported by Ramírez-Mella et al. (2010), with 0, 4 and 8 kg DM/cow/d of fresh chopped maize. The milk yield differences may be due mostly to the advance stage of lactation of their cows (508 ±259 days), whereas the cows in this experiment were on average 107 days in milk at the beginning of the experiment.

The effectiveness of MS supplement was observed since animal production (milk, live weight, condition score), remained constant throughout experimental periods. The high stocking rate together with environmental conditions, were factors that determined poor sward conditions (net accumulation rate and height), despite these, milk yield remained unchanged.

The effect of high stoking rate over pasture yields has to be considered in the long term, in order to determine the levels of supplements needed, according to pasture conditions, avoiding compromising future pasture yields, maintaining acceptable milk yields per cow and per hectare.

The economic responses to supplementation under high stocking rate, should be evaluated on milk yields per hectare rather than for cows, higher levels of supplementation will allow higher stoking rates, resulting in more milk per hectare. However, under small scale productions systems, this is an unlikely situation since the number of cows is limited (Ramírez-Mella et al., 2010). Under this situation a balance between pasture conditions and supplementation levels should be determined in order to reduce feeding cost due to supplements, allowing at the same time high rates pasture utilization and acceptable animal yields (Dale et al., 2008).

Results in this experiment show short term effects on animal and pasture variables, as well as economic returns, from which it is difficult to suggest any MS supplementation level. The suggestion would be to run continuous experiments testing the three MS supplementation levels, in order to assess long term carryover effects (summer and autumn) on pasture (net herbage accumulation, height and nutritive value of pasture), and animals (milk production, bodyweight and body condition score), and the subsequent impact on economics. Since, high stocking rate will reduce herbage allowance and sward heights, decreasing cow’s intake per bite, and milk yields per cow; but on the other side, will increase efficiency of herbage utilization (%), and milk yield per hectare, the question then would be which supplementation level will maximise herbage utilization (%), along with reasonable milk yield per hectare without affecting cows body weight and body condition score, as well as pasture productivity for the next season.

CONCLUSION

Maize silage supplement of 3 kg/cow/d to dairy cows grazing on a ryegrass white clover pastures with low levels of concentrates gives a daily milk yield close to 20 kg/cow/d. Increasing maize
silage to either 6 or 9 kg/cow/d does not increase milk yields, but it does increase total feeding cost reducing profits.

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