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Maize silage as sole forage source for dairy cows in small-scale systems in the highlands of central Mexico

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ABSTRACT

Present study was undertaken to evaluate forage options for dairy cows in small-scale dairy systems under lower availability of water for irrigation, using maize silage as sole forage or grazed cultivated pasture plus maize silage. Two groups of 5 Holstein cows balanced in live-weight, parity and days in milk were formed. The productive and economic performance of treatment T_1 that received a diet of maize silage (12.8 kg DM/cow/day) plus 3.5 kg/day of a high protein concentrate (71% soyabean meal and 29% ground maize grain) was compared with treatment T_2 of grazed ryegrass-white clover irrigated pasture for 8 h/day, 8.1 kg DM/cow/day of maize silage and 5.0 kg of commercial concentrate with 18% CP. The experiment lasted for 11 weeks. Milk yields were 19.2 and 17.1 kg/cow/day for T_1 and T_2. There were no significant differences for milk fat or protein content, live-weight or body condition score. Although total feeding costs were higher in T_1 (4%), the slightly higher milk yield resulted in a cost per litre 10.5% less in T_1; representing 7% higher returns/feeding cost ratio. T_1 is an option in future scenarios of scarce water for irrigation and for small-scale dairy farmers without access to irrigation.

Key words: Forages, Grazing, Highlands, Maize silage, Small-scale dairy systems

Feeding of herds in small-scale dairy farms in the highlands of Mexico with irrigation is based on cut-and-carry irrigated pastures, maize straw, and bought-in inputs as large amounts of concentrates (Martínez-García *et al.* 2015). Farms with a higher use of home-grown forages in diets are more sustainable and profitable (Martínez-García *et al.* 2015).Strategies implemented in terms of quality forages are intensive grazing of pastures and ensiled forages (Hernández-Ortega *et al.* 2011). Maize silage is a valid technology for improving the supply of good quality, high energy but low protein forage, for small-scale dairy systems (Albarrán *et al.* 2012). Although maize silage is commonly used in large-scale systems, only 30% of small-scale dairy farms utilise maize silage (Martínez-García *et al.* 2015).

The objective of this study was to assess the use of maize silage as sole forage, supplemented with a high protein concentrate, compared to grazing of pastures complemented with maize silage and commercial concentrates in the feeding of dairy cows in small-scale farms.

MATERIALS AND METHODS

The work followed a participatory livestock technology development with 2 participating small-scale dairy farmers from the municipality of Aculco in the state of Mexico (which surrounds Mexico City).

Aculco is located between 20° 06' and 20° 17' N and 99° 40' and 100° 00' W, an altitude of 2,440 m having sub-humid temperate climate, mean temperature of 13.2°C and annual rainfall above 700 mm. The experiment took place from 18 March to 3 June 2013, with one week for adaptation and 11 experimental weeks.

Animals and treatments: Two small-scale dairy farmers participated in this experiment with 10 Holstein cows, divided into 2 groups; arranged in pairs of cows according to parity and days in milk, with initial milk yield of 17.8±2.3 kg/cow/day and initial live-weight of 495±79 kg. Each group of 5 cows was randomly assigned to one of the following treatments:

Treatment 1 (T_1): *Ad lib.* maize silage as only source of forage, 3.5 kg of a high protein concentrate made in farm from 2.5 kg of soyabean meal (71% fresh weight) and 1.0 kg of ground maize grain (29% fresh weight), with a crude protein (CP) content of 296.8 g/kg DM (Table 2).

Treatment 2 (T_2): Continuous grazing of ryegrass-white clover pasture for 8h/day, maize silage (6 kg DM/cow/d), and 5.0 kg fresh weight (4.75 kg DM/cow/day) of a commercial concentrate with 18% CP.

Feeds were offered twice daily, and for treatment 2 (T_2)

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the concentrate and silage were offered at milking times. Offered and refused feeds were weighed once a week (due to logistical issues of the participatory nature of the experiment), to determine intake of silage and concentrates. Samples of all feeds for both treatments were collected every 21 days to determine DM, OM, NDF, ADF, as well as CP following the procedures reported by Anaya-Ortega *et al.* (2009).

Animal variables: Milk yield (kg/cow/day) was recorded once a week by weighing with a spring balance and a sample was taken to determine milk fat and protein by an ultrasound milk analyser. Live-weight (LW) and body condition score (BCS) were recorded every 14 days, with the 1 – 5 point score for BCS.

Pasture variables: Continuous grazing for 8 h/day in treatment T_2 took place in a pasture of 1.8 ha sown in April 2012 to a mixture of perennial ryegrass (*Lolium perenne* cv. Bargala), anual ryegrass (*Lolium multiflorum* cv. Maximus), orchard grass (*Dactylis glomerata cv.* Potomac) and white clover (*Trifolium repens* cv. Ladino). Approximately 5.0 ton DM/ha of manure was applied before sowing to 1.0 ha, and a 46-92-60 NPK/ha formula was applied to the total area prior to sowing. Every 7 weeks the pasture was fertilised with 37.5 kg urea (46% N). The pasture was irrigated with simple sprinklers once a month, which was sub-optimal but enabled the pasture to stay alive with minimal herbage growth.

Net herbage accumulation (NHA) was determined every 21 days in 6 exclusion cages from which 2.0 × 0.25 m quadrants were cut and expressed as kg dry matter (DM)/ha and per day. Also, every 21 days, a simulated grazing sample of the pasture was collected.Samples were dried at 60°C in a forced draught oven to constant weight to determine DM, and ashed at 600°C in a furnace to determine ashes and organic matter (OM). CP was determined by the Kjeldahl method (AOAC 1990). NDF and ADF were determined by the Ankom micro-bag technique (Van Soest *et al.* 1991).

Experimental design and statistical analysis

Analysis was in a split-plot design recommended by Stroup *et al.* (1993) for on farm experiments where replications are limited. Analysis of variance was applied according to the following model:

$$Y_{ijkl} = m + b_i + T_j + E_k + p_l + Tp_{jl} + e_{ijk}$$

where, m, general mean; b, effect of cow pairs (i = 1, …, 5); T, effect of treatment (Main Plot); j = 1, 2E, error term for Main Plots [b(R)ij];P, effect of measurement periods (split - plot); k = 1, …, 12; Tp, interaction term between ryegrass pasture type and measurement periods; and e, error term for split plots.

Economic analysis: Feeding costs were compared from partial budgets following previous work, taking into account only the costs and returns in cash. Expenditures were the cost of grazed pasture during the experiment considering irrigation and fertilisation costs, cost of concentrates and the end cost of silage in US $/kg DM taking all costs involved in growing, harvesting and ensiling the maize crop by a sub-contractor. Returns were the milk sales for the duration of the experiment. The opportunity cost of the farmers' labour was not included in this partial budget following established procedures in former studies on feeding strategies (Anaya-Ortega *et al.* 2009) in order to specifically compare the costs incurred directly in feeding.

RESULTS AND DISCUSSION

Animal variables: Milk yields in T_1 (19.2 kg/cow/day) were higher (Table 1) than for treatment T_2 (17.1 kg/cow/day) with nonsignificant differences (P>0.05) (although numerically the non-significant difference observed was 12%). There were also nonsignificant differences for milk fat and protein content (P>0.05) between treatments. There were differences among periods for milk yields, although expected due to the progression of lactation.

The experimental concentrate in T_1 was low in fibre, both NDF and ADF when compared to the commercial concentrate, and with 297 g/kg of CP represented a diet with around 130 g/kg DM of CP, which was able to sustain the reported milk yield of 19.1 kg/cow/day.

These results were similar to the results reported by Hernández-Ortega *et al.* (2011) and Albarrán *et al.* (2012) in small-scale dairy systems integrating grazing of cultivated pastures, silages and concentrates, showing the potential of maize-silage as only source of forage, supplemented with high energy concentrates.

Yields were also similar to reports from work in Northern Ireland on grazing dairy cows receiving different forage and concentrate supplements (Morrison and Patterson 2007), and for lower yielding cows on continuous grazing supplemented with maize silage and soybean meal in New Zealand (Woodward *et al.* 2013).

Results showed how a feeding strategy based on maize silage as the sole forage source, complemented with moderate amounts of a high protein concentrate made from straight ingredients available locally as soybean meal and maize grain, can meet the challenge of improved animal production that contributes to the livelihood of rural families, and with lower feeding costs than other strategies. Soyabean meal is widely available in all livestock producing areas of central and northern Mexico, as the country is the seventh largest producer and the sixth largest importer in the world (Indexmundi 2016).

There were no differences between treatments (P>0.05) for LW or BCS, but there were differences among measurement periods (P<0.05) for both variables. As time progressed, milk yield decreased so that there was less mobilization of body reserves. The interaction was significant between treatments and periods (P<0.05) only for BCS, although differences were too small for any biological importance since there were only decimal differences in scores.

Milk fat showed nonsignificant differences between treatments (P>0.05). Observed milk fat content was higher than reports by Anaya-Ortega *et al.* (2009), due to lower milk yields in the work herein reported.

In terms of protein content of milk there were also non significant differences between treatments (P>0.05) with values similar to those reported by Hernández-Ortega *et al.* (2011) (31.2 g/kg) and Albarrán *et al.* (2012) (32.6 g/kg). Milk composition mean that milk from both treatments met Mexican standards for the composition of raw milk.

Pasture, maize silage and feed variables: Net herbage accumulation (NHA) in the grazed pasture was 2679.71 kg DM for the 12 week period (1 week for adaptation and 11 experimental weeks) representing a mean of 31.9 kg DM/ha/day.

Table 1. Milk yield and composition, live-weight and body condition score

	T_1	T_2	SEM treatments	SEM periods	SEM interaction
Milk yield (kg/cow/day)	19.20	17.10	1.27	0.84*	4.16
Milk fat (g/kg)	37.0	39.0	0.22	0.13	0.71
Milk protein (g/kg)	33.0	33.0	0.02	0.02	0.08
LW (kg/cow)	444.9	497.4	18.56	12.41*	61.03
BCS	1.8	1.9	0.04	0.07*	0.16*

* P < 0.05, LW, Live-weight; BCS, body condition score.

Chemical composition of grazed pasture, maize silage and concentrates are given in Table 2. Results showed that the actual crude protein content of the home made high protein concentrate was 29.7%; and maize silages showed small differences given mostly by differences in time of harvesting due to weather circumstances that did not enable ensiling to take place on the same date. Climatic conditions in the highlands of central Mexico mean that maize may not always be harvested at optimal or similar dates given soil conditions. However, highland maize silage had good quality even at different harvesting times (Hernández-Ortega *et al.* 2011, Albarrán *et al.* 2012). Grazed pasture showed a high content of dry matter, caused mainly by dehydration between sampling and processing in the laboratory.

Maize silages were lower in NDF than reported by Anaya-Ortega *et al.* (2009) and near to the values reported for NDF by Hernández-Ortega *et al.* (2011), but lower than reported by Alfonso-Ávila *et al.* (2012) for small-scale farmers who have incorporated maize silage into their feeding strategies in the study area.

Tropical highland maize is characterised by slow growth due to lower than optimal temperatures for maize growth leading to lower NDF and lignin contents leading to higher digestibilities (Estrada Flores *et al.* 2006). Observed differences may arise when compared to hybrids used in the work of Anaya-Ortega *et al.* (2009) and Hernández-Ortega *et al.* (2011).

In an international context NDF content of maize silages were above than reported by Morgensen *et al.* (2010) in Denmark and Velik *et al.* (2008) in Austria, but similar to values reported by Morrison and Patterson (2007) in Northern Ireland. In terms of ADF, values for the maize silage reported herein were lower than reported by other researchers, whether from Mexico or the international context, indicating that maize silages in the present work had a good digestibility.

Crude protein content of maize silages was within the values reported by Morrison and Patterson (2007) in Northern Ireland, Velik *et al.* (2008) in Austria, and Anaya Ortega *et al.* (2009) and Hernández-Ortega *et al.* (2011) in central Mexico, but below than Morgensen *et al.* (2010) in Denmark and above those reported by Alfonso-Ávila *et al.* (2012) in the study area.

Protein content in the maize plant is determined both by variety as well as maize type and days from sowing to harvest. Temperate maize varieties used in temperate countries are faster growing that tropical highland maize, and the observed differences may be explained by the long growing cycle of maize used in this study and similarities or differences in harvest date within tropical highland maize silages (Anaya-Ortega *et al.* 2009, Hernández-Ortega *et al.* 2011, Albarrán *et al.* 2012, Alfonso-Ávila *et al.* 2012).

Chemical composition of grazed pasture was within values reported by Anaya-Ortega *et al.* (2009) and Hernández-Ortega *et al.* (2011). These results (Table 2) indicated that grazed pasture was short and cows were able to harvest herbage high in protein as the case in other work.

Economic analysis: It is worth noting that notwithstanding the high cost per kg of the experimental soyabean meal + ground maize grain concentrate, the lower

Table 2. Chemical composition of forages and concentrates

	T_1				T_2		
	SM	MG	HPC	MS	CC	MS	GP
DM (g/kg)	953.1	929.3	897.7	401.0	934.5	338.6	361.0
NDF (g/kg DM)	222.4	271.8	235.7	484.6	244.3	548.4	451.4
ADF (g/kg DM)	69.6	23.7	47.00	165.4	65.18	179.3	140.8
Crude protein (g/kg DM)	438.7	77.6	296.8	77.6	174.8	72.0	223.6

T_1, treatment 1; T_2, treatment 2; SM, soybean meal; MG, maize grain; HPC, high protein concentrate; MS, maize silage; CC, commercial concentrate; GP, grazed pasture.

intake at 3.5 kg/cow/day fresh weight against the 5.0 kg of commercial concentrate given in T_2, resulted in concentrate costs in treatment T_1 lowerthan in T_2 treatment. Not having to spend on pasture maintenance, T_1 showed just 4% higher feeding costs (Table 3).

In spite of slightly higher feeding costs in treatment T_1, a slightly higher milk yield resulted in less feeding costs per litre of milk (10.5%) than in T_2; representing a 7% higher returns/feeding cost ratio for T_1 compared to T_2. Maintenance costs for pasture in T_2 represented 16.7% of feeding costs for that treatment, which were not incurred in T_1.

Table 3. Feeding costs for treatments T_1 and T_2 (US $) (considering 5 cows/treatment in 11 experimental weeks)

Attribute	T_1	T_2
Concentrates	702.82	765.04
Pasture	0.00	210.13
Maize silage	608.07	285.03
Total feeding costs	1,310.89	1,260.21

Table 4. Feeding costs and returns (considering 5 cows/ treatment in 11 experimental weeks)

	T_1	T_2
Total milk produced in 11 weeks (kg)	7,302	6,550
Selling price (US US$/kg)	0.41	0.41
Income from milk sales (US$)	2,993.82	2,685.5
Total feeding costs (US$)	1,310.89	1,260.21
Margin over feeding costs (US$)	1,682.93	1,425.29
Feeding cost per litre (US$/kg)	0.17	0.19
Margin over feeding costs per litre (US$/kg)	0.24	0.22
Income / feeding costs ratio (US$)	2.28	2.13

Results supported the statement that the profitability of small-scale dairy farms increase when they rely on home-grown forages with reduced need to buy-in external inputs as concentrates that increase feeding costs (Alfonso-Ávila *et al.* 2012). Feeding costs of T_1 per kg of milk produced were 10.5% lower than T_2. Improved profitability increases the economic performance of the farms, and therefore their sustainability. Fadul-Pacheco *et al.* (2013) identified the economic scale as limiting sustainability so that improved profitability increases the sustainability score; which would also be enhanced by the lower irrigation water requirements of the maize crop compared to pastures.

Treatment T_1 can be applied in future scenarios of scarce water for irrigation purposes since previsions point towards reductions in the availability of irrigation water (Davies *et al.* 2011), so that available water must be utilised with the highest efficiency, where maize forage has shown high water use efficiency, with less water requirements than ryegrass pastures (Neal *et al.* 2011).

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