Supplementation with soya bean meal during the dry season for dairy cows fed on pasture and maize silage in the highlands of Mexico

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Abstract

Small-scale dairy systems (SSDS) are a viable option to ameliorate rural poverty, and in Mexico represent over 78% of dairy farms and provide over 35% of the national milk supply. The economic scale limits the sustainability of SSDS in the highlands of central Mexico, due mainly to high feeding costs due to a large dependence of external inputs, mainly commercial compound concentrates. In these systems where irrigation is available, grazing of temperate cultivated pastures reduces feeding costs in the highlands of central Mexico, although herbage production is limited in the dry season due to low temperatures and limited irrigation. Grazing of cultivated pastures by milking cows complemented with maize silage have been evaluated positively in these systems, but protein intake may be suboptimal. The objective was to evaluate substituting 2 kg/cow/d of soya bean meal (treatment T1) for 4 kg/cow/d of an 18% CP commercial concentrate (treatment T2) in the supplementation of dairy cows grazing for 9 h/d cultivated ryegrass-white clover pastures with limited irrigation complemented with 6 kg DM/cow/d of maize silage. The experiment ran for 10 weeks and was undertaken under a participatory technology development approach in the small-holder *campesino* village of *Ejido San Cristóbal*, following a split-plot design with 6 Holstein cows arranged in pairs by number of calvings and calving date. Cows were assigned at random to one of two treatments. Mean milk yield per week and fortnightly recorded body condition score were used for the analysis. Mean milk yield for T1 was 15.9 kg/cow/d and 16.7 kg/cow/d for T2 (SEM ± 1.1), CP content of milk was 31.46 g/kg in T1 and 31.24 g/kg for T2 (SEM±0.62), milk fat content was 23.33 g/kg for T1 and 34.250 g/kg for T2 (SEM±3.56). Mean body condition score was 1.79 and 1.54 (SEM ± 0.04) for T1 and T2 respectively. There were no statistically significant differences between treatments (P>0.05) for milk yield, milk protein and milkfat content, and body condition score although there were highly significant differences between periods (P<0.001). In spite of no significant difference in animal performance variables, the economic analysis shows that the use of soya bean meal reduced feeding costs in 8 %.

Keywords: Soya bean meal; grazing; maize silage, small-scale dairy systems; Mexico

Introduction

Small-scale dairy systems (SSDS) have the potential to ameliorate rural poverty (FAO, 2010); and small-scale dairy farming in the highlands of central Mexico has the potential of contributing to the regional supply of milk and milk products and is an option to improve living conditions of farming families and communities where dairying is feasible, overcoming poverty indices (Espinoza-Ortega *et al.*, 2007).The assessment of the sustainability of SSDS in the highlands of Mexico showed that the economic scale is the limiting factor, due to high dependence on bought-in inputs resulting in high feeding costs (Fadul-Pacheco *et al.*, 2013).

Feeding expenditures constitute the largest component of direct production costs in cash and of these, expenditures in bought-in concentrates represent the largest expenditure in cash (Espinoza-Ortega *et al.*, 2007; Martínez-García *et al.*, 2015). Forage production is restricted to the summer rainy season (mid May – mid October), with very little rain for the rest of the year. A feeding strategy based on year-round grazing of cultivated ryegrass (*Lolium perenne*) -white clover (*Trifolium repens*) pastures with limited irrigation, complemented with maize silage in the dry season and moderate amounts of conecentrates has been evaluated positively in these systems through participatory on farm trials (Arriaga-Jordan *et al.*, 2002; Anaya-Ortega *et al.*, 2009).

Maize (*Zea mays*) silage represents a number of advantages. Maize originated in Mexico, has been cultivated for millennia, and is the main crop so that farmers have extensive experience and knowledge on the crop that is well adapted. In terms of forage, it has high DM yields with a high content of metabolisable energy. Maize forage also has a high concentration of soluble carbohydrates which makes for easy fermentation (Anaya-Ortega *et al.*, 2009) so that farmers can obtain a well preserved, quality forage if there are conditions for harvesting at the proper timing. However, maize silage is low in protein (Mosqueda and González, 1998; Hernandez-Mendo and Leaver, 2004) which may not be compensated with pasture intake due to low accumulation rates in the dry season that restrict herbage intake; so that cows yielding on average 16 kg milk/cow/day may be deficient in protein under this feeding strategy (Albarran *et al.*, 2012). Soya bean meal is a by-product of the oil extraction process, high in protein content (> 400g CP/kg DM), and a main ingredient in diets for livestock. Although imported in Mexico, it is widely distributed and available to small-scale dairy farmers.

The objective of the present study was to evaluate the supplementation with soya bean meal substituting for 18% PC commercial concentrate in milking dairy cows under continuous grazing of ryegrass-white clover pastures at high stocking rates, complemented with maize silage in the dry season.

Material 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, 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 between the university and the community as described by Albarran *et al.* (2012), and other work undertaken reported previously (Anaya-Ortega *et al.*, 2009; Garduño-Castro *et al.*, 2009).

Animals

Six multiparous Holstein dairy cows with 179 ± 44.4 days in milk were used in the experiment. Cows were grouped in pairs according to size, parity and milk yield previous to the experiment and each cow per pair assigned randomly to treatments. Cows were hand milked twice a day (5:00 h and 16:00 h) when concentrates were fed (half the allocation in each meal. After the morning milking at 7:00 h cows were on continuous grazing for 9 h/day, and brought to the tie-barn for the afternoon milking at 16:00 h, when the silage allocation was also fed. Cows remained indoors for the night in the tie-barn.

Pasture

The pasture consisted of two 0.75 ha plots (1.5 ha in total) sown to perennial ryegrass (*Lollium perenne* cv Nui*)*, intermediate ryegrass (*L. perenne x L. multiflorum* cv. Tama), and white clover (*Trifolium repens* cv. Pitaw). The pasture received limited flood irrigation every 28 days during the dry season, and its management has been reported before (Garduño-Castro *et al.*, 2009; Albarran *et al*., 2012). Stocking rate was high at 4 cows/ha, and cows had water freely available in troughs.

Maize silage

A local landrace of white grain maize was sown on 3 April on 1.5 ha and cultivated following local practice. The maize forage was harvested on 25 October (205 days after sowing), and the maize forage ensiled in a trench silo excavated in the soil, using a tractor to compact the forage. The silo was covered with a 600 calibre black plastic sheet and soil.

Treatments

T1 = Continuous grazing for 9 h/day (7:00 – 16:00 h), plus 6 kg DM/cow/day of maize silage plus 2.0 kg/cow/d of soya bean mal. Soya bean meal was bought locally and had a stated CP content of 440 g/kg DM.

T2 = Grazing and silage similar to T1 plus 4 kg/cow/d of commercial dairy concentrate with a stated CP content of 180 g /kg DM.

Chemical analyses

Pasture herbage, maize silage, soya bean meal and concentrate samples for chemical analyses were dried in a force draught oven at 65 C – 75 °C to constant weight to determine dry matter (DM), ground and ashed at 600 ºC for three hours in a muffle furnace to express results as organic matter (OM). Hand-plucked samples of pasture herbage for chemical analyses were taken randomly every 28 days simulating grazing. analysed for Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin, determined following the procedures of Ankom Technology (2005), and Crude Protein (CP) was determined by the micro Kjeldahl method following standard procedures.

Animal variables

Milk yield (MY) (kg/cow/day) was recorded for morning and afternoon milkings during two consecutive days every week using a spring scale, and mean daily MY per experimental week used for the analysis. Milk samples from individual cows were taken on consecutive milkings for two days on weeks 3, 6 and 9 and milkfat and milk protein contents (g/kg) were determined using an automatic ultrasound analyser (Ekomilk-M). Body condtion score was determined every fortnight on a 1 to 5 point scale with 1 vey thin and 5 over conditioned.

Pasture variables

Sward height was measured weekly by taking 20 recordings from each 0.75 ha pasture plot with an aluminium rising plate grass meter (Hodgson, 1990).

Net herbage accumulation (NHA) (kg OM/ha) of the pasture was estimated every 21 days using ten grazing exclusion cages (2.5 x 0.5 x 0.7 m), five on each plot, and a metal quadrant of 0.50 m^2 (0.25 x 2.0 m) (Hodgson, 1990). Cages were distributed at random at the beginning of the experiment and every 21 days thereafter. Grass was cut to ground level using hand shears. Samples were dried and NHA was estimated by difference between day 21 and day 1. A sub-sample was sent to the laboratory for dry matter (DM) determination.

Statistical analysis

A split-plot experimental design was used, where treatments (T1 and T2) were considered fixed effects (main plots), and the 10 experimental weeks or the fortnightly measurement periods as random effects (split plots); a design suggested as useful for on farm experimentation where replications are limited (Stroup *et al.*, 1993). Response variables were subject to analysis of variance according to the following model:

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

Where:

μ = General mean

b = Effect of cow pairs i = 1, …, 3

T = Effect of treatment (Main Plot) j = 1, 2

E = Error term for Main Plots [b(R)ij]

p = Effect of measurement periods (weeks or periods) (split - plot) k = 1, ..., 10 (or 5 periods for body condition score)

Tp = Interaction term between treatments and measurement periods

e = Error term for split plots

Economic analysis

Feeding costs of the two supplementation treatments (soya bean meal vs. commercial concentrate) were compared by partial budgeting, taking into account the specific costs and returns specific for each treatment following the procedures used previously (Espinoza-Ortega *et al.*, 2007; Martínez-García *et al.*, 2015).

Results

The experiment ran for 10 weeks from 12 March to 20 May. Mean maximal temperature during the experiment was 22.5°C, and mean minimal temperature was 5.5°C, within comfort ranges for dairy cattle and within optimal temperature ranges for the growth of temperate forage grasses and legumes (Hopkins, 2000).

There were a total of 72 mm of rain during the experiment which fell on six days on weeks 3, 4, 8 and 9 of the experiment; insufficient to support pasture growth so that pasture was irrigated every 28 days.

Pasture variables

Mean sward height was 2.55 cm over the experiment, which is considerably lower than the target grass-meter height of 5 cm under which intake by cattle is restricted (Hodgson, 1990). Mean Net Herbage Accumulation was 47.5 kg OM/ha/d representing an availability of 7.9 kg/cow/d insufficient to cover DM intake requirements.

Chemical composition of feeds

Table 1 shows the chemical composition of the hand-plucked herbage for the three measurement periods. Dry matter content was high, above 200 g/kg, reflecting the dry conditions of the season even with irrigation every 28 days and a little rainfall during the experiment. CP content was also high, reflecting tender grass growing through intense spring tillering promoted by the high grazing pressure on continuous grazing.

Table 1. Chemical composition of pasture herbage (*Lollium perenne* cv Nui, *L. perenne x L. multiflorum* cv. Tama), and white clover (*Trifolium repens* cv. Pitaw) (g/kg DM)

	Period	**DM**	**Ash**	**OM**	**CP**	**NDF**	**ADF**
Pasture 1	1	271.32	90.30	909.70	204.30	430.60	294.40
	2	287.83	90.60	909.40	204.00	482.40	359.20
	3	252.11	105.60	894.40	205.10	592.80	309.20
	Mean	270.42	95.50	904.50	204.47	501.93	320.93
Pasture 2	1	332.49	128.10	871.90	285.90	538.80	207.30
	2	248.36	105.70	894.30	242.00	598.20	433.20
	3	252.00	119.60	880.40	199.80	601.00	287.90
	Mean	**277.62**	117.80	882.20	242.57	579.33	309.47

Table 2 shows the chemical composition of the maize silage, the soya bean meal, and the commercial concentrate. Maize silage was harvested later than what had been planned, but there were no frosts so that the maize plants were at 321 g/kg DM, with low CP content and high fibre contents, particularly ADF, as a result of the late harvesting. Optimal harvesting is around 185 days after sowing, but it was not feasible to do it. Nonetheless, the resulting maize silage was of good quality, with a DM content that maximises intake (Phipps *et al*., 2000).

The chemical analysis of the soya bean meal show a very high CP content of 530 g/kg; resulting from the oil extraction process with solvents, higher that the expected CP content. It was thus a good protein source. The commercial concentrate analyses show a CP content of 189.6 g/kg DM, slightly higher than stated in the tag.

Table 2. Chemical composition of maize silage, soya bean meal and commercial concentrate (g/kg DM)

	DM	**ASH**	**CP**	**NDF**	**ADF**
Maize silage	321.1	68.90	62.6	616.4	377.4
Soyabean meal	899.2	74.2	530.2	438.1	213.0
Concentrate	909.1	64.2	189.8	330.8	161.9

Animal variables

Table 3 shows the results for milk yields and milk composition, with no statistical differences between treatments (P>0.05) for these variables although there were highly significant differences (P<0.001) between weeks. The interaction between treatments and experimental weeks was non-significant (P>0.05). There were also no significant differences (P>0.05) for body condition score although cows on Treatment 1 tended to have a slightly better body condition at the end of the experiment.

Table 3. Milk yield, milk composition and body condition score.

	Treatment 1	Treatment 2	SEM
Milk (kg/cow/d)	15.9	16.7	1.10^{NS}
Milk fat (g/kg)	33.33	34.25	3.56^{NS}
Milk Protein (g/kg)	31.46	31.24	0.62^{NS}
Body condition Score	1.79	1.54	0.04^{NS}

^{NS} = P>0.05

Economic Analysis

Table 4 shows the economic analysis by partial budgeting. It only takes into consideration direct expenditures and returns in cash which have most relevance for these small-scale farmers where cash is a limiting resource. Family labour is an opportunity cost and is not included. Maize silage and pasture costs were the same in both treatments.

Table 4. Economic analysis of substituting 2 kg soyabean meal/cow/day for 4 kg commercial concentrate/cow/d for 10 weeks (in US dollars).

Item	T1	T2
Bought in feeds	$ 363.37	$ 614.93
Maize silage	$ 515.91	$ 515.91
Pasture	$ 860.55	$ 860.55
Total direct feeding costs	$ 1,739.83	$ 1,991.39
Sold milk (litres)	3,335	3,501
Income from milk sales (US $)	$ 3,329.36	$ 3,494.97
Margin	$ 1,589.53	$ 1,503.58
Feeding cost (US$ / L)	$ 0.52	$ 0.57
Returns / Feeding cost (US$)	$ 1.91	$ 1.75

Discussion

Pasture conditions

Sward height during the experiment was 2.5 cm measured with the rising plate grass metre, depicting a very high grazing pressure with a sward height below recommendations for dairy cattle (Mayne *et al.*, 2000). Nonetheless, it is worth noting that in spite of a low sward height, NHA was high with 41.16 kg OM/ha/day for pasture I and 88.67 kg OM/ha/day for pasture II, higher than the 12.0 kg OM/ha/day calculated to meet DM requirements of experimental cows. Although mean sward height was low, it increased as the experiment preceded with only 2.1 cm in Period I, increasing to 3.4 cm at the end of the experiment given higher NHA.

NHA was higher to reports by Pincay-Figueroa *et al.* (in press) of 32 kg DM/ha/day, and Celis-Alvarez *et al.* (2016) of 29.5 both during the dry season and under continuous grazing in SSDS near the study area; but NHA results are similar to NHA previously reported in the study area of 39.2 kg DM/ha/day (Albarran *et al.*, 2012), and within the range reported by Lemus-Ramírez et al. (2002), with values between 32 and 65 kg DM/ha/day for temperate pastures under rotational grazing also in Mexico.

Chemical composition of feeds

Herbage chemical composition of simulated grazing (hand-plucked samples) had a high CP content, higher than reports from Albarran *et al*. (2012) in the same study area and reports from Celis-Alvarez *et al.* (2016) also in SSDS in a nearby area; but similar to reports from the UK of grazing dairy cows under continuous grazing at low sward heights and high stocking rates (Hernández-Mendo and Leaver, 2006) who report CP contents of 242 and 272 g/kg DM.

NDF and ADF content of herbage was lower than reported by Albarran *et al.* (2012), but higher than reports by Celis-Alvarez *et al*. (2016) from Mexico, and Hernández-Mendo and Leaver (2006) from the UK. Grazed herbage in this experiment was of good nutritional quality, with high crude protein content, and estimated metabolizable energy (eME) content (from ADF) around 10.5 MJ eME/kg DM)

Maize silage

Maize silage was slightly lower in CP than reports from Mexico (Albarran *et al*., 2012; Celis-Alvarez *et al.*, 2016) and other countries like the UK (Phipps *et al.*, 2000; Hernández-Mendo and Leaver, 2006), and Argentina (Di Marco *et al.*, 2002). Results show clearly that maize silage is deficient in protein. It was lower in NDF and ADF than reports from Mexico (Albarran *et al*., 2012; Celis-Alvarez *et al*., 2016), but higher in both fibre fractions than reports from the UK (Phipps *et al*., 2000; Hernández Mendo and Leaver, 2006), and Argentina (Di Marco *et al.*, 2002).

Late rains make it difficult to harvest maize for silage at the optimal condition due to wet soils that preclude the entrance of machinery into the maize fields (Anaya-Ortega *et al.*, 2009), although nutritional quality is acceptable.

Animal variables

There were no statistical differences between treatments for any of the animal variables recorded. Milk yields were moderate with a mean of 16.3 kg/cow/day, with milk fat and protein contents within Mexican standards for raw milk. Moderate milk yields are usual in SSDS in central Mexico. Observed milk yields and composition are similar to reports by Heredia-Nava *et al.* (2007), Martínez-García *et al.* (2015), and Celis-Alvarez *et al.* (2016); but lower than reports by Anaya-Ortega *et al.* (2009), Hernández-Ortega *et al.* (2011), and Albarran *et al*. (2012).

Body condition score was low, as is the case for Holstein cows in SSDS in central Mexico (Heredia-Nava *et al.*, 2007; Albarran *et al.*, 2012). Hodgson (1990) suggests that concentrate supplementation may improve body condition score, more than milk yields, which was not observed in the present experiment.

Economic analysis

Commercial compound concentrate was 69% more expensive than soya bean meal, which was reflected in 14% higher total feeding cost of T2 with commercial compound concentrate as supplement compared to T1 with soya bean meal.

Taking the nominal milk yields, even though there were no significant differences, the lower feeding cost of T1 resulted in 6% higher total margins over feeding costs and 9.1% higher returns over feeding ratio in T1 compared to T2.

Conclusion

There were no differences in grazing dairy cow performance under the two supplement treatments, but supplementing with 2.0 kg/cow/day of soya bean meal instead of 4.0 kg/cow/day of commercial compound concentrate reduces feeding costs and increases margins over feeding costs and the returns over costs ratio.

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