Productive and environmental performance of dairy cows grazing *Cenchrus clandestinus* in small-scale dairy systems

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Abstract

The objective was to evaluate through on-farm participatory research the productive and environmental effect of dairy cows grazing kikuyu grass (*Cenchrus clandestinus*) pastures in small-scale dairy systems in Mexico. An experiment with six Brown Swiss x Holstein cows were used to evaluate daytime continuous grazing (10 h/d) of kikuyu grass pastures or pastures of two temperate grasses: perennial ryegrass (*Lolium perenne*) or tall fescue (*Lolium arundinaceum*); supplemented with 4.6 kg DM/cow/d of a farm-made concentrate. Measurements were carried out for net herbage accumulation, sward height, milk yield and composition, live weight, body condition score, and dry matter intake, including the estimation of enteric methane emissions. The assessment of pasture variables was with a split-plot design, while animal variables were analyzed with a mirror replicated 3x3 Latin Square design. There were no differences for the animal variables.; Grazing kikuyu grass pastures by dairy cows in small-scale systems is a viable option in small-scale dairy systems because its milk yield and composition are similar to temperate grasses pastures.

Keywords: *dairy cows, kikuyu, methane, ryegrass, tall fescue*

Introduction

Small-scale dairy systems (SSDS), whose herds comprise from 3 to 35 cows plus replacements (Fadul-Pacheco et al 2013), are key to alleviate poverty (FAO 2010). However, in the highlands of central Mexico, these systems face high feeding costs due to the feeding strategies such as cut-and-carry temperate grass pastures and the use of high amounts of commercial concentrates (Fadul-Pacheco et al 2013; Martínez-García et al 2015).

An option to reduce feeding costs is grazing (Prospero-Bernal et al 2017). However, agro-climatic conditions, management problems, and invasion of other species, predominantly kikuyu grass (*Cenchrus clandestinus*), lead to a partial or total loss of pastures sown to temperate grass species as perennial ryegrass (*Lolium perenne*) or tall fescue (*Lolium arundinaceum*) in a span of two or three years (Plata-Reyes et al 2018).

Kikuyu grass (*Cenchrus clandestinus*; KY) is a subtropical grass from Africa, which is the foraging base of dairy systems in zones of New South Wales in Australia (García et al 2014) and in Latin American countries such as Colombia (Carulla and Ortega 2016). Being a subtropical species, it stops growing at temperatures below 8ºC, it resists light frosts but does not survive low temperatures for extended periods (Garcia et al 2014). In Mexico, it is found in subtropical areas and in the highlands of central Mexico may be and alternative forage for SSDS. However, there are scarce studies on kikuyu grass for dairy production particularly in small-scale systems (Plata-Reyes et al 2018; Marín-Santana et al 2020), with no assessment of its environmental impact.

The goal of the present study was to assess in an on-farm experiment in a small-scale dairy farm the productive and environmental performance of cows grazing a kikuyu-invaded pasture in comparison with pastures of two temperate grasses.

Materials and methods

Study Area

The study was at the end of the rainy season (September 11 to October 22), following a participatory livestock research approach (Conroy 2005) through an on-farm experiment on a small-scale dairy farm in the municipality of Aculco (20° 00'-20° 17' North and 99° 40' - 100° 00'West), in the highlands of central Mexico; at an altitude of 2440 m, with a subhumid temperate climate, a mean annual temperature of 15 °C, summer rains and a mean annual rainfall 700 -1000 mm (Celis-Álvarez et al 2016). The experimental methods with dairy cows and with the participating farmer followed accepted research procedures by Universidad Autónoma del Estado de México.

Pastures

Three pastures of 0.86 ha were assessed: perennial ryegrass (Lolium perenne; RG), tall fescue (*Lolium arundinaceum*; TF) as temperate C3 grass species, and KY (*Cenchrus clandestinum*, established by invasion) as the subtropical C4 grass. The pastures were associated with white clover (*Trifolium repens*). Pastures were fertilized 20 days before the experiment began using 46 kg of nitrogen (urea). Two cows grazed on each pasture at a stocking rate of 2.33 cow/ha.

Pasture variables were net herbage accumulation (NHA) estimated according to López-González et al (2010); sward height, by means of a rising plate meter taking 20 measurements per pasture in a zig-zag pattern (weekly) and hand-plucked herbage samples simulating grazing taken over the last four days of each experimental period.

Animals

Six multiparous low yielding Brown Swiss x Holstein cows from the participating farmer's small herd were used, with a pre-experimental yield of 8.0 kg milk/cow/day, 160 days in lactation and a mean weight of 459 kg. Cows were milked twice a day, recording yields with a clock spring balance and individual samples per cow taken at each milking. Milk fat and protein content were determined with an ultrasound milk analyzer. Live weight (LW) was recorded at the beginning of the experiment and on the last day of each experimental period using a portable electronic scale with 1000 kg capacity. At the same time, body condition score (BCS) was determined on a scale from 1 to 5 (Wildman et al 1982).

Treatments

Cows continuously grazed the pastures (from 7 to 17 hrs) with free access to water. Cows were supplemented with 4.6 kg DM/cow/day of concentrate made in the farm with 9.5 – 10% crude protein (CP): 26% ground sorghum, 26% ground maize, 26% soybean husk, 17% sugarcane bagasse with molasses, and 5% minerals; supplying half the allocation in each milking. At night, cows were kept in a tie-stall barn.

Forage and milk evaluation

Herbage and concentrate samples were dried in a drought oven at 60ºC until constant weight. Crude protein (CP) content, neutral detergent fiber (NDF), acid detergent fiber (ADF) and in vitro dry matter digestibility (IVDMD), were determined following procedures described by Celis-Alvarez et al (2016). The metabolizable energy (ME) of the forage was estimated from CSIRO (2007) equation:

$$ME\ (MJ/kg\ DM) = 0.172\ IVDMD - 1.707$$

Where: IVDMD = in vitro dry matter digestibility.

Milk fat (MF) and milk protein contents were determined with an ultrasonic analyzer. Energy corrected milk was calculated as (Niu et al 2018):

ECM (kg/day) = 12.95x fat yield (kg/day) + 7.65 x protein yield (kg/day) + 0.327 x milk yield (kg/day).

Statistical analysis

Pasture variables were analyzed with a split-plot design. The model for the analysis was:

$$Y_{ijk} = \mu + r_i + T_j + E_{ij} + p_k + Tp_{jk} + e$$

Where: response variable; general mean; r = repetitions; = effect of treatment (grass species in the pastures as main plot), = 1… 3; = residual term for main plots; = effect of the experimental periods (split plot), =1…3; = effect of the interaction between treatment and experimental period; = residual term.

Cow productive and environmental performance followed a 3x3 Latin Square design mirror repeated two times, with three 14-day experimental periods (ten days for adaptation and four days for assessment). The cows were assigned to two groups of three cows per square in function according to pre-experimental daily milk yield, parity, and days in lactation.

Treatment sequences and cows were assigned at random in the first square, while the second square was in mirror; that is to say, the sequences were repeated inversely to reduce possible residual effects (Kaps and Lamberson, 2004). The cows in the second square were similarly assigned at random to the treatment sequence (Celis-Alvarez et al 2016). The model for the analysis was:

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

Where: μ General mean; *C*= effect due to the square (i = 1,2), *V* = Effect due to the cows in the square (j= 1,2,3), *P* = Effect due to the experimental period (k = 1,2,3); t = Effect due to treatment (l = 1,2,3), *e* = experimental error

Experiments using repeated Latin Square designs are very useful to maximise limited experimental units (Kaps and Lamberson, 2004), particularly useful in on-farm research in small-scale farms where collaborating farmers have limited resources and herds. Experiments with small number of cows and short experimental periods are well validated and accepted in the scientific literature (Miguel et al 2014; Civiero et al 2021). Short experimental periods in experiments on dairy cow feeding and nutrition research are also validated and accepted in recognised peer reviewed journals (Pérez-Ramírez et al 2012; Miguel et al 2014; 2019); so that conclusions from these experiments are valid.

Results

Pasture Variables

A positive relationship between sward height and NHA was observed between treatments (Table 1). In general, NHA was 9% higher for KY than for C3 grass. Whilst sward height of KY was 10% lower in comparison with the average height of the C3 grasses, but slightly higher (3%) than the RG height.

Table 1. Net herbage accumulation and sward height

Variable	Treatments			Period		
	KY	RG	TF	1	2	3
NHA (kg DM/ha/d)	35.4	29.3	35.4	32.5	32.1	35.7
Sward height (cm)	6.0	5.8	7.6	7.8	6.0	5.1

KY= Kikuyu; RG= Ryegrass; TF= Tall fescue; NHA= Net herbage accumulation

There were no differences between treatments (P>0.05) in the chemical composition of herbage (Table 2). However, there were differences (P<0.05) between periods as the third period exhibited higher CP, IVDMD and ME, and lower NDF.

Table 2. Chemical composition of pastures

Variable	Treatments			SEM	*p*	Period			SEM	*p*
	KY	RG	TF			1	2	3		
CP (g/kg DM)	178	165	189	11.9	0.113	165^{b}	173^{b}	192^{a}	13.7	0.034
NDF (g/kg DM)	476	467	499	16.7	0.152	507^{a}	466^{b}	468^{b}	23.2	0.040
ADF (g/kg DM)	231	231	238	4.1	0.485	243	234	224	9.9	0.051
IVDMD (g/kg DM)	734	721	736	8.5	0.940	712^{b}	727^{b}	752^{a}	20.3	0.006
ME (MJ/kg DM)	10.9	10.7	11.0	0.2	0.931	10.5^{b}	10.8^{b}	11.2^{a}	0.4	0.006

Treatments × period interaction = P > 0.05. KY= Kikuyu grass; RG= Ryegrass; TF= Tall fescue; CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; IVDMD = in vitro dry matter digestibility; ME=metabolizable energy; DM= Dry matter; SEM = standard error of the mean ^{a,b} (P<0.05)

Animal Performance

Table 3 shows results for animal performance variables. There were no differences (P>0.05) for ECM yields, milk fat or protein content.

Differences were observed (P<0.05) for LW between treatments and periods (Table 3). Cows in KY lost 2.6% of their initial LW; whereas, in C3 pastures, only 1.2% of LW was lost; such loss was more marked in the first period, with a recovery over the two following periods. However, values of live weight and body condition score should be taken only as indicators, as the short experimental periods preclude any further interpretation. On the other hand, DMI exhibited a trend (P=0.071) for a larger DM intake in the RG pasture.

Table 3. Productive performance of cows

Variable	Treatments			SEM	*p*	Period			SEM	*p*
	KY	RG	TF			1	2	3		
ECM (kg/cow/d)	9.0	9.0	8.6	0.5	0.739	9.5	8.7	8.3	0.5	0.095
Milk fat (g/kg)	39.0	35.9	39.0	3.1	0.535	39.7	37.5	36.7	3.1	0.630
Milk protein (g/kg)	31.1	31.3	32.3	1.0	0.447	31.0	32.3	31.4	1.0	0.440
Live weight (kg)	447^{b}	452^{a}	455^{a}	2.6	0.001	441^{c}	483^{a}	451^{b}	2.6	<0.001
BCS (1-5)	2.3	2.4	2.3	0.1	0.536	2.3	2.3	2.4	0.1	0.560
DMI (kg DM/cow/d)	9.5	9.8	9.4	0.2	0.730	9.8	9.5	9.4	0.2	0.750

KY= Kikuyu; RG= Ryegrass; TF= Tall fescue; ECM= energy corrected milk production, BCS, body condition score; DMI=Dry matter intake; DM= dry matter; SEM= standard error of the mean. ^{a,b,c} *(P<0.05)*

Discussion

Pastures

The NHA of KY was lower in comparison with reports by Plata-Reyes et al (2018) in the same area, though in the rainy season, in which KY presented 40% more NHA compared to C3 pastures. This agrees with Neal et al (2011), in which optimally irrigated KY produced 15% more forage than RG; while in water deficit, this difference reaches 22%. The above was observed in the third period, which was the period with highest NHA, possibly from higher rainfall during such period. Sward height was within the range (5 – 8 cm) for continuous grazing (Mayne et al 2000), since below 5 cm albeit measured with a ruler, herbage DM intake is restricted. For its part, sward heigh was negatively related to its nutritional characteristics, which agrees with reports by Tuñon et al (2013), where at a lower height, the leave-stem ratio increases and so does quality.

The chemical composition of forage did not present differences between treatments possibly because the central Mexican highlands have a positive effect on KY (Marín-Santana et al 2020). This may explain why KY had a higher IVDMD than in Colombia where Carulla and Ortega (2016) reported 665 g/kg DM for regrowths at 32 and 58 days compared to 717 g/kg DM herein reported; or in Australia (631 g/kg DM) reported by García et al (2014). Nutritionally, CP content for KY was similar to reports by García et al (2014) in Australia (178 g/kg DM) and by Carulla and Ortega (2016) in Colombia (166 g/kg DM). While CP reported by Celis-Álvarez et al (2016) and Rosas-Dávila et al (2020) for RG and TF, respectively, were similar to this work's observations.

Animal Performance

The low DMI observed (2% of LW) was the result of the high supplementation level, which reduces pH, forage digestion and decreases the pasture DMI (Bargo et al 2003). However, the supplementation level was decided by the participating farmer, which was respected as a premise of participatory rural research.

Milk yield was lower than the values observed by Clark et al (2018) in Australia, with yields of 22 – 27 kg milk/cow/day grazing KY and RG, respectively.

Tropical grasses tend to emit more CH_4 than temperate species because of a higher NDF content as well as higher lignification (Archiméde et al 2011). Albeit, in this work, C3 grasses produced 0.6% more CH_4 as a result of a larger content of fiber (1.5%), which decreased 0.8% of IVDMD in comparison with KY. A higher percentage of fiber accounts for a larger contribution of structural carbohydrates, which are associated to longer feed retention times in rumen and changes in the pattern of volatile fatty acids, generating a larger production of CH_4 (Johnson and Johnson, 1995).

Conclusion

Results obtained in this work show that kikuyu grass pastures are a viable alternative in feeding strategies for dairy cows over the second third of lactation with no significant effect on MY or its components for small-scale dairy systems, with a nutritional value par to herbage from RG and TF temperate pastures. However, more studies are needed to assess the full potential of kikuyu for these systems in the highlands in terms of agri-environmental, economic, and productive impacts over time.

Conflict of interest

The authors declare that there was no conflict of interest regarding the material in this manuscript.

Acknowledgements

The authors express gratitude to the farmer and his family for their participation in this work, and his privacy and that of his family respected by not disclosing their names. We also thank Ms. L.E. Martínez Contreras for her support in laboratory analyses. This work received funding from Universidad Autónoma del Estado de México, through the project “Livestock feeding strategies based on quality forages for small-scale dairy production systems” funded by Program for the Strengthening of Education Quality, and a postgraduate grant for S. Carrillo-Hernández and a postdoctoral grant for J. Velarde-Guillén from the Mexican National Council for Science and Technology (CONACYT – Consejo Nacional de Ciencia y Tecnología).

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Received 29 January 2022; Accepted 30 January 2022; Published 1 April 2022