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ORIGINAL RESEARCH

Effect of silage from ryegrass intercropped with winter or common vetch for grazing dairy cows in small-scale dairy systems in Mexico

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Abstract The objective was to determine the effect of including silages of annual ryegrass (*Lolium multiflorum*) intercropped with winter vetch (*Vicia villosa*) (ARG-VV) or with common vetch (*Vicia sativa*) (ARG-VS) compared with maize silage (MS) on milk yield and milk composition of dairy cows grazing cultivated perennial ryegrass–white clover pastures with supplemented concentrate during the dry season. Six Holstein dairy cows with a mean yield of 19.0 kg/cow/day at the beginning of the experiment were randomly assigned to a 3×3 repeated Latin square. Treatments were: 8 h/day intensive grazing, 3.6 kg of dry matter (DM) per cow per day of concentrate plus MS, and ARG-VV or ARG-VS ad libitum at a stocking rate of 3.0 cows/ha for three experimental periods of 3 weeks each. Milk yield (MY) and milk composition, live weight and body condition score as well as silage and concentrate intakes were recorded during the third week of each experimental period, and pasture intake was estimated indirectly from utilised metabolisable energy. Economic analysis was obtained by preparing partial budgets. There were no statistical differences ($P>0.10$) in MY, milk fat or protein content nor for live weight, but there was significant difference ($P<0.10$) in body condition score. There were non-statistical differences in silage DM intake ($P<0.11$); however, significant differences ($P<0.10$) were obtained for estimated grazed herbage intake whilst no differences for total DM intake. Slightly higher economic returns (10%) were obtained with ARG-VS over MS, and this was 7% higher than ARG-VV. It is concluded that ARG-VS could be an option for complementing grazing for small-scale dairy production systems in the dry season as it is comparable to MS in animal performance and slightly better in economic terms.

Keywords Small-scale dairy systems · Annual ryegrass–vetch silage · Maize silage · Grazing · Highlands · Mexico

Abbreviations

ADF	Acid detergent fibre
ADL	Acid detergent lignin
ARG	Annual ryegrass
DM	Dry matter
IVDMD	In vitro DM digestibility
IVOMD	In vitro OM digestibility
m a.s.l	Metres above sea level
ME	Metabolisable energy
NDF	Neutral detergent fibre
NHA	Net herbage accumulation
OM	Organic matter
SEM	Standard error of the mean

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Introduction

The highlands of central Mexico concentrate a large proportion of the rural poor of the country which share many common ecological and social features with other highland communities in Latin America (Rushton 2008) where improvement of the living conditions of these rural populace is part of the main national objectives.

To increase their income, small-scale dairy farming may be a development option for these smallholder *campesino* farmers, given its ability to generate daily incomes, employment opportunities and economic stability in these rural areas (Espinoza-Ortega et al. 2007). Livestock and dairy production have contributed to the economies of other Latin American countries, and they are seen as a path out of rural poverty (Pica-Ciamarra and Otte 2008), e.g. Peru (Bartl et al. 2009) and in other countries like Kenya and India (Mwangi et al. 2005).

Grazing is the least costly source of nutrients for dairy cows as grazed pasture has a high nutritional value and is the most economic source of feed although its seasonal growth pattern results in insufficiency of feed for animals (Burke et al. 2008). This also applies to temperate areas of Mexico where the seasonal pattern in herbage growth is due to a marked rainy season with abundant herbage, followed by the dry season with reduced forage even when under irrigation. Therefore, complementing diets with conserved forages is a viable alternative to maintain dry matter (DM) intakes and milk yields (Morrison and Patterson 2007; Bartl et al. 2009).

Maize silage has proven to be a viable alternative for these systems with positive economic benefits (Anaya-Ortega et al. 2009). It is a preferred forage constituent for dairy cattle feeding systems because of its ability to produce high yields and good energy supply at a relatively low cost, and also, it can easily be conserved as silage due to its high soluble carbohydrate content which is needed during fermentation. However, maize silage (MS) has low protein content which may be a limiting factor, and there are indications that dairy cows with limited access to pasture with moderate amounts of commercial concentrate supplements and maize silage may be consuming less protein than required.

Maize silage may also decrease the intake of grazed herbage due to its substitution effects (Morrison and Patterson 2007; Burke et al. 2008), and in the Mexican highlands, it is difficult to harvest maize silage at optimum stage of growth (Anaya-Ortega et al. 2009) without decreasing the quality. To overcome this, silage of temperate grasses like annual ryegrass (*Lolium multiflorum*) may be an option. They provide good quality forage especially if intercropped with legumes to enhance their protein content (Kaiser et al. 2007).

Previous work (Anaya-Ortega et al. 2009) showed that ensiled annual ryegrass improved the feeding of cows in small-scale dairy production systems. The intercropping of annual legumes with grass may increase the protein content of the silage (Kaiser et al. 2007; Pursiainen and Tuori 2008) resulting in higher feed intake and higher milk production, thus improving the management of the herds during dry season.

The use of common vetch is widespread in temperate, Mediterranean and subtropical environments (Pursiainen and Tuori 2008; Erol et al. 2009, Nadeem et al. 2010), whilst the use of hairy vetch is less common but has the advantage of being frost resistant. Vetches have the advantage of an erect growth habit that favours harvesting when used for conservation purposes, thus maximising harvested legume herbage when compared to more prostrate growing pasture legume species (Kaiser et al. 2007). There are a number of reports (Kaiser et al. 2007; Erol et al. 2009; Nadeem et al. 2010) on the intercropping of vetches with small grain cereals for forage, but it is uncommon to intercrop vetches with grasses (Kaiser et al. 2007).

In this study, silages from annual ryegrass (*L. multiflorum*) were intercropped with either common vetch (*Vicia sativa*) or hairy vetch (*Vicia villosa*) in comparison with maize silage (*Zea mays*) so as to complement the diet of dairy cows on restricted grazing given moderate amounts of concentrate during the dry season.

Furthermore, the work is aimed at developing low-cost feeding strategies for small-scale dairy systems in the highlands of Mexico. This will enable these systems to survive in competitive scenarios where milk prices are expected to be low so that lower costs of production are the way forward for these systems (Pica-Ciamarra and Otte 2008).

Material and methods

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

Maize silage

The maize crop was sown on 13 May 2007 in a 1.5-ha plot following the farmers' management style of disc ploughing followed by two passes with a disc harrow and one irrigation before sowing. A white hybrid maize cv. H-33 was sown at a density of 35 kg /ha. Two mechanical cultivations for weed control and ridge formation were undertaken at 30 and 60 days after sowing. Fertiliser was applied at sowing and also at the first cultivation. Besides mechanical cultivation, weeds were controlled with the application of herbicides. Plant density (PD) and DM yields were estimated following a linear method of counting plants using 54 transects of 3 m long which are systemically located in the maize plot. Mean plant weight per plant was determined from 40 individual plants collected before harvest by recording their height and weight. DM estimation was done taking the relationship between weight, height and PD. The maize silage (MS) harvest was done 186 days after sowing and chopped to a 5 cm particle size. They were then placed in a trench silo and covered with a black plastic sheet (600 gauge) with soil on top.

Intercropped silages

The intercrop of annual ryegrass and winter vetch (*V. villosa*) (ARG-VV) and annual ryegrass and common vetch (*V. sativa*) (ARG-VS) were sown on 13 June 2007. Each intercrop was sown on a 0.5-ha plot with a density of 35 kg/ha of annual ryegrass seed (*L. multiflorum* cv. Tetragold) and 50 kg/ha for winter vetch (*V. villosa* L. cv. Rot) and common vetch (*V. sativa* L. cv. Michoacano). Both intercrops were harvested 48 days after sowing with a forage yield of 958.7 and 1,833.7 kg DM /ha for ARG-VV and ARG-VS, respectively. Silage was prepared from the second cut 84 days after the first cut. The long time between the first and second cut was due to excess moisture in the soil which impeded taking the second cut earlier.

Forage was ensiled in ‘pie’ silos overground, which were compacted and covered with a 600-gauge black plastic sheet and soil. Herbage mass was estimated before harvest with five quadrants (2.0×0.25 m) per plot placed randomly. The forage was cut to ground level using shears. Samples were dried for 48 h at 60°C in a draught oven and yields as DM kilogrammes per hectare.

Pasture

The cows grazed continuously for 8 h/day at a stocking rate of 3 cows/ha on a pasture sown to perennial ryegrass (*Lolium perenne* L. cv. Nui), annual ryegrass (*L. multiflorum cv.* Tetragold) and white clover (*Trifolium repens* L. cv. Ladino) at a seed density of 20, 15 and 3 kg/ha, respectively. The pasture was irrigated every 28 days and fertilised after each irrigation with 45 kg/ha of urea (46% N). Net herbage accumulation (NHA) was determined using exclusion cages (2.5×0.5×0.80 m) which are randomly located. The record for NHA was taken every 28 days following the procedure described by Heredia-Nava et al. (2007).

Animals and treatments

Six Holstein-Friesian dairy cows were used (three first-calf heifers and three multi-calved cows) with mean live weight (LW) of 500.4±34.25 kg, milk yield of 19.5±2.65 kg/day, 1.83±0.92 calvings and 101.17±78.52 days in lactation. The experiment lasted for 9 weeks.

Treatments were the inclusion of the three types of silage in the feeding based on 8 h/day access to grazing and moderate amounts of concentrate as follows:

MS	Grazing for 8 h/day plus 4 kg/cow/day of commercial concentrate (180 g/kg of crude protein (CP)) plus ad lib maize silage at night
ARG-VV	Grazing for 8 h/day plus 4 kg/cow/day of commercial concentrate (180 g/kg CP) plus ad lib annual ryegrass+winter vetch silage at night
ARG-VS	Grazing for 8 h/day plus 4 kg/cow/day of commercial concentrate (180 g/kg CP) plus ad lib annual ryegrass+common vetch silage at night.

Cows were milked with a portable milking machine twice a day (0430 and 1630 hours) in a tie-stall barn when the concentrate is provided. The silages were fed after the second milking ad libitum.

Experimental design

The experimental design was a repeated 3×3 Latin square. Cows were assigned to two squares (groups) according to parity and were randomly assigned to treatment sequences.

Square 1 was formed by first-calf heifers in early lactation with 35.3±34.4 days in lactation, 462.3±31.8 kg LW and 19.6±1.3 kg/cow/day MY. Square 2 are cows in mid lactation with 145.3±18.4 days in lactation, 541±41.3 kg LW and 18.9±1.7 kg/cow/day MY.

The experiment lasted was for 9 weeks with experimental periods of 3 weeks each, where the first 14 days were for adaptation to diets and the last week was for recordings.

Animal measurements

Recordings were undertaken on the last 7 days of each period; MY was recorded using a spring balance. Mean daily MY (kilogrammes per cow per day) was used in analysis. LW (kilogrammes per cow) was recorded for three consecutive days after the morning milking with a portable electronic weigh bridge, and mean LW was used for analysis. The day before the recording week, body condition score (BCS) was determined on a 1 to 5 scale.

Milk samples of two consecutive milkings were obtained on days 13, 16 and 19 of each experimental period. Milk fat and protein content (grammes per kilogramme) were determined using an ultrasound analyser (Ekomilk-M®) and mean values used for analysis.

Silages and concentrate intakes (kilogrammes of DM per cow per day) were recorded during the third week in each experimental period by calculating the difference between the amounts of silage offered and refused. Representative samples of offered and refused silages were obtained and dried to obtain DM content. Grazed herbage intake was estimated indirectly from calculations for energy requirements of milking dairy cows from Animal and Food Research Council (1993) and estimated metabolisable energy (ME) content of feeds from chemical analysis following Anaya-Ortega et al. (2009).

Chemical analysis

On each measurement week, daily plucked samples of simulated grazing were obtained and dried. Samples of concentrate and silages were also taken daily during the third week in every period. Samples were thoroughly mixed and a sub-sample taken for chemical analysis for DM and ash according to standard procedures, CP by micro Kjeldahl, neutral detergent fibre (NDF) and acid detergent fibre (ADF) by the ANKOM method, and in vitro DM digestibility (IVDMD) was determined by the gas production technique following an established procedure by Anaya-Ortega et al. 2009.

Experimental design and statistical analysis

The experiment followed a repeated 3×3 Latin square design with three 21-day experimental periods and two squares with three cows each grouped as described above. The model for analysis followed Anaya-Ortega et al. (2009):

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

Where:

- μ General mean
- S Effect due to squares i=1, 2, 3
- C Effect due to cows within squares j=1, 2, 3
- P Effect due to experimental periods k=1, 2, 3
- T Effect due to silage treatment l=1, 2, 3
- e Residual error term

Significant differences between means were compared with the Tukey test (P<0.10).

Economic analysis

Feeding costs of the three silage treatments were compared by partial budgeting, taking into account only the costs and returns in cash. Expenditures considered 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 dollars per kilogramme of DM taking all costs involved in growing, harvesting and ensiling the maize crop by a subcontractor. Returns were the milk sales for the duration of the experiment. The opportunity cost of the participating farmer's labour is 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, although all opportunity costs of family labour are included in whole farm studies for longer periods (Espinoza-Ortega et al. 2007).

Results

Weather conditions

The experiment started on the 26th of March and ended on the 27th of May 2008. Climatic conditions in 2007 when crops were established showed a mean temperature of 14°C, with a maximal temperature of 27.6°C and 491.3 mm of rainfall during the growth period of crops. During the nine experimental weeks, rainfall was 124.7 mm, minimum temperature of −0.4°C and maximal temperature of 27.8°C, with the lowest temperature recoded in period 1.

Maize crop

Estimated maize plant density was 69,474 plants per hectare and a DM yield of 18,063 kg DM/ha of which 15,896 kg DM/ha were actually ensiled (88% harvest efficiency). DM content of the MS was 0.345 kg DM/kg.

Intercropped silages

The ARG-VV and ARG-VS silages were done from the second cut. Forage yield for silage was 5,688.5 kg DM/ha for ARG-VV and 8,053.3 kg DM/ha for ARG-VS. Total yields were 6,647.20 kg DM for ARG-VV and 9,887.0 kg DM/ha for ARG-VS, when the yields of the first cut were added.

Perennial ryegrass–white clover pasture

NHA of the pasture was 1,826 kg DM/ha for the 63 days that the experiment lasted with a daily herbage growth of 28.98 kg DM/ha representing a daily allowance of 9.66 kg DM/cow/day with variations between experimental periods. NHA was higher in period 1 (696 kg DM/ha) with a daily allowance of 11.05 kg DM/cow/day.

Chemical composition of feeds

Grazed herbage was of good quality with 189 g CP/kg and high in vitro organic matter (OM) digestibility (IVOMD; 800 g/kg DM). The delay in taking the second cut of the intercropped ARG-VV and ARG-VS crops affected the quality of silages with higher NDF and ADF than MS resulting in lower IVOMD (Table 1).

Animal performance

Table 2 shows the results for the animal variables. There were no statistical differences ($P>0.10$) in MY. There were no differences ($P>0.10$) in milk protein or milk fat contents, and all were within Mexican standards for milk constituents. There were small but significant differences ($P<0.10$) in BCS, with cows on MS having a higher score; but there were no statistical differences observed in live weight ($P>0.10$) among treatments with a mean live weight of 501.5 kg/cow.

Also, there were no significant differences in silage intake among treatments ($P>0.10$). However, there were some indications of higher intake of silage by cows on MS treatment ($P<0.11$) consuming a mean of 8.4 kg DM/cow/day which was 1.2 and 1.9 kg DM/cow/day higher than ARG-VS and ARG-VV silages, respectively. This resulted in significant differences ($P<0.10$) in estimated herbage intake although there were no significant differences ($P>0.10$) in total mean daily dry matter intake (DMI). DMI represented 2.9% of mean live weight. There were no concentrate refusals.

Economic analysis

Table 3 shows the partial budget analysis for direct costs and returns of the experiment. Treatment ARG-VV showed the highest costs due to low forage yield compared with ARG-VS and MS. The higher costs for ARG-VV was due to the cost of winter vetch seed which is imported compared with common vetch which is readily available in Mexico since it is home-produced coupled to significantly lower DM crop yields in ARG-VV. There was also a 48.7% higher yield in the ARG-VS treatment over the ARG-VV silage yield.

All treatments had favourable returns with feeding costs representing 37% of the milk sale price, and returns over feeding costs had ratios ranging from US $2.47 for ARG-VV to US $2.70 for MS and US $2.76 for ARG-VS.

Discussion

This work was undertaken in small-scale dairy systems in the central highlands of Mexico. It is aimed at optimising the use of available forage resources in the feeding of dairy herds to lower production costs and increase the viability of these systems. This is sought for in many regions both in developed (Kaiser et al. 2007; Burke et al. 2008) and developing countries (Bartl et al. 2009; Mekonnen et al. 2010).

The use of silages as complement in the feeding of grazing dairy cows has been researched in a variety of systems (Woodward et al. 2006; Burke et al. 2008; Anaya-Ortega et al. 2009; Slots et al. 2009), particularly when there is limited availability of forage like in the dry season. Also, complementary silage may sustain or even improve milk yields even with low herbage allowance (Woodward et al. 2006; Burke et al. 2008). Silage from forage legumes can improve milk yields because of their protein content (Woodward et al. 2006), which was why the vetches were intercropped with annual ryegrass in this work.

There were differences in the DM yield between ARG-VS and ARG-VV which can only be explained based on differences in vetch species since both annual ryegrass–vetch crops received similar management. The ARG-VS yield of ensiled DM was 40% higher than ARG-VV; however, Heredia-Nava et al. (2007) reported that the ARG-VS yield was higher in DM than annual ryegrass–white clover pasture. The ensiled maize DM yield was within reports obtained in Mexico (González-Castañeda et

Table 1 Chemical composition of grazed pasture, MS, ARG-VV, ARG-VS and concentrate

	Pasture	MS	ARG-VV	ARG-VS	Concentrate
DM (g DM /kg)	229	345	186	230	910
Ash (g/kg DM)	121	68	180	173	69
OM (g/kg DM)	879	931	820	827	931
CP (g/kg DM)	189	79	98	112	178
NDF (g/kg DM)	499	491	501	529	202
ADF (g/kg DM)	243	245	283	336	72
ADL (g/kg DM)	46	61	57	60	54
IVDMD (g/kg DM)	794	785	755	722	868
IVOMD (g/kg DM)	800	792	791	735	879

DM dry matter, *OM* organic matter, *CP* crude protein, *NDF* neutral detergent fibre, *ADF* acid detergent fibre, *ADL* acid detergent lignin, *IVDMD* in vitro DM digestibility, *IVOMD* in vitro OM digestibility

Table 2 Animal variables of dairy cows grazing perennial ryegrass–white clover pastures with supplemented concentrate during dry season

Variable	MS	ARG-VV	ARG-VS	SEM	P
MY (kg/cow/day)	18.5	18.3	18.8	0.47	0.847 NS
Milk protein content (g/kg)	31.6	31.0	31.2	0.07	0.228 NS
Milk fat content (g/kg)	32.3	32.1	33.0	1.46	0.810 NS
LW (kg)	506.4	495.2	502.9	34.65	0.276 NS
BCS (1–5)	1.8	1.7	1.7	0.004	0.057*
Silage intake (kg DM/day)	8.4	6.5	7.2	0.41	0.107 NS
Grazed herbage intake (kg DM/day)	2.1	3.8	4.0	0.057	0.287*
Concentrate intake (kg DM/day)	3.6	3.6	3.6		
Total DM intake (kg DM per day)	14.1	13.9	14.8	0.18	0.275 NS

NS not significant, $P>0.10$

$*P<0.10$

al. 2006; Anaya-Ortega et al. 2009) and was 60% higher than the ARG-VS yield.

Pasture growth during the experiment restricted herbage allowance to less than 10 kg OM/cow/day. This is due to the limited irrigation available which was unable to fully compensate the water deficit of the pasture need as the dry season progressed coupled with high temperatures that reached a maximum of 27.6°C above the ceiling of 20–25°C for herbage growth for temperate grasses. The low herbage availability in the dry season calls for the complement of other forage sources which was evaluated in this paper.

The chemical composition of MS was similar to that reported by Anaya-Ortega et al. (2009) in the same study area in Mexico and compares in CP content of maize silage composition reported by authors in other countries (Morrison and Patterson 2007). However, MS in this study had higher

Table 3 Economic analysis of dairy cows grazing cultivated perennial ryegrass–white clover pastures with supplemented concentrate during dry season (in US dollars)

	Treatments		
	MS	ARG-VV	ARG-VS
Expenditures (US$)			
Concentrate	184.62	184.62	184.62
Silage	59.28	86.42	55.55
Grazed pasture	95.60	95.60	95.60
Feeding costs	339.51	366.65	335.78
Returns ($)			
Milk produced (l)	2,408.3	2,377.9	2,438.6
Milk sales (US$)	916.56	905.02	928.09
Margin	577.05	538.37	592.31
Feeding cost of production (US$/L)	0.14	0.15	0.14
Sale price (US$)	0.38	0.38	0.38
Difference (US$ /L)	0.24	0.23	0.24
Returns/feeding costs ratio (US$)	2.70	2.47	2.76

NDF and higher in vitro digestibility of the DM than the maize silage used in the work of Burke et al. (2008) and similar in comparison with the maize silage reported by Anaya-Ortega et al. (2009) who utilised the same hybrid variety within the same study area.

The CP contents in the ARG-VS and ARG-VV silages were low due to the reason that ensiling took place after an 84-day re-growth after the first cut. This is similar to the CP content of the ARG silage without legumes reported by Anaya-Ortega et al. (2009). Also, the CP contents in both ARG-VV and ARG-VS were lower compared to the annual ryegrass–vetch crop reported by Kaiser et al. (2007) of 130 g CP/kg DM harvested at 126 days after sowing in New South Wales, Australia, although OM digestibility was similar for ARG-VS (0.740 g/kg OM) but higher OM digestibility in ARG-VV (0.790 g/kg OM). At these OM in vitro digestibilities, the estimated ME content would be around 9.5–10.0 MJ ME/kg DM which can support high cattle production (Kaiser et al. 2007).

Chemical composition of the grazed pasture was similar in CP to reports by Ferris et al. (2008) and Hernández-Mendo and Leaver (2006). NDF and ADF in the grazed herbage reported by Ferris et al. (2008) are very similar to values reported in this study but lower than reports by Hernández-Mendo and Leaver (2006). Digestibility of OM in the grazed perennial ryegrass–white clover pasture in this work is higher than reports by Woodward et al. (2006) but similar to that reported by Anaya-Ortega et al. (2009).

Milk yields were lower to those reported by Anaya-Ortega et al. (2009) but similar to yields reported by Heredia-Nava et al. (2007). However, milk yields reported in the study are higher than those reported by Woodward et al. (2006) from work in New Zealand with no concentrate supplements and similar to those reported by Morrison and Patterson (2007) and Ferris et al. (2008) from work in Northern Ireland. There were no significant differences between treatments for protein and fat contents in milk which was also observed by other authors as Woodward et al. (2006) in New Zealand and Burke et al. (2008) in Northern Ireland.

Milk protein content was similar to that reported by Woodward et al. (2006) and Morrison and Patterson (2007) but lower than the report from Ferris et al. (2008). Milk fat content was significantly lower in this work than in the papers from these referred authors but nearer to those reported by Anaya-Ortega et al. (2009) who evaluated complementing grazing dairy cows with silage from annual ryegrass, maize or their mixture. Low milk fat contents in these small-scale systems may reflect the Holstein lineage of the cows coupled with the fact that the feeding regime may be causing an acid rumen environment.

The MS resulted in the highest silage intake and ARG-VV in the lowest although there were no differences ($P>0.10$) in total DM intake due to substitution effects. The substitution effect was due to the low herbage availability between silage intake and grazed herbage intake. The lowest grazed herbage intake was observed when cows were on MS whilst there were higher DM intakes on ARG-VS and ARG-VV although differences in intakes were not significant.

Total DM intakes were similar to those reported by Morrison and Patterson (2007) although the major component of intake in this work was the silages. Total DM intakes are higher than the intake reported by Woodward et al. (2006) although lower when compared to the full pasture allowance or the restricted pasture plus supplements.

There were small but significant differences in body condition scores which were not reflected in live weight. However, results on live weight and body condition score must be taken cautiously since the change over nature of the Latin square design makes it difficult to infer results on these variables.

The advantages of systems based on grazing are the low feeding costs. Good quality conserved forages like silages are a complement option for the dry season as they have lower costs per unit of DM compared to the large amounts of concentrates farmers usually feed their animals during this period.

The best options in this work are the ARG-VS and MS treatments that yielded the lower feeding costs whilst the ARG-VV treatment resulted in 9% higher costs. The lower silage cost is for the ARG-VS treatment although only $4.00 lower than MS. However, economic returns were positive in the three treatments.

These results show how conserved forages may be included in the dry season feeding strategies for small-scale dairy systems in the highlands of central Mexico with positive economic returns, which may be applicable to similar systems in Latin America. Intercropped annual ryegrass with common vetch may be an option compared to maize silage since it does have similar productive and economic responses, although its lower forage yield which was nearly half that of the maize crop should be taken into account.

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