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ORIGINAL ARTICLE

# Feeding strategies for small-scale dairy systems based on perennial (*Lolium perenne*) or annual (*Lolium multiflorum*) ryegrass in the central highlands of Mexico

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**Abstract** Small-scale dairying is an option for *campesinos* in Mexico. The costs of feeding are high and strategies based on quality forages are a priority. The performance, agronomic variables and feeding costs were evaluated for dairy cows continuously grazing perennial ryegrass–white clover for 9 h/day (PRG) or fed cut herbage from annual ryegrass for 8 weeks followed by 9 h/day for 6 weeks on a tethered rotational grazing pattern (ARG). All cows received 3 kg/day of an 18% crude protein (CP) concentrate. A 14-week split-plot on-farm experiment was designed with 10 cows from two participating farmers, and 1.5 ha per strategy. Milk yield was recorded weekly and milk composition, live weight and body condition score were recorded every 14 days. Net herbage accumulation was greater for ARG (8222 kg organic matter (OM)/ha) than for PRG (5915 kg OM/ha) ($p<0.05$), with higher CP in PRG ($p<0.05$). Milk yield was 19 kg/cow per day for PRG and 15.9 kg/cow per day for ARG ($p>0.05$). Over 14 weeks, PRG produced 1422 kg more milk. There were no differences for live weight or condition score ($p>0.05$), but linear regression shows a live weight gain of 0.200 kg/cow per day for PRG. Protein and fat content showed no differences ($p>0.05$), but milk fat content in PRG was below standard. ARG had 60% higher costs, and margins were 38% higher in PRG. ARG has a place in rain-fed fields. The results provide viable options for improving these systems that may be suitable in their socio-economic context and their social and personal objectives.

**Keywords** Small-scale dairy farming · Grazing · Perennial/annual ryegrass · White clover · Highlands · Mexico

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**Abbreviations**

| | |
|---|---|
| ADF | acid detergent fibre |
| ADL | acid detergent lignin |
| CP | crude protein |
| DM | dry matter |
| NDF | neutral detergent fibre |
| NHA | net herbage accumulation |
| OM | organic matter |
| SEM | standard error of the mean |

## Introduction

Small-scale dairy farming, representing small farms and herds of less than 20 cows plus replacements, may be a rural development option for smallholder *campesino* farmers in the highlands of Central Mexico, comprising the region between 18° and 22°N at altitudes above 1500 m, given its capacity to generate daily incomes and provide employment opportunities for farming families, reducing poverty and the need to migrate to cities (Arriaga-Jordán *et al*., 2002).

A limiting factor in these systems is the high cost of cattle feeding, which represents most of the production costs, particularly in terms of cash expenditures given the usual provision of large amounts of commercial concentrates (Arriaga-Jordán *et al*., 2002). Therefore, developing appropriate feeding strategies for these systems has been a priority (Arriaga-Jordán *et al*., 2001).

An option to reduce feeding costs is a larger reliance on home-grown high-quality forages, which ensures low production costs (Delaby *et al*., 2001). Well-managed forage produced in temperate climates is of high quality, favouring a lower dependence on external inputs such as commercial concentrates. The intensive grazing of perennial ryegrass (*Lolium perenne*)–white clover (*Trifolium repens*) pastures under irrigation has proved to be a viable option for these farmers (Arriaga-Jordán *et al*., 2002). However, cut-and-carry systems of annual grasses have been promoted as an alternative by the local extension service; and farmers expressed their interest in evaluating this alternative during the summer rainy season; annual ryegrass (*Lolium multiflorum*) is a good option.

The objective of this study was therefore to compare two feeding strategies on animal performance in terms of milk yields, milk composition, live weight and body condition score from dairy cows grazing perennial ryegrass pastures, or fed cut herbage from annual ryegrass followed by grazing as rain subsided. Agronomic variables and the production costs of milk under the evaluated strategies were also recorded.

## Materials and methods

The study was carried out in the *campesino* village of Ejido San Cristóbal, in the central highlands, located between 19°24′ N and 99°51′ W, at an altitude of 2650 m; with a sub-humid temperate climate, a mean yearly temperature of 13°C, and rains concentrated in the summer (June to October).

A Participatory Technology Development approach, through on-farm research, was used (Reijntjes *et al.,* 1992). Five *campesino* farmers were actively involved in the project assessing annual ryegrass pastures in comparison to the perennial ryegrass pastures from another local farmer who has been grazing his herd for several years now. Farmers provided the arable land for growing the ryegrass plots, the cost of establishing and maintaining their pastures, their dairy herds for the productive evaluation including the concentrates, and their labour; the research team provided the ryegrass seed and undertook sward and animal measurements.

The small herds in these systems change constantly as farmers buy and sell their cows, heifers and calves when the opportunity for buying or exchanging for better cows or heifers arises, or when there is a need to sell to meet cash requirements. Therefore, this paper presents only the results from one farmer who participated in the evaluation of the annual forage and one farmer in the evaluation of the perennial ryegrass pasture, both of whom kept a constant number of cows in their herds and were able to commit five cows each for the length of the experiment reported here.

The experiment ran for 14 weeks (9 August to 14 November 2004), with an eight-day period for adaptation to the feeding strategy before the start of the experimental period.

### Treatments

Two feeding strategies were evaluated. The first strategy was based on annual ryegrass (ARG) which was hand cut daily with a scythe and fed *ad libitum* in troughs administered three times a day. After eight weeks, towards the end of September when the rains had subsided, the annual ryegrass was well established and the peak of herbage growth had passed (making it less attractive to cut), the farmer switched to rotationally grazing the pasture by tethering the cows to a 12.17 m rope giving access to 465.31 $m^2$ per cow for 9 hours per day for the last six weeks of the experiment, plus cut herbage overnight.

The second strategy was continuous grazing of perennial ryegrass (PRG) pastures for 9 hours per day (07:00 to 16:00) and housing overnight for the whole of the 14-week experiment. Cows in PRG treatment did not received any other forage or feed during the housed period.

All cows also received 3.0 kg/day of a commercial compound concentrate containing 180 g/kg crude protein (CP), split into two meals at milking times.

## Animals

Ten similar upgraded Holstein cows from the two participating farmers were selected; eight were multiparous and two primiparous; they were paired according to calving date and parity, and assigned to each treatment. Cows in both treatments were hand milked twice daily (at 05:00 and 16:00). Cows were on average 47 days in lactation at the beginning of the experiment and had a mean milk yield of 17.6±2.04 kg milk/day for ARG and 18.0±3.64 kg milk/day for PRG, and overall initial live weight of 419±79.20 kg on average, with no significant differences between these variables at the start of the experiment ($p>0.05$).

Milk yield was recorded once a week using spring scales, and analyses for fat and protein content were undertaken every 14 days, when cows were also weighed after the morning milking with an electronic weighbridge, and body score was recorded following ESCA (1976). Milk composition was determined automatically using an Ecomilk-M automatic analyser.

## Pasture management

Each treatment was allocated an area of 1.5 ha, giving an overall stocking rate of 3.33 cows/ha in both treatments. The ARG sward was sown to annual ryegrass (*Lolium multiflorum* cv. Gulf) on 21 May 2004 with 35 kg/ha of grass seed and 3 kg of white clover (*Trifolium repens* cv. Ladino). Fertilization of the ARG sward at sowing time was at a rate of 46N-46P-60K/ha, and thereafter every 4 weeks with 21 kg N/ha (as urea). The PRG sward was 4 years old, sown in May 2000 to 35 kg perennial ryegrass seed (*Lolium perenne* cv. Barvestra)/ha and 3 kg/ha of white clover (*Trifolium repens* cv. Ladino). At the beginning of the experiment, the proportion of grass to clover was 65:35 in DM. As with the ARG sward, the PRG pasture was fertilized at a rate of 21 kg N/ha every 28 days (as urea).

Pasture utilization started in the ARG pasture 69 days after sowing with its first cut on 29 July, and the PRG pasture was monitored since the sowing of ARG on 21 May. Net herbage accumulation (NHA) was estimated using six grazing exclusion cages (0.5 m× 2.5 m×0.8 m) per treatment (4 cages/ha), and a metal quadrant of 0.50 $m^2$ (0.25 m×2.0 m). Cages were distributed at random at the beginning of the evaluation, and every 21 days thereafter (measurement periods of 3 weeks). Grass was cut to ground level using shearing scissors, next to each cage on day 1 and inside the cage on day 21, utilizing the metal quadrant. Cages in the ARG during the cut-and-carry periods were placed in the cut areas of the field to measure regrowth.

Cut samples were dried to constant weight in a draught oven at 65–75°C for determination of dry matter (DM); they were ashed at 600°C in a muffle furnace and NHA was estimated by difference and expressed as kg OM/ha. Hand-plucked samples were taken on a similar interval to determine DM, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents in herbage by the micro-bag technique (Ankom, 2005). Crude protein (CP) was determined using the Kjieldhal nitrogen method (Tejada, 1985).

## Statistical analysis

A split-plot experimental design was used, where feeding strategies (ARG or PRG) were considered fixed effects (main plots), and the 14 experimental weeks or the fortnightly measurement periods as random effects (split plots); this is 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, …, 5; $T$=effect of treatment (feeding strategy) (main plot) $j$=1, 2; $E$=error term for main plots [$b(R)_{ij}$]; $p$=effect of measurement periods (weeks or periods) (split-plot) $l$=1, ..., 14 (or 7 periods for live weight and condition score); $Tp$=interaction term between ryegrass pasture type and measurement periods; and $e$=error term for split plots.

The mean milk yield and the live weight of the cows in each treatment were also regressed on the experimental week or recording period, respectively, to obtain the linear relationship with time (Steele and Torrie, 1989).

### Economic analysis

Partial budgets were used to compare feeding costs between the two feeding strategies, from which summary measures were derived. This method has been used successfully in the economic analysis of *campesino* dairy production systems in Mexico (Wiggins *et al*., 2001).

## Results

### Weather conditions

Mean maximum temperature during the study period was 20.1°C, with a mean minimum of 7.6°C, giving an overall mean temperature of 15°C in line with previous historical records in the area. At the end of the experiment in early November, however, there were four days with temperatures below zero. Accumulated rainfall during the rainy season was 1115.8 mm, which was 30% higher than mean rainfall in previous years (860 mm), and as is usual in the area, the rains stopped in November.

### Net herbage accumulation (NHA)

Net herbage accumulation during the experiment was 8222 kg OM/ha for ARG, with a daily mean of 56.0 kg OM/ha per day, while PRG had a total NHA of 5915 kg OM/ha and a daily mean of 34.1 kg OM/ha per day over the 14 weeks, with significant differences between treatments and periods ($p<0.05$). NHA values for each measurement period and per day along the experiment are shown in Table 1.

NHA for the first period was higher for PRG, which is the result of three measurements, while the first cut of the ARG at 69 days from sowing was only 0.72 of the PRG NHA. Thereafter, for period 2 the ARG pasture showed vigorous growth, reaching a marked peak in herbage accumulation of 2997 kg OM/ha in 21 days. Excess forage from ARG during this stage was cut and offered in troughs to other cattle. NHA declined to a moderate growth between periods P3 and P5 with a decline towards the end of the experiment. The PRG pasture, which had passed its primary spring growth, recorded its highest NHA per day in period 3, with the lowest NHA per day in P4 and P5. Overall, total NHA was 40% higher in ARG.

### Herbage chemical composition

Table 2 shows the mean chemical composition for herbage of both treatments, which showed significant differences in CP and in OM ($p<0.05$).

### Milk yield and composition

Mean milk yield for ARG was 15.9 kg/cow day and 19.0 kg/cow day for PRG (SEM±1.70) ($p>0.05$). Figure 1 shows mean milk yield over the experiment, with highly significant differences between experi-

**Table 1** Net herbage accumulation in annual and perennial ryegrass swards (kg OM/ha)

| | NHA (kg OM/ha per period) | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | P1[a] | P2 | P3 | P4 | P5 | P6 | |
| ARG | 1680.0 | 2997.0 | 911.0 | 922.0 | 1217.0 | 495.0 | 8222.0 |
| PRG | 2323.0 | 707.0 | 1184.0 | 489.0 | 517.0 | 695.0 | 5915.0 |
| | NHA (kg OM/ha per day) | | | | | | Mean |
| | P1 | P2 | P3 | P4 | P5 | P6 | |
| ARG | 24.3 | 142.7 | 43.4 | 43.9 | 58.0 | 23.6 | 56.0 |
| PRG | 33.7 | 33.7 | 56.4 | 23.3 | 24.6 | 33.1 | 34.1 |

[a] Period 1 Lasted 69 days.

**Table 2** Chemical composition (g/kg DM) of hand-plucked herbage in ARG and PRG swards

| | ARG | PRG | Level of significance[a] |
|---|---|---|---|
| Crude protein (CP) | 126.6 | 209.6 | * |
| Organic matter (OM) | 887.0 | 936.0 | * |
| Neutral detergent fibre (NDF) | 525.7 | 532.5 | NS |
| Acid detergent fibre (ADF) | 307.4 | 282.4 | NS |
| Acid detergent lignin (ADL) | 74.6 | 82.4 | NS |

[a] NS, P>0.05; *$p$<0.05.

**Table 3** Protein and fat contents in milk (g/kg), live weight (kg) and body condition score of cows

| | ARG | PRG | EEM[a] |
|---|---|---|---|
| Protein (g/kg) | 30.7 | 30.5 | $0.60^{NS}$ |
| Fat (g/kg) | 30.1 | 29.2 | $1.83^{NS}$ |
| Body score | 1.61 | 1.57 | $0.04^{NS}$ |
| Live weight (kg) | 382 | 458 | $37.8^{NS}$ |

[a] NS, $p$>0.05.

mental weeks ($p$<0.001), but with no significant interaction ($p$>0.05) between strategies and weeks. Cows on PRG showed a climb towards peak milk yield in week 3, after which it declined at a rate of 0.56 kg/cow per week ($r^2$=0.97, $p$<0.001); in comparison, milk yield of cows on ARG declined consistently from the first week although at a lower rate (0.20 kg/cow per week, $r^2$=0.86, $p$<0.01) over the whole 14-week experiment.

Table 3 shows fat and protein contents in milk, as well as live weight and body condition score of cows. There were no significant differences between treatments, periods or the interaction ($p$>0.05) for protein content in milk. In the case of fat there were no differences between treatments ($p$>0.05), but there were differences between periods ($p$<0.05) and the interaction was not significant ($p$>0.05). Mean milk fat content in cows in the PRG treatment did not reach the minimum fat content of 30 g/L established as the Mexican norms for milk.

There were no significant differences ($p$>0.05) in body condition score or live weight between treatments, periods or the interaction. However, the linear regression of mean live weight over 14-day weighing periods showed that cows on PRG increased their weight at a rate of 2.8 kg/cow per period or 0.200 kg/cow per day ($r^2$=0.95, $p$<0.001), while there was no significant ($p$>0.05) change in live weight over the whole experiment for the cows on ARG.

## Economic analysis

Table 4 shows the partial budget considering only the direct feeding costs and milk income. Feeding costs in ARG were US$ 0.08/L, 60% higher than the feeding cost of milk in PRG at US$ 0.05/L. The higher feeding costs in ARG were directly influenced by the annual sward establishment costs. Lower feeding

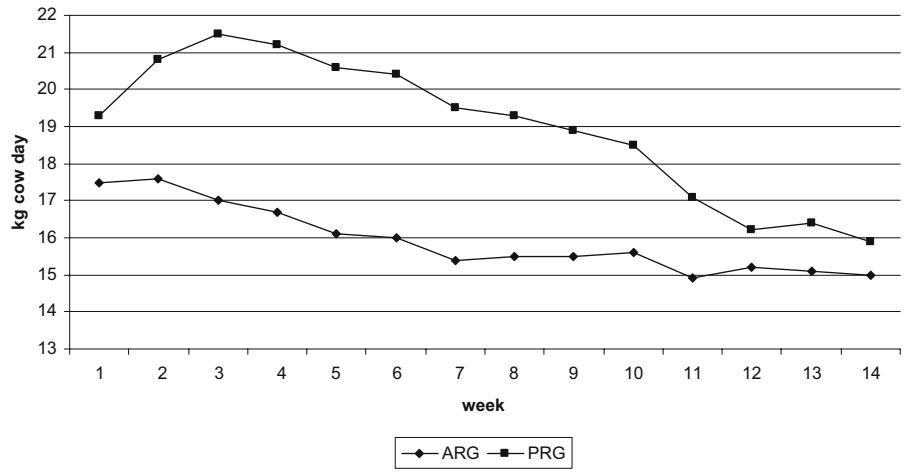


**Fig. 1** Milk yields over 14 experimental weeks (kg milk/cow per day)

**Table 4** Costs and returns for milk production in both treatments (US dollars)

| | Treatment | |
|---|---|---|
| | ARG | PRG |
| *Feeding costs* | | |
| Commercial concentrate | $ 333.79 | $ 333.79 |
| Pastures and forage | $ 329.73 | $ 175.75 |
| Total | $ 663.53 | $ 509.54 |
| *Returns* | | |
| Milk sales ($) | $ 2046.18 | $ 2418.75 |
| Margin | $ 1382.65 | $ 1909.21 |
| Cost ($/L) | $ 0.08 | $ 0.05 |
| Sale price ($/L) | $ 0.26 | $ 0.26 |
| Margin ($/litre) | $ 0.18 | $ 0.21 |

costs plus the higher milk sales in PRG meant 38% greater margins than ARG. No opportunity cost was assigned to the family labour invested in cutting, carrying and providing the forage to the ARG cows during the first eight experimental weeks, which would further increase the feeding cost of the ARG treatment and the difference in margins in favour of the PRG treatment.

## Discussion

### Weather conditions

Observed temperatures were within the range for adequate herbage production (Hopkins, 2000), although during the last four days of the experiment there were frosts of −3.0°C that reduced grass growth, especially in the annual pastures. Since rainfall was higher than previous years' averages, there was no risk of water shortage and therefore milk production was not affected. However, Smit and colleagues (2005) obtained higher forage yields under similar conditions.

### Net herbage accumulation

Net herbage accumulation in ARG was higher than in PRG, particularly in period 2 when there was a very vigorous regrowth after the first cut; which then levelled to lower accumulation rates, although higher than NHA in PRG.

NHA recorded in this experiment was similar to growth rates between 32 and 63 kg DM/ha per day reported by Lemus-Ramírez and colleagues (2002) from irrigated temperate pasture in other areas of the highlands of Mexico.

The NHA for PRG at nearly 6 t OM/ha over the recorded period represented low daily herbage growth rates similar to other measurements in the area with total herbage yields around 12 t OM/ha per year with irrigation over the dry winter period and heavy stocking rates above 3.0 cows/ha. The daily NHA of 34.1 kg OM/ha per day meant a herbage allowance of only 10.3 kg OM/cow per day that could barely meet the estimated OM intake requirements of grazing dairy cows yielding around 18–20 kg milk/day, so that grazing pressure was high and cows had to graze below the initial herbage mass, resulting in a very dense, short sward with a mean sward height measured with a rising-plate grass meter of 2.4 cm and a mean tiller density of 18 649 tillers/$m^2$.

On the other hand, herbage production in ARG at 8.2 t OM/ha represented 40% more OM over the evaluated rainy season than for PRG, which is an important aspect to take into account in the development of appropriate feeding strategies, particularly for those farmers without irrigation or for rain-fed fields. The decrease of herbage growth in ARG during the last period could be attributed to lower rainfall and temperatures, as well as shortening daylight (Velasco-Zebadúa *et al*., 2005).

Observed NHA in this study was below other evaluations carried out in other temperate places but at other latitudes (Ribeiro *et al*., 2003; Smit *et al*., 2005); this may be due, among other reasons, to fertilization management, cultivar, or soil type.

### Herbage chemical composition

The chemical composition of the herbage from both ARG and PRG is similar for OM, NDF and ADF to that of ryegrass herbage from other work in the area (Arriaga-Jordán *et al*., 2001). Similar OM content to that recorded for ARG has been reported from Australia, with 0.886 kg OM/kg DM for *Lolium multiflorum* cv. Concord grazed rotationally by dairy cows (Granzin, 2003).

The chemical composition of the herbage was also similar to values reported in Mexico by other authors, such as by Lemus-Ramírez and colleagues (2002) for

mixed pastures of perennial ryegrass with other perennial grasses associated with white clover and lucerne rotationally grazed by dairy cows, by Velasco-Zebadúa and colleagues (2005) for perennial ryegrass under cutting, by Cervantes-Ramírez and colleagues (2000) for annual ryegrass, and in southern Chile (Hargreaves *et al*., 2001), although the herbage had higher levels of fibre than ryegrass herbage grown in other latitudes such as in Great Britain (Pulido and Leaver, 2003) or France (Delaby *et al*., 2001) but lower levels than ryegrass pasture in Spain (Mosquera-Losada and González-Rodríguez, 1998).

The higher protein content in PRG compared to ARG is due both to the very short sward height that the intensive continuous grazing created in PGR (mean sward height of 2.4 cm), such that cows were eating very tender and nutritive grass with a high leaf content (Pulido and Leaver, 2003), and to the fact that the PRG sward had a high proportion of white clover (overall mean of 420 g/kg DM) compared to ARG, where clover content was negligible. There were no differences in the other constituents, except in OM content. Ribeiro and colleagues (2003) report similar crude protein contents in the herbage of young regrowth in perennial ryegrass–white clover pastures in France under strip grazing of dairy cows, which had a clover content of 420 g/kg DM, similar to the PRG pasture reported here, while in this study the NDF content was higher and the ADF content lower than in the ryegrass–clover pasture reported by Ribeiro and colleagues.

## Milk production and composition

The overall mean for milk yield was 17.5 kg/cow per day. This is considered satisfactory for these *campesino* systems considering the small size of cows and the relatively low level of inputs and management. These yields are similar to those reported from grazing with limited supplementation of concentrates in the area (Arriaga-Jordán *et al*., 2001, 2002) or in Great Britain without supplementation (Phillips and James, 1998), as well as in Chile (Hargreaves *et al*., 2001) and Ireland (Gowen *et al*., 2003), although with heavier cows and for longer periods in the latter two countries. Ribeiro and colleagues (2003) report yields of 13.8 and 16.3 kg/cow per day for cows in mid-lactation strip grazing perennial ryegrass, and of 16.0 and 17.7 kg/cow per day when strip grazing perennial ryegrass–white clover pasture, with significant effects ($p<0.05$) of sward type and age of the regrowth (19 and 35 days). The obtained milk yields indicate that for these small-scale *campesino* farms, feeding strategies based on good-quality temperate forages and moderate concentrate supplementation are able to supply appropriate nutrients to sustain yields of around 20 kg/cow per day, as has been shown in temperate countries of Europe and South America (Phillips and James, 1998; Delaby *et al*., 2001; Hargreaves *et al*., 2001; Gowen *et al*., 2003).

The strategy based on continuous grazing of PRG showed a non-significant difference ($p>0.05$) of 3.1 kg/cow per day, almost 0.20 higher yield, than cows on AGR. However, the model was not able to detect this difference between the two strategies; although over the 14-week experiment this difference amounted to 1422 kg of milk, which marked the difference in the economic analysis.

The observed difference may be explained both by the fact that the PRG pasture had a well-established population of white clover, with a mean proportion of 426 g/kg DM; while the content of clover in ARG was negligible. The inclusion of white clover in perennial ryegrass pastures, in a mean proportion as small as 111 g/kg DM, has been shown to increase milk yield and the yield of milk constituents compared to perennial ryegrass on its own or with other forms of offering white clover (Phillips and James, 1998), through its effect on herbage nutrient content as well as by increasing herbage intake. Ribeiro and colleagues (2003), from a strip grazing experiment of perennial ryegrass or perennial ryegrass pastures with 420 g/kg DM of white clover, conclude that the positive effect of inclusion of white clover in the pasture is related to an increase in herbage intake and not to any improvement in the nutritive value of the herbage.

Also, Laidlaw and Søegaard (1995) state that the advantages of inclusion of clover have an important role in cutting regimes such as the one followed for 8 weeks in the ARG strategy.

Fat and protein contents in milk of cows on the ARG strategy were low, as is the case with upgraded Holstein cows, but met Mexican standards for raw milk. Mean fat content in the milk from cows on the PRG strategy was just below those standards. This might have been due to the clover in the PRG pasture. Phillips and James (1998) report significantly lower fat content in cows continuously grazing perennial ryegrass–white clover pastures. Further studies should

enable better elucidation of the factors affecting fat and protein contents of milk in these systems and ways to improve them. Unfortunately, *campesino* farmers are paid a fixed price for their raw milk, with no premiums or penalties for milk content, but in time these issues in place in the commercial farming sector will be enforced and *campesino* farmers must be aware of and prepared to meet these new challenges to their systems.

## Live weight and body condition score

There were no differences in live weight or body condition score between the two strategies; however, it is notable that cows in the PRG strategy, besides yielding over 1400 kg more milk in the 14-week period, were able to maintain a slight live weight gain of 0.200 kg/day, as shown by the regression of mean live weight over measurement period. This may be another effect of the better nutritional quality of the PRG herbage.

## Economic analysis

The advantages of feeding systems based on pasture are the low feeding costs compared with systems based on concentrate and cut forage. New Zealand dairy farming is recognized around the world for the efficient production of milk products by pasture-based systems (Kolver, 2003). This is due to the low prices paid for milk, since 90% of New Zealand's milk production is exported as dairy products, so that their industry has developed efficient low-cost systems given the cost ratio between grazed pasture, silage and supplements, such that silage is 1.30 the cost of grazed pasture DM and cereal grains are 2.22 times the cost per kg DM compared to grazed pasture (Verkerk, 2003). Even in the United States, given the unstable and low milk prices and increasing input costs, there is a move to develop production strategies that may reduce input costs, particularly feed expenses, so that pasture-based systems are being considered particularly for small to moderate-sized dairy farms in the north-east United States (Soder and Rotz, 2001).

*Campesino* dairy production systems in the highlands of Mexico face similar scenarios, where their small scale makes them unable to compete satisfactorily with low milk prices and rising input costs. The costs of silage in these small-scale systems is between 1.5 and 2.0 times the cost of pasture herbage DM, and commercial dairy concentrates are between 2.9 and 3.3 times that cost. Therefore, forage-based systems reducing the reliance on bought-in concentrates have been explored as a viable option (Arriaga-Jordán *et al*., 2001, 2002).

The economic results obtained in the experiment reported here illustrate how intensive grazing of PRG pastures results in low feeding costs that enable *campesino* farmers to make attractive incomes from their farms, resulting in 0.38 higher margins over feed costs in PRG compared to ARG.

An econometric study by Gloy and colleagues (2002) in the state of New York in the United States, comparing profitability of grazing and non-grazing farms, concluded that farms based on grazing may generate returns on assets at least as high as if not higher than non-grazing farms and may improve lifestyles because farmers often cite non-financial reasons for adopting grazing systems. Other studies in the United States indicate that grazing is a better means of forage utilization, considerably decreasing costs.

In this study, feeding costs were below US$ 0.10 in both PRG and ARG strategies, which is attributed to the use of grazing of introduced pastures and a low supplementation level, resulting in competitive production costs and providing participating farmers with attractive margins. Even though the ARG strategy shows a lower economic benefit given the higher feeding costs incurred, it still has a place in *campesino* small-scale dairy production systems in the highlands for the production of good-quality forage during the rainy season in fields without access to irrigation.

The development of appropriate feeding strategies for small-scale *campesino* dairy production systems is a challenge, since there is a diversity of management between farms and there are a number of different objectives, which together with the small resource allotment they have mean that these farming systems are very dynamic and need an array of options they may resort to in order to meet their productive, social and family goals within their resource base and the socio-economic context in which they operate. The work reported here attempts to provide viable options for improving the performance of these small herds. Rather than attempting to provide these small-scale farmers with one solution or ‘technological package’ for their farming systems, the project proposes the development of ‘baskets of options’ as mentioned by

Chambers (1993), where *campesinos* may find those that best suit their farming systems given the socio-economic context in which they develop, and their social and personal objectives.

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**Stratégies d'alimentation pour les systèmes d'élevage de bétail laitier sur de l'ivraie vivace (*Lolium perenne*) ou annuelle (*Lolium multiflorum*) dans moyennes montagnes du Mexique**

**Résumé –** Élevage à petite échelle d'animaux laitiers pour les *campesinos* au Mexique. Les coûts de l'alimentation sont élevés et les stratégies basées sur fourrages verts de qualité sont une priorité. Les variables agronomiques et les coûts de l'alimentation ont été évalués pour déterminer les performances des vaches laitières paissant continuellement sur de l'ivraie vivace – du trèfle blanc pendant 9 h/jour (PRG) ou de l'herbage donné coupé provenant de l'ivraie annuelle pendant 8 semaines, suivi de 9 h/jour pendant 6 semaines sur un modèle de pâturage en rotation (ARG) avec les animaux maintenus attachés. Toutes les vaches ont reçu 3 kg/j d'un concentré de protéines brutes (CP) dosé à 18%. Une expérimentation en ferme à parcelles subdivisées de 14 semaines a été mise en place avec 10 vaches provenant de deux fermes participantes et sur une superficie de 1,5 ha par stratégie. Le rendement laitier a été enregistré toutes les semaines et la composition du lait, le score du poids vif et de la condition corporelle tous les 14 jours. L'accumulation nette d'herbage (NHA) a été supérieure pour l'ARG (8222 kg de matières organiques (OM)/ha) que pour le PRG (5915 kg OM/ha) ($P<0.05$), avec une teneur en protéines brutes (CP) plus élevée pour le PRG ($P<0.05$). Le rendement laitier a été de 19 kg pour le PRG et de 15.9 kg/vache/j pour l'ARG ($P>0.05$). Sur 14 semaines, le PRG a produit 1422 kg plus de lait. Aucune différence n'a été notée pour le score du poids vif ou de la condition ($P>0.05$) mais la régression linéaire a mis en évidence un gain de poids vif de 0,200 kg/vache/j pour le PRG. La teneur en protéine ou en graisse n'a révélé aucune différence ($P>0.05$), mais la teneur en graisse du lait dans le groupe PRG s'est située sous la norme. L'ARG a coûté 60% de plus et les marges ont été 38% plus élevées pour le PRG. L'ARG détient une place dans les champs non irrigués. Les résultats procurent des options viables d'amélioration de ces systèmes qui pourraient être adéquates dans leur contexte socio-économique et leurs objectifs sociaux et personnels.

**Estrategias de alimentación para sistemas lecheros a pequeña escala basándose en ballica perenne (*Lolium Perenne*) o anual (*Lolium Multiflorum*) en zonas altas centrales de Méjico**

**Resumen –** La producción y distribución de leche a pequeña escala es una opción para los campesinos de Méjico. Los costes de alimentación son altos y las estrategias que tienen como base los forrajes de calidad una prioridad. Se evaluó el rendimiento de las vacas lecheras apacentando continuamente sobre ballica perenne – trébol blanco durante 9 horas/día (BP) o alimentadas con yerbajos cortados de ballica anual durante 8 semanas seguidos de 9 h/día durante 6 semanas en sistema de pastoreo rotacional restringido (BA), junto con las variables agronómicas y los costes de alimentación. Todas las vacas recibieron 3 kg/día de un concentrado de proteína cruda (PC) al 18%. Se diseñó un experimento en granja de parcelas o lotes subdivididos de 14 semanas con 10 vacas de dos granjeros participantes, y 1.5 ha por estrategia. Se registró semanalmente la producción de leche, y cada 14 días la composición de la leche, el peso vivo del animal y la condición corporal. La acumulación neta de forraje (ANF) fue mayor para BA (8222 kg de materia orgánica/ha) que para BP (5915 kg MO/ha) ($P<0.05$), con mayor proteína cruda (PC) en BP ($P<0.05$). La producción de leche fue de 19 kg para BP y 15.9 kg/vaca/día para BA ($P>0.05$). En 14 semanas BP produjo 1422 kg más de leche. No hubo diferencias para el peso vivo o la puntuación de la condición corporal ($P>0.05$) pero la regresión lineal muestra una ganancia del peso vivo de 0.200 kg/vaca/día para BP. El contenido de proteínas o grasas no mostraba diferencias ($P>0.05$), pero el contenido de grasa láctea en BP estaba por debajo de lo normal. BA tuvo un 60% de costes más altos, y los márgenes de beneficio fueron un 38% más altos en BP. BA tiene razón de ser en los campos lluviosos. Los resultados aquí expuestos proporcionan opciones viables para mejorar estos sistemas que pueden ser adecuados en su contexto socio-económico, y sus objetivos sociales y personales.