Colegio de Postgraduados

Festulolium and annual ryegrass pastures associated with white clover for small-scale dairy systems in high valleys of Mexico

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ABSTRACT

Background: The implementation of polyphytic pastures composed of grasses and legumes is an important component of agricultural systems in temperate zones, since grazing pastures which can reduce feed costs— are a viable option for small-scale dairy systems (SSDS).

Objective: To evaluate the continuous grazing of dairy cows in Festulolium pastures associated with annual and perennial ryegrass and with clover in two farmrs.

Methodology: Two experiments were carried out. The first experiment was established in the municipality of Almoloya of Juárez using eight cows that were divided into two groups of four; the cows grazed on two pastures with Festulolium associated with annual ryegrass and they were fed with 3.6 kg DM/cow/day of commercial concentrate, for 16 weeks. The second experiment was carried out in the Northwest of State of Mexico; six multiparous cows grazed on two pastures, under a cross over design arrangement; one pasture features Festulolium cv Spring Green and the other, annual ryegrass. Milk and body condition ere measured every 3 and 12 d, respectively. Variables from both experiments were analyzed using a split-plot experimental design.

Results: Neither experiment recorded significant differences for the net accumulation of forage, the height of the pastures, and their chemical composition ($P>0.05$). No significant differences between treatments ($P>0.05$) were recorded regarding the yields and chemical composition of the milk.

Study Limitations/Implications: The study of mixed pastures can be an alternative for feeding grazing cows, helping to reduce costs in SSDS.

Findings/Conclusions: Festulolium/annual ryegrass pastures with white clover are a viable forage alternative for small-scale dairy systems.

Keywords: pastures; milk; grazing; grasses; white clover.

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INTRODUCTION

Small-scale dairy systems (SSDS) contribute more than 35% of production in Mexico (Hemme *et al.*, 2009); they have persisted over time and generate a constant income. They are characterised by herds of 3 to 35 cows plus replacements, by farming activities carried out in small farms (Fadul-Pacheco *et al.*, 2013), and by family labour-based production. They have proven to be an option to overcome rural poverty (Espinoza-Ortega *et al.*, 2007).

The economic scale of sustainability is the most vulnerable aspect of these systems, given the high production costs. Feed is the major component of these costs (Fadul-Pacheco *et al.*, 2013; Prospero-Bernal *et al.*, 2017), as a result of the use of large amounts of commercial concentrates, straws, and stubble (Martínez-García *et al.*, 2015), which represent up to 70% of a farm's expenses (Espinoza-Ortega *et al.*, 2007).

Grazing grass and legume pastures has proven to be a viable option for SSDS. This practice obtains better results than conventional grassland management (mowing and grazing), significantly reducing feeding costs (Pincay-Figueroa *et al.*, 2016; Prospero-Bernal *et al.*, 2017). However, future scenarios about the uncertain availability of irrigation water, changes in rainfall patterns, and an increasing frequency of extreme temperatures —factors which have a direct influence on pasture production— require the development of feeding strategies that enable the optimization of resources within the production unit, seeking the species and varieties of pasture that are best adapted to the agroecological and management conditions of the SSDS (Plata-Reyes *et al.*, 2018).

Perennial ryegrass (*Lolium perenne*) —which is usually associated with white clover (*Trifolium repens*)— is the grass of choice for temperate pastures, but it does not tolerate temperatures above 25 °C or water deficit (Parsons and Chapman, 2000). In this sense, an alternative to the low persistence of perennial ryegrass-based grasslands may be short-duration grasslands based on fast-growing, highly nutritional quality grasses whose lifespan is a long as that of perennial ryegrass grasslands. Grasses that meet these characteristics include annual ryegrass (*Lolium multiflorum*) and hybrids of ryegrass species and species of the genus *Festuca* known as festulolium.

Annual ryegrass is a native species of Europe and North Africa, but it is widely distributed throughout the world. It is a biennial plant used to establish short-term grasslands, because its establishment is faster than other grasses (Humphreys *et al.*, 2003) and it can be grazed within 70 d of sowing. It can achieve high forage yields of excellent nutritional quality and is widely adapted to the different temperate and semi-arid climate regions of Mexico (Hernández-Ortega *et al.*, 2011).

Fescue species are more persistent than ryegrass: they have a more developed root system that tolerates low nutrient levels and cold or drought stress. These characteristics improve performance in pastures associated with *Lolium* (Thomas *et al.*, 2003).

Festulolium is an inter-specific hybrid of perennial or annual ryegrass and *Festuca* species. It was developed to have the hardiness and ability to grow in hostile environments of fescue (higher drought tolerance) and the high nutritional value and rapid germination and establishment ability of ryegrass (Touno *et al.*, 2011; Barnes *et al.*, 2013). As a result of its high yield, Festulolium cultivars obtained from the cross between *L. multiflorum* and

Festuca arundinacea have been adapted to Nordic conditions; however, these hybrids have not been evaluated in Mexico.

One of the festulolium varieties available in Mexico is festulolium cv. Barfest, a *loliaceum*-type festulolium (×*Festulolium loliaceum* (Huds.) P. Fourn.) resulting from crossing perennial ryegrass with meadow fescue (*Festuca pratensis* Hudson) (Orloff *et al.*, 2016).

Therefore, the objective of this study was to compare, on the one hand, the continuous grazing of dairy cows on a short-duration fescue pasture associated with annual ryegrass versus a perennial ryegrass pasture. On the other hand, an annual ryegrass pasture was compared with a fescue pasture. All these pastures are associated with white clover and all are located in two small-scale dairy systems farms.

MATERIALS AND METHODS

The work was carried out in two communities in the Toluca Valley, within a rural participatory research framework, specifically through the participatory research approach for livestock technology development. This approach is characterized by on-farm experimentation with the participation of farmers aimed to identify, plan, develop, and establish new management practices that favour the improvement of their production processes and that are disseminated in their communities (Conroy, 2005). Each community was considered as a case study.

Bromatological analyses were performed at the Instituto de Ciencias Agropecuarias y Rurales (ICAR) of the Universidad Autónoma del Estado de México (UAEMex), following the standardized procedures described by Celis- Alvarez *et al.* (2016).

Experiment 1

Location

The farm is located in the ejido San Cristóbal, Almoloya de Juárez, in the State of Mexico, Mexico. Its production unit is located at 19° 24’ N and 99° 51’ W, at an altitude of 2650 m.a.s.l. The climate is temperate sub-humid with a rainy season from May to October and a dry season from November to April. The average annual rainfall ranges from 800 to 1,000 mm and the average temperature is 13 °C (Albarrán *et al.*, 2012).

Experimental specifications

Eight cows were divided into two groups of fourand were randomly assigned to the treatments. Cows were grouped in pairs (blocks), according to the number of calvings, days open, and performance prior to the experiment. The cows in each pair were randomly assigned to each experimental treatment. The experiment lasted 16 weeks.

Establishment of grasslands

Two 1.0-ha pastures were used. The first one was established in April 2011 with Festulolium cv. Barfest (*Lolium multiflorum* × *Festuca pratense*), associated with annual ryegrass cv. Maximus (*Lolium multiflorum*) and white clover cv. Ladino (*Trifolium repens*). The seeding rate was 22.5 kg/ha. 15 kg/ha, and 3 kg/ha for Festulolium, annual ryegrass, and white clover, respectively. The second grassland was established 2 years earlier with perennial ryegrass cv. Bargala, annual ryegrass cv. Maximus, and white clover cv. Ladino, at of 22.5 kg/ha, 15 kg/ha and 3 kg/ha rates, respectively. At the time of the experiment, the cycle of annual ryegrass had ended and this type of grass was non-existent; therefore, the area was considered a perennial ryegrass pasture associated with white clover. For both pastures, the fertilization rate at sowing was 80-80-60 kg/ha. A maintenance application was carried out every 28 d with 50 kg urea/ha.

Treatments

The following treatments were evaluated: FL-AR=grazing of fescue and annual ryegrass with white clover; and PR=grazing of perennial ryegrass and white clover. The cows of both treatments were fed 3.6 kg DM/cow/day of commercial concentrate (18% CP).

Animal variables

The cows were milked by hand twice a day (5:00 am and 4:00 pm). The stocking rate was four cows (larger livestock units) per ha. Milk yield (RL) was recorded in kg/cow/day once a week with a 20-kg Torino® clock scale, manufactured in Mexico. The protein and fat composition of milk samples collected every 15 days was determined using an Ekomilk® Ultra 40s ultrasound milk analyzer (BULTEH 2000 Ltd., Bulgaria).

Live weight (LW) and body condition (BC) were measured every 15 d. LW was determined using a 1,000-kg electronic scale while BC was estimated on a scale of 1 to 5 (Yabuta *et al.*, 1997).

Grassland variables

Net herbage accumulation (NHA) was estimated following the procedure established by Hoogendoorn *et al.* (2016), using six 0.70×3.0×0.70 m exclusion cages and cutting 0.25 m×2.0 m quadrats inside and outside, at the start and end of each measurement (15 d). The pasture was nominally divided in two.

The grassland was sampled by simulated grazing to determine the chemical composition of the forage (dry matter (DM), organic matter (OM) and crude protein (CP) content), following the standardized procedures described by Celis-Alvarez *et al.* (2016).

Statistical analysis

Grassland and production response variables were analysed with a split-plot experimental design (Kaps and Lamberson, 2004), according to the following model:

$$Y_{ijk}=\mu+B_i+M_j+E_{ij}+p_k+Mp_{jk}+e_{ijk}$$

Where μ=Overall mean; B=Block effect (pair) of cows per lactation stage $i=1,2$; M=Effect of treatments (major plot) $j=1,2$; E=Residual term for major plots; p=Effect of experimental period (minor plot) $k=1,...16$ (for milk yield); Mp=Effect of interaction between pasture type and experimental period; e=Residual term for minor plots. When significant differences were detected, Tukey's test was applied ($P<0.05$).

Experiment 2

Location

The farm is located in the northwest of the State of Mexico, at an altitude of 2440 m.a.s.l., with a temperate sub-humid climate, an average temperature of 14 °C, and an average annual rainfall of 800 mm (Plata-Pérez *et al.*, 2020).

Experimental specifications

Six multiparous cows crossbred with Brown Swiss, weighing between 415 and 480 kg, were used under a statistical cross over arrangement. The cows were in the third stage of lactation, grazed nine hours per day, and were subjected to three experimental periods of twelve days each (nine days for adaptation and three days for sampling and data recording). Cows were fed 2.0 kg DM of concentrate per cow/day (16% CP), divided into two 1-kg rations per day. The concentrate consisted of a mixture of ground corn and soybean paste (80% corn, 20% soybean).

Establishment of grasslands

Two 0.75-ha pastures were used: the first was established with Festulolium cv. Spring Green (*Lolium perenne*/*L.multiflorum* × *Festuca pratense*) and the second with annual ryegrass cv. Westerwold. The grasses were sown in each meadow on 25 November 2016, with a density of 30 kg/ha (ryegrass) and 3 kg/ha (white clover cv. Ladino) and a fertilization dose was 58N-30P-00K. Once the grasses were established, a maintenance fertilization was carried out every 28 days with 100 kg of urea.

Treatments

The treatments evaluated (Tx) were: FL=Grazing of Festulolium cv. Spring Green + white clover; and AR=Grazing of annual ryegrass cv. Westerwold + white clover. The cows from both treatments were provided with free access to water.

Animal variables

The milk yield (MY) was measured on the last 3 days of each experimental period, during the morning and afternoon milkings. One aliquot per day was prepared with the milk from the morning and afternoon milkings, taking the proportion of the yield of each milking. These aliquots were used to determine the protein and fat content with the Ekomilk® Ultra 40s ultrasonic milk analyzer (BULTEH 2000 Ltd., Bulgaria). Live weight (BW) and body condition (BW) were measured every 12 d.

Grassland variables

The NHA (Hoogendoorn *et al.*, 2016) was estimated using six 0.50×0.50×0.80 m exclusion cages in each pasture, cutting 0.40×0.40 m quadrat cuts on the inside and outside. at the beginning and end of each measurement (12 d). To determine the NHA, the pasture was divided into two parts. Pasture heights were recorded every 12 days, using the rising-plate technique described by Hodgson (1994).

Samples were taken from simulated grazing and cut pasture to determine DM, OM, CP, neutral detergent fiber (NDF), and acid detergent fiber (ADF) content, following the standardized procedures described by Celis-Alvarez *et al.* (2016). *In vitro* digestibility of organic matter (IVDOM) was determined by incubation with rumen fluid (López-González *et al.*, 2020). Metabolizable energy (ME) was estimated applying the equation ME=0.0157 (DOMD), where DOMD is organic matter in g/kg DM (AFRC, 1993).

Statistical analysis

Grassland variables were analysed with a split-plot experimental design (Kaps and Lamberson, 2004) and animal variables with a Double Crossover design, based on the following mathematical model:

$$Y_{ijkh} = \mu + S_i + C_j(i) + + + Tl + e_{ijkl},$$

Where: μ=Overall mean; S_i=Fixed effect due to sequence; $C_j(i)$=Random effect due to cow within sequence; $P\ h(i)$=Random effect due to period within sequence; Tl=Fixed effect due to treatment; e_{ijkl}=Experimental error.

When significant differences were detected, Tukey's test was applied ($P<0.05$).

RESULTS AND DISCUSSION

Fodder production variables

Table 1 shows the net herbage accumulation and pasture height in experiments 1 and 2. No significant differences were recorded for the variables evaluated in either experiment ($P>0.05$). Forage availability in the evaluated pastures is low in both experiments. The NRC (1987) indicates that a forage availability of 2250 kg/ha must be ensured in order to guarantee an adequate intake in grazing cows. The lower forage availability in experiment 2 —which was carried out during the dry season— is attributed to the lower ANF (Muñoz-González *et al.*, 2013; Álvarez *et al.*, 2016).

The average NHA in experiment 1 (989 kg DM/ha) is higher than results reported byLópez-González *et al.* (2020) for perennial ryegrass (820 kg DM/ha); however, just like the treatments in experiment 2 (807 kg DM/ha), they are lower than the 1747 kg DM/ha in perennial ryegrass and fescue pastures likewise reported by López-González *et al.* (2017).

The compressed height of the FL treatment (17.3 cm) was greater than BA (12.3 cm) in experiment 2. Pasture height is an indicator of forage availability, Mayne *et al.* (2000) mention that, in continuous grazing, the meadow should be 5.0-8.0 cm tall to maximize forage consumption (Plata-Reyes *et al.*, 2018). The height of the pastures evaluated in experiment 2 is greater than the heights reported by Plata-Reyes *et al.* (2018) for festulolium (4.7 cm) and perennial ryegrass (5.5 cm), by López-González *et al.* (2020) for perennial ryegrass (7.1 cm), and by López-González *et al.* (2017) for perennial ryegrass cv Bargala (5.5 cm), perennial ryegrass cv. Payday (6.1 cm), and Festulolium (5.8 cm).

Table 1. Net herbage and height of the grasslands used in experimental 1 y 2.

Variable	Experiment 1		Mean	SEM_{MP}	SEM_{SP}
	FL-AR	PR			
NHA (kg DM/ha)	1319.0	659.0	989.0	388^{NS}	173^{NS}
NHA (kg DM/ha)	87.9	43.9	65.9	25.9^{NS}	11.5^{NS}
NHA (kg DM/cow/d)	21.9	10.9	16.4	-	-
	Experiment 2				
	FL	**AR**			
Height (cm)	17.3	12.3	14.8	3.5^{NS}	5.1^{NS}
NHA (kg DM/ha)	839.0	776.0	807.5	44.9^{NS}	188.2^{NS}
NHA (kg DM/d)	69.9	64.5	67.2	3.7^{NS}	15.68^{NS}
NHA (kg DM/cow/d)	23.3	22.4	22.4	-	-

FL-AR: grazing of fescue and annual ryegrass with white clover; PR: grazing of perennial ryegrass and white clover; FL: Festulolium associated with white clover; AR: annual ryegrass associated with white clover, NHA: net herbage accumulation; SEM_{MP}: Standard Error of the Mean of the main plot, SEM_{SP}: Standard Error of the Mean of the split plot; NS: Not Significant (P>0.05).

Table 2 shows the chemical composition of the grasslands evaluated in both experiments. No significant differences (P>0.05) were recorded for the variables evaluated in both experiments. As a result of low rainfall, the average DM values for FL and BP in experiment 1 are higher than those reported by Plata-Reyes *et al.* (2018) for Festulolium (212 g/kg) and perennial ryegrass (185 g/kg) associated with white clover.

CP, NDF and FDA content are important parameters of forage quality that determine intake and digestibility of forage. High protein content increases milk yield and milk protein, while NDF and FDA are related to digestibility (Yang *et al.*, 2017).

Table 2. Chemical composition of grazed grassland, cut grassland, and concentrates.

Variable	Experiment 1		Mean	SEM_{MP}	SEM_{SP}
	FL-AR	PR			
DM (g/kg)	246.0	251.3	248.5	26.3^{NS}	87.4^{NS}
Ash (g/kg MS)	114.0	113.2	113.6	5.0^{NS}	1.65^{NS}
OM (g/kg MS)	882.5	847.5	865.0	6.65^{NS}	30.2^{NS}
CP (g/kg MS)	170.8	182.2	176.5	24.3^{NS}	6.02^{NS}
	Experiment 2				
	FL	**AR**			
CP (g/kg MS)	101.1	106.3	103.7	3.7^{NS}	18.7^{NS}
NDF (g/kg MS)	615.7	626.1	620.9	7.3^{NS}	24.4^{NS}
ADF (g/kg MS)	320.2	331.7	326.0	8.1^{NS}	11.8^{NS}
DIVOM (g/kg MS)	722.1	723.6	722.8	1.0^{NS}	43.7^{NS}
ME (MJ/kg MS)	9.6	10.4	10.0	0.2^{NS}	0.3^{NS}

FL-AR: grazing of fescue and annual ryegrass with white clover; PR: grazing of perennial ryegrass and white clover; FL: Festulolium associated with white clover; AR: annual ryegrass associated with white clover; DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; DIVOM: in vitro dry matter digestibility; ME: metabolizable energy; SEM_{MP}: Standard Error of the Mean of the main plot; SEM_{SP}: Standard Error of the Mean of the split plot; NS: Not Significant (P>0.05).

The CP values of experiment 1 are slightly higher than those reported by Opitz *et al.* (2006), Dierking *et al.* (2008), and Touno *et al.* (2011), who evaluated different festulolium cultivars and, at different stages, obtained a CP content of 138 to 152 g/kh DM. Nevertheless, they fall within the values previously reported for these systems, which range from 176 g/kg DM (López-González *et al.* 2017), to 209 g/kg DM (Heredia-Nava *et al.* 2007). The CP content of the treatments in experiment 2 is below that reported by López-González *et al.* (2017) and Heredia-Nava *et al.* (2007). The average height of the pastures evaluated by López-González *et al.* (2017) did not exceed 6.0 cm, whilethe height of the treatments (14.8 cm) in experiment 2 indicates that the pastures had higher amounts of structural carbohydrates and, therefore, lower CP content. According to Arriaga-Jordan *et al.* (1999), CP contents for pasture ranging from 160 g/kg DM to 280 g/kg DM are sufficient to cover the requirements of cows with moderate milk production.

The NDF (620.9 g/kg DM) and FDA (326.0 g/kg DM) contents of the treatments in experiment 2 are higher than those reported by López-González *et al.* (2017) in festulolium and perennial ryegrass (515 g/kg DM for NDF and 265 g/kg DM for FDA) and by Plata-Reyes *et al.* (2018) in festulolium (485 g/kg DM for NDF and 234 g/kg DM for FDA) and perennial ryegrass (524 g/kg DM for NDF and 219 g/kg DM for FDA).

The DIVMO of the treatments in experiment 2 (722.8 g/kg DM) and ME (10.0 MJ/kg DM) are similar to those reported byLópez-González *et al.* (2017): a DIVMO of 721.5 g/kg DM and ME of 11.2 MJ/kg DM in festulolium and perennial ryegrass pastures.

Table 3 presents the results for milk yield and chemical composition, PV, and CC for experiments 1 and 2, showing that there were no significant statistical differences between treatments ($P>0.05$) for both experiments.

In experiment 1, the FL-BA treatment presented an RL of 17.1 kg/cow/day and a BP of 18.9 kg/milk/day, while the average milk fat and protein content was 31.9 g/kg and 30.0 g/kg, respectively. Cow weighed 544 kg (FL-BA treatment, with a CC of 1.6) and 524 kg (BP treatment, with a CC of 1.8).

The RL in experiment 2 was 10.1 kg/cow/day for the FL treatment and 10.6 kg/cow/day for the BA treatment, while the average milk fat and protein content was 39.1 g/kg and 30.8 g/kg, respectively. On average, cows in the FL treatment weighed 450 kg with a CC of 2.5, while cows in the BA treatment weighted 448 kg with a CC of 2.5.

López-González *et al.* (2017) and Plata-Reyes *et al.* (2018) obtained lower yields in grasslands of Festulolium cv. Spring Green associated with white clover cv. Ladino under similar production systems than the yields of experiment 1 (15.8 kg/cow/d and 15.4 kg/cow/d, respectively). However, their yield was higher than the LR of experiment 2. The same authors reported cows that weighted 519 kg and 495 kg, respectively.

Another factor that directly influences the LR is the physiological state of the cow and the third stage of lactation (when the cow is in production), which has an impact on the chemical composition of the milk.

A quality ryegrass pasture can cover the energy requirements for intensively grazed cows with milk yields of up to 30 kg/cow/d (Arriaga-Jordan *et al.*, 1999). Work in small-scale systems has obtained values of 19.0 kg/cow/d (Heredia-Nava *et al.*, 2007) and 14.6 kg/cow/d

Table 3. Productive response of cows in small-scale dairy systems.

Experiment 1				
Variable	**Experiment FL-AR**	**PR**	**Media**	**EEM**
MY (kg/cow/day)	17.10	18.90	18.0	1.26^{NS}
Fat (g/kg)	32.40	31.40	31.9	0.04^{NS}
Protein (g/kg)	29.10	30.90	30.0	0.05^{NS}
PV (kg)	544.20	524.50	534.3	32.50^{NS}
CC (1-5)	1.60	1.80	1.7	0.04^{NS}
Experiment 2				
	FL	**AR**		
MY (kg/cow/day)	10.1	10.6	10.3	0.8^{NS}
Fat (g/kg)	40.0	38.3	39.1	0.14^{NS}
Protein (g/kg)	30.8	30.8	30.8	0.3^{NS}
LW (kg)	450.8	448.7	449.8	3.1^{NS}
BC (1-5)	2.5	2.5	2.5	0.1^{NS}

FL-AR: grazing of fescue and annual ryegrass with white clover; PR: grazing of perennial ryegrass and white clover FL: Festulolium associated with white clover, AR: annual ryegrass associated with white clover, MY: Milk yield, LW: Live weight, BC: Body condition, SEM_{MP}: Standard Error of the Mean of the main plot, SEM_{SP}: Standard Error of the Mean of the split plot; NS: Not Significant (P>0.05).

(Plata-Reyes *et al.*, 2018), so the results of experiment 1 for the BP treatment are within those reported by these authors.

The average values of milk chemical composition (fat and protein), fall within the parameters acceptable by the Mexican standard -NMX-F-700-2004 COFOCALEC (fat ≥32g/kg and protein ≥31g/kg), which regulates Mexican standards. The fat and protein content of experiment 1 and the protein of experiment 2 result lower than those reported by López-González *et al.* (2017) (34.3 g/kg for fat and 31.76 g/kg for protein) and Plata-Reyes *et al.* (2018) (34.2 g/kg fat and 31.8 g/kg protein), however, the milk fat content of experiment 2 is above those reported by these authors.

According to Arriaga-Jordán *et al.* (2010), ryegrass can be used as a strategy to enrich the feed of dairy cows while decreasing the feed cost and thus increasing the level of sustainability (Juárez-Morales *et al.*, 2017).

CONCLUSIONS

The FL-AR treatment (Festulolium cv. Barfest and annual ryegrass) associated with white clover, from experiment 1, produced more forage compared to the rest of the treatments evaluated in both experiments.

As there were no differences in yield, milk chemical composition and nutritional quality of the grasslands evaluated in both experiments, it is concluded that the integration of the grasslands evaluated in these production systems represents a good alternative as a feed base for dairy cows.

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Data availability. Data are available from the correspondent upon reasonable request.

REFERENCES

AFRC, Animal and Food Research Council, 1993. Energy and protein requirements of ruminants, CAB International, Wallingford, UK.

Albarrán, B., García, A., Espinoza, A., Espinoza, 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*(4), 317-324. https://www.arccjournals.com/journal/indian-journal-of-animal- research/ARCC474

Arriaga-Jordán, C. M., Albarrán-Portillo, B., García-Martínez, A. and Espinoza-Ortega, A., 2010. Small-scale cow milk production through two systems of using cultivated grassland. *Ciencias Agrícolas Informa*. 19, 37-47.

Arriaga-Jordán, C. M., Espinoza-Ortega, A., Albarrán-Portillo, B. and Castelán-Ortega O. A., 1999. Grazing milk production on cultivated pastures: an alternative for the central highlands. *Science Ergo Sum. 6*(3), 290-300. http://www.redalyc.org/articulo.oa?id=10401610

Barnes, B. D., Adam, J. D. K. and Baird, J. H., 2013. Evaluation of turf-type interspecific hybrids of meadow fescue with perennial ryegrass for improved stress tolerance. *Crop Science. 54*(1), 355-365. https://doi.org/10.2135/cropsci2013.03.0198

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. 48*(6), 1129-1134. https://doi.org/10.1007/s11250-016-1063-0

Conroy, C., 2005. Participatory Livestock Research: A Guide. Warwickshire, UK: ITDG Publishing. 320 pp.

Dierking, R. M., Kallenbach, R. L., Kerley, M. S., Roberts, C. A. and Lock, T. R., 2008. Yield and nutritive value of "Spring Green" festulolium and "Jesup" endophyte-free tall fescue stokpiled for winter pasture. *Crop Science. 48*(6), 2463-2469. http://dx.doi.org/10.2135/cropsci2008.01.0005

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*(2), 241-256. https://doi.org/10.1017/S0014479706004613

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*(8), 882-901. https://doi.org/10.1080/21683565.2013.775990

Hemme, T., Ramanovich, M., Buchardi, H., Asmussen, E., Wesseling, K., Slabon, A. and Stöfen F., 2009. IFCN Dairy Report 2009, International Farm Comparison Network, Dairy. Research Center, 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 Mexico. *Tropical Animal Health and Production. 39*(3), 179-188. https://doi.org/10.1007/s11250-007-9003-7

Hernández-Ortega, M., Heredia-Nava, D., Espinoza-Ortega, A., Sánchez-Vera, E. and Arriaga-Jordán, C. M., 2011. Effect of silage from ryegrass intercropped with winter or common vetch for grazing dairy cows in small- scale dairy systems in Mexico. *Tropical Animal Health and Production. 43*(5), 947-954. http://dx.doi.org/10.1007/s11250-011-9788-2

Hodgson, J., 1994. Pasture management, theory and practice. Diana, Mexico.

Hoogendoorn, C. J., Newton, P. D., Devantier, B. P., Rolle B. A., Theobald, P. W. and Lloyd-West, C. M., 2016. Grazing intensity and micro-topographical effects on some nitrogen and carbon pools and fluxes in sheep- grazed hill country in New Zealand. *Agriculture, Ecosystems and Environment. 217*(3), 22-32. http://dx.doi.org/10.1016%2Fj.agee.2015.10.021

Humphreys, M. W., Canter, P. J. and Thomas, H. M., 2003. Advances in introgression technologies for precision breeding within the *Lolium - Festuca complex*. *Annals of Applied Biology. 143*(1), 1-10. http://dx.doi.org/10.1111/j.1744-7348.2003.00001.x

Juárez-Morales, M., Arriaga-Jordán, C. M., Sánchez-Vera, E., García-Villegas, J. D., Rayas-Amor, A. A., Rehman T. and Martínez-García, C. G., 2017. Factors influencing the use of cultivated grasslands for small-scale milk production in the Mexican central highlands. *Mexican Journal of Livestock Sciences. 8*(3), 317-324. https://doi.org/10.22319/rmcp.v8i3.4509

Kaps, M. and Lamberson, W., 2004. Split-plot designs. In Biostatistics for Animal Science. M. Kaps and W. Lamberson (Eds). Trowbridge, England: Cromwell Press. Pp: 342-354.

López-González, F., Rosas-Dávila, M., Celis-Alvarez, M. D., Morales-Almaraz, E., Domínguez-Vara, I. A. and Arriaga-Jordán C. M., 2017. Milk production under grazing of different pasture grasses in small-scale dairy systems in the highlands of central Mexico. *Journal of Livestock Science*. 8, 92-97. http://livestockscience.in/wp-content/uploads/milkprod-grazgrass-mexico.pdf

López-González, F., Cantú-Patiño, M.G., Gama-Garduño, O., Prospero-Bernal, F., Colín-Navarro, V. and Arriaga- Jordán, C.M., 2020. Tall fescue and ryegrass pastures grazed by dairy cows in small-scale milk production systems in the high valleys of central Mexico. *Tropical and Subtropical Agroecosystems. 23*(39): 1-10 https://www.revista.ccba.uady.mx/ojs/index.php/TSA/article/view/3126/1447

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*(2), 331-337. https://doi.org/10.1007/s11250-014-0724-0

Mayne, C.S., Wright, I. and Fisher G. E. J., 2000. Grassland management under grazing and animal response. In: Hopkins A. et al. (ed) Grass: Its production and utilisation. Chapter 10. Blackwell Science,Oxford, UK.pp. 247-291.

Muñoz-González, J.C., Huerta-Bravo, M., Lara Bueno, A., Rangel Santos, R., de la Rosa Arana, J.L., 2016. Dry matter production of forages under humid tropical conditions in Mexico. *Mexican Journal of Agricultural Sciences*. 16: 3329-3341. https://doi.org/10.29312/remexca.v0i16.400

Mexican Standard NMX-F-700-COFOCALEC-2004. Sistema Producto Leche-Alimento-Lácteo-Leche cruda de vaca- Especificaciones Fisícoquímicas, Sanitarias y Métodos de prueba. DOF - Official Journal of the Federation

Opitz, W., Boberfield, V. and Banzhaf, K., 2006. Yield and Forage Quality of Different x Festulolium cultivars in winter. *Journal of Agronomy and Crop Science. 192*(4), 239-247. https://doi.org/10.1111/j.1439-037X.2006.00214.x

Orloff, S. B., Brummer, E. C., Shrestha, A. and Putnam, D. H., 2016. Cool-season perennial grasses differ in tolerance to partial-season irrigation deficits. *Agronomy Journal. 108*(2), 692-700. https://doi.org/10.2134/agronj2015.0384

Parsons, A. J. and Chapman, G. F., 2000. The principles of pasture growth and utilization. In A. Hopkins (Ed.), Grass: Its production and Utilization 3rd. edition (pp. 31-89). Oxford, UK: British Grassland Society and Blackwell Science.

Pincay-Figueroa, P. E., López-González, F., Velarde-Guillén, J., Heredia-Nava, D., Martínez-Castañeda, F. E., Vicente, F. and Arriaga-Jordán, C. M., 2016. Cut and carry vs. grazing of cultivated pastures in small-scale dairy systems in the central highlands of Mexico. *Journal of Agriculture and Environment for International Development. 110*(2), 349-363. https://doi.org/10.12895/jaeid.20162.496

Plata-Pérez, G., Sánchez-Vera, E., Martínez-García, C.G., López- González, F. and Arriaga-Jordán C. M., 2020. Short- term mixed pastures of *Lolium multiflorum*, *Avena sativa* and *Vicia sativa* or *Lolium multiflorum* × *Festuca pratensis*, *Avena strigosa* and *Vicia villosa* for grazing low yielding dairy cows during winter in small-scale dairy systems in the highlands of Mexico. *Indian Journal Animal Science. 90* (3): 456-461. http://epubs.icar.org.in/ejournal/index.php/IJAnS/article/view/102533

Plata-Reyes, D. A., Morales-Almaraz, E., Martínez-García, C. G., Flores-Calvete, G., López-González, F., Prospero- Bernal, F. and Arriaga-Jordán, C. M., 2018. Milk production and fatty acid profile of dairy cows grazing four grass species pastures during the rainy season in small-scale dairy systems in the highlands of Mexico. *Tropical Animal Health and Production. 50*(8), 1797-1805. https://doi.org/10.1007/s11250-018-1621-8

Prospero-Bernal, F., Martínez-García, C. G., Olea-Pérez, R., López-González, F. and Arriaga-Jordán, C. M., 2017. Intensive grazing and maize silage to enhance the sustainability of small-scale dairy systems in the highlands of Mexico. *Tropical Animal Health and Production. 49*(7), 1537-1544. https://doi.org/10.1007/s11250-017- 1360-2

Thomas, H. M., Morgan, W. G. and Humphreys, M. W., 2003. Designing grasses with a future-combining the attributes of Lolium and Festuca. Euphytica. 133, 19-26. https://doi.org/10.1023/A%3A1025694819031

Touno, E., Kushibiki, S., Shingu, H., Shinoda, M., Oshibe, A., Oda, S. and Saiga, S., 2011. Evaluation of festulolium (×*Festulolium Braunii*) 'Paulita' haylage in dairy cows: nutritive value, dry matter intake, animal performance and rumen degradability. *Grassland Science. 57*(1), 51-57. http://dx.doi.org/10.1111/j.1744- 697X.2010.00208.x

Yabuta, O. K. and Bouda, J., 1997. Body condition, evaluation as a preventive diagnosis. Mexico Ganadero. 422: 10. Yang, Z., Nie, G., Pan, L., Zhang, Y., Huang, L., Ma, X. and Zhang, X., 2017. Development and validation of nearinfrared spectroscopy for the prediction of forage quality parameters in *Lolium multiflorum*. PeerJ. https://doi.org/10.7717/peerj.3867