Journal of Agriculture and Environment for International Development - JAEID 2016, 110 (2): 349-363
DOI: 10.12895/jaeid.20162.496

Cut and carry vs. grazing of cultivated pastures in small-scale dairy systems in the central highlands of Mexico

Paola Estefanía Pincay-Figueroa[1], Felipe López-González[1], José Velarde-Guillén[2], Darwin Heredia-Nava[3], Francisco Ernesto Martínez-Castañeda[1], Fernando Vicente[4], Adela Martínez-Fernández[4] and Carlos Manuel Arriaga-Jordán[1*]

[1] *Instituto de Ciencias Agropecuarias y Rurales (ICAR), Universidad Autónoma del Estado de México (UAEM), Toluca, México*

[2] *Département des Sciences Animales, Université Laval, Québec, Canada*

[3] *CONACYT, Centro Universitario de Los Altos (CUALTOS), Benemérita Universidad de Guadalajara, Tepatitlán de Morelos, Jalisco, México.*

[4] *Servicio Regional de Investigación y Desarrollo Agroalimentario (SERIDA), Villaviciosa, Asturias, España*

[*] *Corresponding author: cmarriagaj@uaemex.mx*

Submitted on 2016, 29 May; accepted on 2016, 2 december. Section: Research Paper

Abstract: Small-scale dairy systems are an option to alleviate poverty and contribute up to 37% of milk production in Mexico; however high costs affect their economic sustainability. Since grazing may reduce feeding costs, a participatory on farm experiment was undertaken to compare animal performance and feeding costs of the traditional cut-and-carry strategy or grazing cultivated pastures, during the dry season in the highlands of Mexico. Pastures of perennial and annual ryegrasses with white clover were utilised, complemented with maize silage and commercial concentrate. Five dairy cows were assigned to each strategy. The experiment ran for 12 weeks, recording weekly milk yields and fat and milk protein content; live-weight and body condition score every 14 days. Analysis was as a split-plot design. The adjusted (covariance) mean milk yield was 18.78 kg/cow/day with no significant differences (P>0.05) between treatments, and no significant differences for live-weight or body condition score. There were no significant differences for milk fat (P>0.05), but there were for protein in milk (P<0.95) Grazing cultivated pastures resulted in 25% less feeding costs, and 15% higher margin over feeding costs. It is concluded that grazing is a viable option to reduce feeding costs and increase the profitability of small-scale dairy farms.

Keywords: participatory technology development, small-scale dairy systems, feeding strategies, highlands, Mexico

Introduction

Small-scale dairy systems play an important role in many areas of the world as they reduce rural poverty and contribute to food production (McDermott *et al.*, 2010); which has been shown in the central highlands of Mexico (Espinoza-Ortega *et al.*, 2007). These systems also provide around 37 % of the national milk production in Mexico (Hemme *et al.*, 2007), and represent over 78% of dairy farms.

Studies of small-scale dairy systems in Mexico show that feeding the herds represents the largest proportion (70%) of production costs (Espinoza-Ortega *et al.*, 2007); and the assessment of the sustainability of these systems showed that high reliance on external inputs and high feeding costs result in a lower score for the economic component of sustainability. These results indicate that maximizing the efficient use of farm resources like the feeding of good quality forages to reduce costs is an area for improvement that would increase the overall sustainability of small-scale dairy systems (Fadul-Pacheco *et al.*, 2013).

The State of Mexico, surrounding Mexico City, is the 7th largest producer of milk in the country, and the Northwest of the State represents the fourth largest producing area. Given the availability of irrigation, cultivated pastures of temperate grasses and legumes were introduced in the 1970's under a cut-and-carry system and have been used by farmers under that system since then (Martínez-García *et al.*, 2013).

Grazing of cultivated ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pastures complemented with maize silage (*Zea mays)* in the dry season has been shown as an appropriate technology for these systems (Albarrán *et al.*, 2012). However small-scale dairy farmers in the study area are reluctant to change their cut-and-carry system and to adopt grazing, both due to their lack of knowledge and expertise on grazing, as well as by the role that social referents have on influencing adoption and changes in these farming communities (Martínez-García *et al.*, 2013).

As part of on-going rural participatory research projects on the evaluation and enhancement of the sustainability of small-scale dairy systems, the work herein reported had the objective of undertaking a participatory development of technology experiment to compare animal performance and feeding costs of the traditional cut and carry strategy or grazing cultivated pastures, during the dry season.

There are clear differences in the feeding strategies in the rainy and the dry season, with an abundance of green forage in the rainy season and a lack of forages in the dry season, when farmers resort mainly to straws and hays since silage is practised by only 30% of farmers (Alfonso-Avila *et al.,* 2012; Martínez-García *et al.,* 2015).

The dry season is an economically difficult time for these systems, with high costs for bought-in feeds. The project to which this work belongs, promotes the inclusion of maize silage as a complement to grazed pastures and reduced concentrate use during the dry season (Albarran *et al.*, 2012), in contrast to traditional feeding strategies that supplement large amounts of concentrates and use straws as complementary roughage.

The objective of the work herein reported was to compare the productive performance of milking dairy cows under cut and carry or intensive grazing of cultivated pastures, complemented with maize silage and concentrates in the dry season; and to determine the feeding costs under both strategies.

Materials and methods

The work took place in the municipality of Aculco, in the State of Mexico (which surrounds Mexico City) located between 20° 06' and 20° 17' North and between 99° 40' and 100° 00' West, at an altitude of 2,440 m with a sub-humid temperate climate, a mean annual temperature of 13.2 °C and annual rainfall above 700 mm (Fadul-Pacheco *et al.*, 2013).

The study area is characterised by small-scale dairy systems, with herds between 3 and 35 cows in small farms with a mean size of 4.25 ha (Fadul-Pacheco *et al* 2013: Martínez-García *et al* 2013). Participating farmers belonged to a group of 22 farms, selected by snow-ball sampling that have been participating in on-going projects on the participatory improvement of small-scale dairy systems to enhance their sustainability and as a rural development option (Alfonso-Avila *et al.*, 2012; Fadul-Pacheco *et al.*, 2013; Martínez-García *et al.*, 2015; Celis-Alvarez *et al.*, 2016).

Three small-scale dairy farmers participated in the experiment. A participatory development of technology approach was used, in line with the model proposed by Peters *et al.* (2001) and Stür *et al.* (2002); with an on - farm experiment following guidelines for participatory livestock technology research developed by Conroy (2005).

The intensive grazing of cultivated pastures was discussed in meetings of the *Asociación Ganadera Local General del Poniente de Aculco Estado de México*, a farmers' association to which several of the 22 farmers participating in the project belong. Benefits of grazing were presented as well as results obtained in other areas. Farmers stated their interest but said it would be necessary for them to see the proposal working on their conditions.

One innovative farmer stated his interest in assessing intensive grazing in his farm, for which the project provided seed for 1.5 ha of new pasture and an electric fence, and the farmer contributed his farm, cattle, machinery, fertilizer, and his labour. Previous work on the spread of successful technologies has shown that farmers do adopt technologies by the dissemination by word of mouth by other farmers (Heredia-Nava *et al.*, 2012) and social referents (Martínez-García *et al.*, 2013). Two farmers who shared a cut and carry pasture, accepted to participate in the experiment on the cut-and-carry strategy.

The experiment ran for 12 weeks during the dry season, after experimental cows had been on an adaptation period of 4 weeks, particularly for the grazing treatment where cows had never grazed before.

Two treatments were evaluated, traditional cut-and-carry of fresh herbage and intensive continuous grazing, complemented with maize silage and commercial compound concentrates.

Pastures

The cut and carry pasture was established over 20 years ago sown to annual ryegrass (*Lolium multiflorum*) of unknown variety and white clover (*Trifolium repens* cv. Ladino) and other temperate grass species that currently represent a small proportion of the herbage. In order to keep a population of annual ryegrass in these pastures, every year farmers leave selected plants to go to head in different areas of their pastures, so that they drop seeds and so keep the population of annual ryegrass over the years.

These pastures are fertilised with manure approximately every month, when the manure is spread after cutting. No synthetic fertilizer is applied to these pastures.

The intensive grazing pasture of 1.47 ha was sown in April 2012 to a mixture of perennial ryegrass (*Lolium perenne* cv. Bargala), annual ryegrass (*Lolium multiflorum* cv. Maximus), cocksfoot or orchard grass (*Dactylis glomerata cv.* Potomac) and white clover (*Trifolium repens* cv. Ladino). Approximately 5.0 ton/ha of farmyard manure were applied before sowing to 1.0 ha, and a 46-92-60 NPK/ha formula using urea, triple calcium superphosphate and potassium chloride, was applied to the total area also prior to sowing. Every 7 weeks the pasture was fertilised with 37.5 kg urea (46% N). As mentioned above, an electric fence was installed for managing the grazing cows. Stocking rate was 3.4 cows/ha.

Both the cut-and-carry and the grazed pastures are irrigated during the dry season (mid-October to mid-May) about every 4 weeks, with water from a reservoir.

Animal variables and management

In the current experiment, ten milking cows were used belonging to three small-scale dairy farmers who participated in the trial. One farmer participated with five cows and two farmers (who are brothers), who manage their pasture jointly, with the other five cows.

The cows had a mean milk yield of 17.56 ± 3.8 kg of milk/d, a live weight of 486 ± 84.5 kg and a mean of 59.7 ± 62.7 days in milk. The cows were grouped in pairs according to parity (two were primiparous and eight were multiparous) and days in milk.

The cows in the study area were originated from up-grading breeding of local cattle (called *criollo*) with specialized dairy breeds (mostly Holstein but also Brown Swiss and Jersey) (Arriaga-Jordán *et al.*, 2005); so that it is common for farmers to have up-graded Holstein cattle with some animals with Brown Swiss (or less common, Jersey) lineage**.** Of the ten cows, eight cows were Holstein breed and two Holstein breed with some Brown Swiss lineage. Five Holstein breed cows were used for the cut and carry treatment and the rest for the intensive grazing treatment.

Selection of cows was determined by the small herd of the participating farmers, and having less than optimal experimental conditions is one of the trade-offs in participatory livestock research between work at an experimental station and on-farm experiments (Conroy, 2005). Stroup *et al.* (1993) and Conroy (2005) state that on-farm experiments under these conditions "does not make them incorrect or invalid", understanding that there are trade-offs that have to be made. The two experimental groups were deemed representative samples of dairy herds in the study area

Cows on the cut and carry strategy remained indoors in a tie barn the whole time, where an average of 36.8 kg/cow/day of fresh herbage (approximately 7 kg of DM) was provided in troughs. Cows in the grazing treatment were turned out at 9:00 and brought in for milking at 17:00 h, and remained indoors in a tie barn until turnout the next morning, under a continuous grazing system at a stocking rate of 3.4 cows/ha.

Boonbrahm *et al.* (2004) reported that milking method in up-graded Holstein cows did not have a significant effect from day 83 of lactation, similar to the days in milk of cows in this experiment; so that it was assumed that the milking method, in this experiment, did not have a significant effect in the yield milk.

Due to the low growth rates of pasture in the dry season, the rations were complemented with 24 kg fresh maize silage (7.49 kg DM)/cow/day) offered immediately after milking; as well as 5.0 kg/cow/day of a 20% CP commercial compound concentrate.

Pasture in the cut and carry treatment was cut by hand with a scythe every morning after milking, as is the traditional practice in the study area. The cut herbage was transported in a pick-up truck into the barn and supplied to the herd over the day.

Initial mean live-weight of cows in the cut and carry treatment was 504.50 ± 14.37 kg, and 468.63 ± 17.32 kg for cows in the grazing treatment; with a mean initial milk yield of 19.07 ± 0.70 and 16.98 ± 1.14 kg for cut and carry, and grazing respectively.

Individual milk yields were recorded with a spring balance every week for the weeks prior to the experiment and the 12 experimental weeks; and milk samples were taken from each cow to determine milk fat and milk protein content using an ultra-sound milk analyzer (Ekomilk-M).

Live-weight and body condition score were recorded every 14 days after the morning milking, using a portable electronic weighbridge for live weight**,** and a 1 to 5 score for body condition following Ferguson *et al.* (1994).

Pasture measurements

Sward height was recorded weekly in the grazed pasture with a rising plate grass-metre, taking 30 random recordings following a "W" pattern in the pasture. Net herbage accumulation (NHA) was estimated every 21 days through 6 exclusion cages (3.0 x 0.9 x 0.8 m) from which 2.0 x 0.25 m quadrants were cut. On day 0, a quadrant outside the cage was cut to ground level and on day 21 inside the cage, calculating NHA by difference and expressed as kg dry matter (DM)/ha and per day following procedures described by Heredia-Nava *et al.* (2007). Also, every 21 days a sample of the grazed pasture was collected by simulated grazing, hand plucking the sample.

Collected samples were dried at 60°C in a forced draught oven till constant weight to determine DM, and ashed at 600°C in a furnace to determine ashes and Organic Matter (OM).

Samples of all feeds for both treatments were also collected every 21 days to determine DM, neutral detergent fibre (NDF), acid detergent fibre (ADF), as well as crude protein (CP) following the procedures reported by Anaya-Ortega *et al.* (2009).

Statistical analysis

Analysis was undertaken according to a split-plot design recommended by Stroup *et al.* (1993) for on farm experiments where replications are limited. Treatments (cut-and-carry or grazing) were fixed effects (main plots), and the 12 experimental weeks or the fortnightly measurement periods for live-weight and body condition score, as random effects (split plots). Milk yield before the experiment was used as a covariate for milk yield, Variables were subjected to analysis of variance according to the following model:

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

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) k = 1, ..., 12 (or 6 periods for live weight and body condition score)
Tp = Interaction term between pasture management and measurement periods
e = Error term for split plots

Economic Analysis

Feeding costs for the two treatments were compared from partial budgets from where summary measures were derived (Dillon and Hardaker, 1980). This method has been used successfully in the economic analysis of small-scale dairy systems in Mexico as reported by Espinoza-Ortega *et al*., (2007). In the sake of simplicity, no economic cost (or opportunity cost) was considered for family labour in any of the two treatments, since the cost of family is assumed the same for farmers whether cutting and carrying pasture or tending for grazing cows or undertaking other activities. Family members engaged in dairying do not receive a salary, and live from the farm earnings. Family labour enhances the profitability and competitivity of small-scale dairy farms, which are viable even when economic costs for family labour are considered (Posadas-Domínguez *et al*., 2014).

The cost of cut and cearry pastures included the cost of irrigation, manure application (no synthetic fertilizers are applied to cut and carry pastures), the cost in scythes and files for their sharpening, as well as fuel for the pick-up truck to take the herbage from the pasture into the barn. The cost of grazed pastures included irrigation, manure and synthetic fertilisers.

Results

Chemical composition of feeds

Table 1 shows the chemical composition of herbages, maize silages and commercial compound concentrate. The only observable differences were in the CP contents of herbage, which was 80% higher in the grazed herbage compared to the cut and carry herbage

Sward height and net herbage accumulation in grazing

Sward height of the grazed pasture over the 12 experimental weeks was on average 3.1 cm (measured with a plate metre), with maximum height on week 4 (3.8 cm) and lowest on week 11 (2.2 cm). These results reflect a very high stocking rate and grazing pressure. Total net herbage accumulation was 2,679.6 kg DM/ha with a mean daily herbage accumulation of 31.9 kg DM/ha/day.

Table 1 - Chemical composition of feeds

	Cut and Carry			Grazing	
	Herbage	Maize Silage	Concentrate	Herbage	Silage
Dry matter (g/kg)	NA	301.85	971.45	NA	322.27
CP (g/kg DM)	121.65	70.21	182.23	221.61	71.63
NDF (g/kg DM)	417.83	542.34	257.26	441.00	556.57
ADF (g/kg DM)	156.75	194.42	76.40	145.18	206.38

NA = Not available

Table 2 - Milk yields, milk composition, live-weight and body condition score in cut and carry or grazing of pastures

	Cut and Carry	Grazing	SEM T	SEM P	SEM TxP
Covariance Adjusted Milk yield (kg/cow/day)	19.92	17.64	1.49^{NS}	0.91^{NS}	5.08*
Fat (g/kg milk)	34.80	34.30	0.306^{NS}	0.292^{NS}	1.089^{NS}
Protein (g/kg milk)	31.50	32.9	0.028^{**}	0.036^{**}	0.182^{NS}
Live-weight (kg/cow)	520.07	492.17	30.413^{NS}	6.164^{NS}	4.839^{NS}
Body condition score	1.74	1.85	0.153^{NS}	0.365^{NS}	0.637^{NS}

NS = P>0.05; * = P<0.05; SED T (Standard Error of the Mean for Treatments); SEM P (Standard Error of the Mean for Periods) and SEM TxP (Standard Error of the Mean for the interaction between Treatments and Periods).

Milk yields and composition

Table 2 shows the results for the animal variables. There were no significant differences between treatments (P>0.05) for the covariate adjusted milk yields, 19.9 kg/cow/day for the cut and carry treatment and 17.6 kg/cow/day for the grazing treatment, with a covariate adjusted mean of 18.8 kg/cow/day.

As part of the participatory nature of the trial, the farmer implementing grazing decided to delay for 2 h/d the turn-out of his cows to pasture due to late frosts. The reduced access to grazing resulted in a drop in milk yields during four weeks, which recovered when original grazing times were re-established.

In participatory research, the farmers are "associated partners" because they provide their land, cattle, labour and risk (mostly economic) in their farms, so that farmer decisions have to be respected (Conroy, 2005).

The information is always provided to participating farmers by the research team on the adequate management and specific procedures for the on-farm experiments.

However, many farmers think wrongly that cold weather affects the cows (projecting on their own human comfort), so the farmer decided to keep the cows inside because of the low temperature, taking out the herd to graze two hours after the stipulated time. When he noticed the drop in milk yields, he corrected his action.

As mentioned before, Stroup *et al.* (1993) and Conroy (2005) state that on-farm experiments under these conditions are not incorrect or invalid.

Nonetheless, there were no significant differences between weeks (P>0.05), but the interaction of treatments by experimental weeks was significant (P<0.05) due to the drop in milk yield and its recovery thereafter.

Table 2 also shows the fat and protein contents of milk, with no significant differences between treatments, periods or for the interaction (P>0.05) for milk fat; although there were significant differences between treatments and periods for protein (P<0.05), but not for the interaction (P>0.05).

Live-weight and body condition score

Table 2 also shows the results for live-weight and body condition score, with no significant differences between treatments, periods or the interaction (P>0.05).

Economic analysis

Table 3 shows the results of the partial budget analysis for feeding costs for each treatment. The partial budgets were done taking into consideration the recorded milk yields (Table 2).

Even when taking recorded milk yields for the analysis, 19.2 kg/cow/day under cut and carry and 17.64 kg/cow/day in the grazing treatment that were not statistically different between treatments (P>0.05), feeding costs for cows under grazing were 25% less than for cut and carry, and margins over feeding costs were 15% higher for grazing, although no statistical differences were detected (P>0.05).

Table 3 - Costs and returns for milk production under cut-and-carry or grazing of cultivated temperate pastures (US$)

	Treatments	
	Cut-and-carry	Grazing
Feeding costs		
Commercial concentrate	889.83	889.83
Pasture	739.66	248.81
Maize silage	330.51	330.51
Total	1,960.00	1,469.15
Income		
Milk production (L)	8,064.00	7,408.80
Milk sales (US$)	3,386.88	3,111.70
Margin over feed costs	1,426.88	1,642.55
Feeding cost (US$/L)	0.243	0.198
Sale price	0.42	0.42
Margin (U$/L)	0.177	0.222
Returns / Cost (US$)	1.73	2.12

Discussion and conclusions

Chemical composition of pastures was similar to what has been reported by (Heredia-Nava et. al., 2007) in that a high CP content was linked to young tender herbage under intensive grazing whilst in cut and carry systems the herbage is cut when it achieves a “cutting height” over 25 – 30 cm, when the grass component tends to be heading. Also the grazed pasture had a higher proportion of white clover than the cut and carry pastures. Observed chemical composition is in line to other work undertaken in central Mexico (Anaya-Ortega *et al*., 2009; Albarrán-Portillo *et al*., 2012). There were no other observed differences in chemical composition between the two herbages, or between the maize silages.

Daily NHA of the grazed pasture was 32 kg DM/ha/day, similar to that reported by Lemus-Ramírez *et al*. (2002), with values between 32 and 65 kg DM/ha/day for temperate pastures under rotational grazing in another place 60 km north of Aculco, where the work herein reported took place.

NHA was lowest during periods 2 and 3 when late frost hit the area and reduced growth rates in the grazed pasture, obtaining NHA values of 25.6 and 23.1 kg DM/ha/day respectively.

In terms of animal variables, covariate adjusted overall mean milk yield for the 12 experimental weeks was 18.8 kg/cow/day. In these small-scale dairy systems in central Mexico, this yield is considered a good yield; higher than yields reported for the study area of 13.9 kg/cow/day with traditional feeding strategies in the rainy season (Alfonso-Ávila *et al*., 2012), or between 10 and 15 kg milk/cow/day for the dry season (Martínez-García *et al*., 2015). Heredia-Nava *et al*. (2007) reported milk yields of 17.5 kg/cow/day for small-scale dairy systems based on pasture or cut herbage with a supplement of 3 kg of commercial compound concentrate.

Morrison and Patterson (2007) report 19.8 kg/cow/day for grazing dairy cows in Northern Ireland under rotational grazing and supplemented with maize silage with an intake of 6.3 kg DM/cow/day plus 4.5 kg DM of concentrates; similar to the feeding management in the grazing treatment of the experiment herein reported.

Woodward *et al*. (2006), on a study on the supplementation of different silages to rotationally grazed dairy cows in New Zealand, reported daily milk yields of 14.3 kg/cow/day with a restricted pasture allowance and 5.0 kg DM maize silage/cow/day, although with no concentrate supplementation.

In regards to the significantly ($P<0.05$) higher protein content of milk under grazing, higher protein and energy contents of the grazed herbage may explain the higher protein in milk in the grazing treatment (Sutton, 1989).

The economic analysis shows that feeding costs were 25% lower for grazing than for the cut-and-carry strategy, resulting in margins over feed costs 15.1% higher for grazing; with a returns over costs ratio of US$ 1.73 for the cut and carry feeding strategy, compared to a ratio of US$ 2.12 for the treatment implementing intensive grazing of pastures.

Economic results coincide with studies undertaken by Heredia-Nava *et al.* (2007) working also with small-scale dairy farmers, who report higher margins per litre by implementing grazing of perennial ryegrass pastures, which allows farmers to obtain lower feeding costs.

In the United States, a comparative study on the profitability of grazing vs. farms with mechanical harvesting of forages reported equal or higher returns over assets for farms based on grazing (Gloy *et al.*, 2002). That report coincides with a previous work from Dartt *et al.* (1999) done in Michigan who report that the lower costs of production in farms that had implemented management intensive grazing was through lower feeding costs. They conclude that farms that graze their herds intensively had more economic profit and were more efficient in asset use, operation of the farms and labour use.

Similar results have been reported more recently by Hanson *et al.* (2013) whom from an extensive revision of data for a 15 year period in the Mid-Atlantic region of the USA, conclude that farms that base their feeding on management intensive grazing are more profitable per unit of milk produced and unit of land, with overall farm profitability equal to confinement based farms, which reported higher expenses than grazing based farms.

Feeding strategies based on quality forages reduce the need for large amounts of concentrates (Arriaga – Jordán *et al.*, 2002), shown in this study where concentrates represented 45.4% and 60.7% of feeding costs for cut-and-carry and grazing respectively, which are lower than the 70% of costs represented by concentrates reported by Espinoza-Ortega *et al.* (2007) for these systems.

As mentioned before, no economic or opportunity cost was ascribed to family labour, following Posadas-Domínguez *et al.* (2014) who stated that family labour that do not pay themselves a salary enhances the competitiveness and profitability of small-scale dairy systems, reporting that the profitability of small-scale dairy farms persists even when an economic cost for family labour is ascribed. In the paper herein reported, no opportunity cost for family labour was included in the sake of simplicity and in order to better perceive the systems in the context in which they operate. Farmers do not incur in differentiated costs for the work performed by them or their family members. In the case of this study, labour costs are the same whether farmers cut-and-carry herbage form their pastures or if there is no work involved in the feeding of herbage when the herd grazes the pastures, since farming families in these systems live from the earnings generated by the farms, without receiving any salary.

It is concluded that grazing of cultivated pastures in these small-scale dairy systems is a good feeding strategy that results in similar milk yields to the traditional cut and carry strategy, but reduces feeding costs up to 25% and increases margins over feeding to 15%, which enhances the sustainability of the systems by improving the economic scale.

These results are important in the context of small-scale dairy systems in the highlands of Mexico and other smallholder dairy production areas of Latin America and other parts of the world, where farmers reject grazing of cultivated pastures in the belief that it would damage their pastures and reduce profits.

Acknowledgments
Authors express their gratitude to the three farmers and their families participating in the experiment. This work was undertaken thanks to funding by the Spanish Agency of International Cooperation for Development (*Agencia Española de Cooperación Internacional para el Desarrollo*) through project AECID 11-CAP2-1526, the Mexican Nacional Council for Science and Technology (*Consejo Nacional de Ciencia y Tecnología CONACYT*) through the grant 129449 CB-2009, and the Higher Education – Enterprise Foundation (*Fundación Educación Superior Empresa, A.C.- FESE*) from Mexico through grant UAEM 3300/2012E. Our gratitude also to the National Ministry of Higher Education, Science, Technology and Innovation of Ecuador for the postgraduate grant.

References

Albarrán B., García A., Espinoza A., Espinosa E., and Arriaga C.M., 2012. Maize silage in the dry season for grazing dairy cows in small-scale production systems in Mexico's Highlands. Indian Journal of Animal Research 46: 317-324.

Alfonso-Ávila A. R., Wattiaux M, A., Espinoza-Ortega A., Sánchez-Vera E., and Arriaga-Jordán C.M., 2012. Local feeding strategies and milk composition in small-scale dairy production systems during the rainy season in the highlands of Mexico. Tropical Animal Health and Production 44: 637-644

Anaya-Ortega J.P., Garduño-Castro G., Espinoza-Ortega A., Rojo-Rubio R., and Arriaga-Jordán C.M., 2009. Silage from maize (*Zea mays*), annual ryegrass (*Lolium multiflorum*) or their mixture in the dry season feeding of grazing dairy cows in small-scale *campesino* dairy production systems in the Highlands of Mexico. Tropical Animal Health Production 41: 607 – 616.

Arriaga - Jordán C.M., Pedraza - Fuentes A.M., Nava - Bernal E.G., Chávez - Mejía M.C. and Castelán - Ortega O.A., 2005. Livestock agrodiversity of *mazahua* small-holder *campesino* systems in the highlands of central Mexico. Human Ecology 33 (6): 821 – 845.

Arriaga-Jordán C.M., Albarrán-Portillo B., Espinoza-Ortega A., García-Martínez A., and Castelán-Ortega O.A., 2002. On-farm comparison of feeding strategies based on forages for small-scale dairy production systems in the Highlands of Central Mexico. Experimental Agriculture 38: 375-388.

Boonbrahm N., Peters K.J. and Wanchai Intisang, 2004. The influence of calf rearing methods and milking methods on performance traits of crossbred dairy cattle in Thailand 1. Milk yield and udder Health. Archiv Tierzucht., Dummerstorf 47: 211-224

Celis-Alvarez M.D., López-González F., Martínez-García C.G., Estrada-Flores J.G., and Arriaga-Jordán C.M., 2016. Oat and ryegrass silage for small-scale dairy systems in the highlands of central Mexico. Tropical Animal Health and Production. DOI 10.1007/s11250-016-1063-0.

Conroy C. 2005. Participatory Livestock Research. ITDG Publishing, Bourton-on-Dunsmore, Warwickshire (UK) .

Dartt B.A., Lloyd J.W., Radke B.R., Black J.R., and Kaneene J.B., 1999. A Comparison of profitability and economic efficiencies between management-intensive grazing and conventionally management dairies in Michigan. Journal of Dairy Science 82: 2412-2420.

Dillon J.L. and Hardaker J.B., 1980. Farm management research for small farmer development. FAO Agricultural Services Bulletin 41, Food and Agriculture Organization (FAO), Rome.

Espinoza-Ortega A., Espinosa-Ayala E., Bastida-López J., Castañeda-Martínez T., and Arriaga-Jordán C.M., 2007. Small-scale dairy farming in the highlands of central Mexico: Technical, economic and social aspects and their impact on poverty. Experimental Agriculture 43: 241-256.

Fadul-Pacheco L., Wattiaux M.A., Espinoza-Ortega A., Sánchez-Vera E., and Arriaga-Jordán C.M., 2013. Evaluation of sustainability of smallholder dairy production systems in the highlands of Mexico during the rainy season. Agroecology and Sustainable Food Systems 37:882-901

Ferguson J.D., Galligan D.T., and Thomsen N., 1994. Principal descriptors of body condition score in Holstein cows. Journal of Dairy Science 77: 2695-2703.

Gloy B.A., Tauer L.W., and Knoblauch W., 2002. Profitability of grazing versus mechanical forage harvesting on New York dairy farms. Journal of Dairy Science 85: 2215–2222.

Hanson J.C., Johnson D.M., Lichtenberg E., and Minegishi K., 2013. Competitiveness of management-intensive grazing dairies in the mid-Atlantic region from 1995 to 2009. Journal of Dairy Science 96: 1894–1904.

Hemme T., IFCN Dairy Team and IFCN Researchers, 2007. IFCN Dairy Report 2007. IFCN Dairy Research Center. International Farm Comparison Network, Kiel (Germany).

Heredia-Nava D., Espinoza-Ortega A., González-Esquivel C.E., and Arriaga-Jordán C.M., 2007. Feeding strategies for small-scale dairy systems based on perennial (*Lolium perenne*) or annual (*Lolium multiflorum*) ryegrass in the central highlands of México. Tropical Animal Health and Production 39: 179-188.

Heredia-Nava D., Martínez-García C.G., Espinoza-Ortega A., Sánchez-Vera E., and Arriaga-Jordán C.M., 2012. Comunicación productor – productor: diseminación y adopción de tecnologías para la alimentación del ganado entre productores de leche en pequeña escala en una región del Estado de México. In: Cavallotti- Vázquez B.A., Cesín-Vargas A., Ramírez-Valverde B., Marcof-Álvarez C.F. (Editors). Ganadería y Alimentación: alternativas frente a la crisis ambiental y el cambio social. Vol. 2. Universidad Autónoma Chapingo, Chapingo (México). 449 – 460.

Lemus-Ramírez V., García-Muñiz J.G., Lugo-León S.G., Valencia-Gutiérrez E., and Villagrán-Vélez B., 2002. Performance of irrigated pasture, established for grazing dairy cattle in temperate climate. Veterinaria México 33: 11–26.

Martínez-García C.G., Dorward P., and Rehman T., 2013. Factors influencing adoption of improved grassland management by small-scale dairy farmers in central Mexico and the implications for future research on smallholder adoption in developing countries. Livestock Science 152: 228-238.

Martínez-García C.G., Rayas-Amor A.A., Anaya-Ortega J.P., Martínez-Castañeda F.E., Espinoza-Ortega A., Prospero-Bernal F., and Arriaga-Jordán C.M., 2015. Performance of small-scale dairy farms in the highlands of central Mexico during the dry season under traditional feeding strategies. Tropical Animal Health and Production 47: 331-337.

Mc Dermott J.J., Stall S.J., Freeman H.A., and Van de Steeg J.A., 2010. Sustaining intensification of smallholder livestock systems in the tropics. Livestock Science 130: 95-109.

Morrison S.J. and Patterson D.C., 2007. The effects of offering a range of forage and concentrate supplements on milk production and dry matter intake of grazing dairy cows. Grass and Forage Science 62: 332 - 345.

Peters M., Horne P., Schmidt A., Holmann F., Kerridge P.C., Tarawali S.A., Schultze Kraft R., Lascano C.E., Argel P., Stur W., Fujisaka S., Muller-Samann K., and Wortmann C., 2001 The role of forages in reducing poverty and degradation of natural resources in tropical production systems. AgREN Network Paper No. 117. July 2001. Overseas Development Institute (ODI), London (UK).

Posadas-Domínguez R.R., Arriaga-Jordán C.M., and Martínez-Castañeda F.E., 2014. Contribution of family labour to the profitability and competitiveness of small-scale dairy production systems in central Mexico. Topical Animal Health and Production 46: 235–240

Sutton J.D., 1989. Altering milk composition by feeding. Journal of Dairy Science 72: 2801 – 2814.

Stroup W.W., Hildebrand P.E., and Francis C.A., 1993. Farmer participation for more effective research in sustainable agriculture. In: Regland J. and Rattan L. (Editors). Technologies for Sustainable Agriculture in the Tropics. Soil Science Society of America, Inc., American Society of Agronomy, Inc. and Crop Science Society of America, Inc., Madison (USA). 153–186.

Stür W.W., Horne P.M., Gabunada Jr. F.A., Phengsavanh P., and Kerridge P.C., 2002. Forage options for smallholder crop–animal systems in Southeast Asia: working with farmers to find solutions. Agricultural Systems 71: 75-98.

Woodward S.L., Chaves A.V., Waghorn G.C., Brookes I.M., and Burke J.L., 2006. Supplementing fresh pasture with maize, lotus, sulla and pasture silages for dairy cows in summer. Journal of the Science of Food and Agriculture 86: 1263-1270.