Triticale (*X. Triticosecale Witt.*) hay as supplement for grazing cows in small-scale dairy systems in the highlands of central Mexico

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Journal of Livestock Science (ISSN online 2277-6214) 12: 206-212
Received on 8/5/21, Accepted on 12/6/21, Published on 10/7/21
doi.10.33259/JLivestSci.2021.206-212

Abstract

Small-scale dairy systems ameliorate poverty and contribute to rural development. The dry season generates feed scarcity, and farmers must develop strategies based on quality forage to reduce purchased inputs. The objective was to assess the performance of dairy cows grazing perennial ryegrass or tall fescue pastures both associated with white clover complemented with triticale (*X. Triticosecale Witt.*) hay during the dry season, as well as the agronomic and chemical composition of pastures and complements. An on-farm experiment was undertaken with a 4x4 Latin Square design with a factorial arrangement, using four Holstein cows. Treatments were TFH= Tall fescue with white clover + 3.0 kg dry matter(DM)/cow/day of triticale hay, RGH= Perennial ryegrass with white clover + 3 kg DM/cow/day of triticale hay, RGNH= Perennial ryegrass with white clover (no hay), and TFNH= Tall fescue with white clover (no hay). Grazing was for 8 h/day in two pastures (ryegrass and tall fescue) of 0.83 ha each, and cows received 4.45 kg DM of concentrate/cow/day. There were no significant differences (P>0.05) in sward height or net herbage accumulation. Contents of dry matter, crude protein, NDF and ADF, as well as the digestibility of organic matter and metabolizable energy were similar between pastures (P>0.05). There were no differences (P>0.05) among treatments for any productive performance variables, but there were statistical differences for estimated herbage intake (P<0.05). Conclusion was that complementing 3.0 kg DM of triticale hay/cow/day did not show any significant effect on any of the evaluated variables but could reduce grazing pressure in pastures.

Keywords: Feeding strategies; alternative forages; Triticale hay; grazing, small scale dairy system; Mexico,

Introduction

Small-scale dairy systems (SSDS) are considered worldwide as a viable option for rural development and for ameliorating poverty of farming families and their communities(Mc Dermott et al., 2010), as is the case in the central highlands of Mexico (Espinoza-Ortega et al., 2007). SSDS are defined by farms with small land holdings, herds between 3 and 35 cows plus replacements, and who rely on family labour for the operation of their farms (Fadul-Pacheco et al., 2013). Milk sales are the main source of income that may be complemented with off-farm work (Espinoza-Ortega et al., 2007).

Feeding strategies in farms with access to some irrigation in the highlands of central Mexico are based on cut and carry pastures of temperate grasses (mainly perennial ryegrass and tall fescue) and legumes (white clover predominantly), complemented with concentrates and conserved forages, mainly straws (Martínez-García et al., 2015).

Grazing of pastures instead of cut and carry herbage reduces feeding costs and improves the profitability of farms (Prospero-Bernal et al., 2017). However, due to restricted irrigation, growth decreases drastically in pastures of both species and there is a need for complementary forages during the dry season (Albarrán et al., 2012; Sainz-Ramírez et al., 2021). Farmers have traditionally supplied maize stover and other cereal straws (like oats, barley, and wheat) as complements during the dry season, and maize silage has proven a useful conserved forage for the dry season reducing feeding costs (Prospero-Bernal et al., 2017), such that 30% of farmers have implemented maize silage in the feeding strategies for their herds in the dry season (Martínez-García et al., 2015). However, maize has a long growth cycle, requires uniform rainfall, and weather conditions in late summer early autumn make it difficult to ensile at the optimal stage (Anaya-Ortega et al., 2009).

Silage of small-grain cereals has been successfully evaluated as an option to provide quality conserved forage in the dry season for dairy cows in these systems (Gómez-Miranda et al., 2020), and these studies have included triticale (*X. Triticosecale Witt.*) silage as an option (González-Alcántara et al., 2020). However, ensiling is a complex process that requires expertise and the machinery to ensile small-grain forage is not always easily available in farming communities being difficult to contract by the smaller farmers.

Hay is the oldest way of conserving forage (Suttie, 2000) and hay is still very important in the feeding strategies of livestock both in developed (Haselmann et al., 2020; Serrapica et al., 2020), as in developing countries both in large scale operations (Santana et al., 2020) as in small-scale livestock systems like in the north-eastern hills of India (Feroze et al., 2017). Suttie (2000) in the book published by FAO states that hay “can be made with simple equipment, manually or with mechanization, and many small-scale farming systems make hay to assure livestock feed through the lean season”. Therefore, conserving forage as hay may be an option for small-scale dairy systems as it can be made manually, or given the long-standing tradition of straw bales, mechanical balers are readily available for small-scale farmers to contract in farming communities in the central highlands of Mexico. Triticale (*X. Triticosecale Witt.*), a hardy intergeneric hybrid between wheat (*Triticum aestivum)* and rye (*Secale cereale*),is an attractive forage alternative given its high yield and low water requirement particularly important for situations where rainfall may be erratic (Sánchez-Gutiérrez and Gutiérrez-Bañuelos, 2015).

The objective was to assess the performance of dairy cows grazing perennial ryegrass or tall fescue pastures both associated with white clover complemented with triticale hay during the dry season, as well as the agronomic and chemical composition of pastures and complements.

Materials and methods

Study area

The study followed a participatory livestock technology development approach (Conroy, 2005) through an on-farm experiment with a collaborating farmer in the municipality of Aculco in the highlands of central Mexico, located between coordinates 20° 06’ and 20° 17’ N and at 99° 40’ and 100° 00’ W, and a mean altitude of 2440 m; with a sub-humid temperate climate, and a mean temperature of 13.2 °C with frosts in winter. Annual rainfall is between 800 and 1000 mm with rains in summer between May and October, and a dry season from November to April (Valle-Aguilar et al., 2020).

Animals and treatments

Four multiparous lactating Holstein cows were used in the experiment. Cows were milked by hand twice daily, at 7:00 and 16:00 feeding was in a mixed system, with day grazing for 8 h/day, and overnight confinement in a tie-stall.

Cows grazed from 8:00 to 16:00 h two 0.83 ha pastures each, one sown to perennial ryegrass (*Lolium perenne*cv. Bargala), and the other to tall fescue (*Lolium arundinaceum*, previously*Festuca arundinacea*cv K31), both pastures were associated with white clover (*Trifolium repens* cv. Ladino).

Drinking water was freely available at pasture. Fertilisation of pastures was with 66 kg N/ha and 23 kg P_2O_5/ha before the experiment, using urea and diamonnium phosphate, and 30 days afterwards with 23 kg N/ha as urea.

Cows were each supplemented with 4.45 kg dry matter (DM) of commercial dairy compound concentrate (with 18% CP) per day divided in two meals, each provided during the morning and evening milkings. Cows on hay treatments received individually 3.0 kg triticale hay/cow/day, also divided in two allocations of 1.5 kg DM after each milking. The participating farmer insisted on the amount of concentrate provided based on their traditional feeding practices, in the belief that dairy cows need large amounts of concentrate to produce milk. Given the participatory nature of the experiment, his decision was respected.

The experiment was a 4x4 Latin Square design with a factorial arrangement, with four dairy cows from the collaborating farmer's small herd. Cows were similar in parity, days in milk and milk yields prior to the commencement of the experiment. Treatments were TFH= Tall fescue with white clover + 3.0 kg DM/cow/day of triticale hay, RGH= Perennial ryegrass with white clover + 3 kg DM/cow/day of triticale hay, RGNH= Perennial ryegrass with white clover (no hay), and TFNH= Tall fescue with white clover (no hay), to enable comparing the two pastures based on different grass species, the effect of the hay complement, and possible interactions between pasture type and hay complement. There were four experimental periods of 14 days duration each, ten days for adaptation to diets and the last 4 days of each experimental period for sampling. Cross-over designs like Latin Squares with short periods are well established in studies on feeding strategies for dairy cows (Miguel et al., 2014; Plata-Reyes et al., 2018; Sainz-Ramírez et al. 2021). Mean daily milk yield was used for analyses.

Milk yield was recorded at each milking for the four days, taking milk samples and a composite aliquot sample was formed (50 mL) and kept at – 20 °C till analyses.Milk fat, protein and lactose content were determined with an ultrasound milk analyser (Lacticheck model LC/01). Milk urea nitrogen (MUN), as an indicator of protein nutrition, was determined with the enzymatic colorimetric method of Chaney and Marbach (1962). Live weight of cows was recorded at the end of each experimental period when body condition score on a 1 to 5 scale was also recorded(Plata-Reyes et al., 2018).

Herbage dry matter intake (HDMI) from pastures was estimated from metabolizable energy (ME) requirements (AFRC, 1993) and the estimated ME content of herbage, triticale hay and concentrate from IVOMD, subtracting ME intake in concentrate and triticale hay from total ME requirements to obtain estimated HDMI following Celis-Alvarez et al. (2016). Sward height of pastures was recorded at the end of each experimental period taking 20 recordings per pasture with a rising plate grass meter following a zig-zag pattern (Plata-Reyes et al., 2018). Net herbage accumulation (NHA) of pastures was estimated from three 0.5 x 0.5 x 0.8 m grazing exclusion cages per pasture from differences between herbage mass on day 14 inside the cages minus the herbage mass on day 1 outside the cages and expressed as kg DM/ha per period and per day following Plata-Reyes et al. (2018).

Chemical analyses

Chemical analyses of feeds followed standard procedures described by Anaya-Ortega et al. (2009). Analyses were for dry matter (DM), organic matter (OM) from ash content, crude protein (CP) and neutral detergent fibre (NDF) and acid detergent fibre (ADF). Enzymatic i*n vitro* organic matter digestibility (IVOMD) followed Riveros and Argamentaría (1987); and estimated metabolizable energy (ME) was determined fromAFRC (1993).

All chemical analyses were performed at the laboratory of the Institute of Agricultural and Rural Sciences of the Autonomous University of the State of Mexico (*Instituto de Ciencias Agropecuarias y Rurales, Universidad Autónoma del Estado de México)* located in the municipality of Toluca in the State of Mexico.

Experimental design

Mean sward height and net herbage accumulation (NHA) as pasture variables were analysed with ANOVA in a split-plot design where pasture type (perennial ryegrass or tall fescue) were fixed effects (main plots), and the four experimental periods were random effects (split plots), with the following model(Kaps and Lamberson, 2004):

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

Where: μ = General mean; r = Effect of replicates (i = 3 for NHA); T = Effect of pasture type (Main Plot) (j = 1, 2); E = Error term for Main Plots ［r(T)ij］; p = Effect of experimental periods (split - plot) (k = 1, ..., 4); Tp = Interaction term between treatments (pasture type) and measurement periods; e = Error term.

Animal variables were analysed via ANOVA with a 4 x 4 Latin Square with a 2 x 2 factorial arrangement (Kaps and Lamberson, 2004). Factors were the grass species in pastures (perennial ryegrass vs. tall fescue), and the second factor was triticale hay complementation (with or without hay).

The statistical model was:

$Y_{ijkl} = \mu + C_i + P_j + G_k + H_l + G{*}H_m + e_{ijklm}$

Where: μ = General mean, C = Effect due to cows(i = 1, 2, 3, 4); P = Effect due to experimental periods(j = 1, 2, 3, 4); G= Effect due to grass species in pastures(k = 1, 2), H= Effect due to hay inclusion(l= 1,2); G*H= Effect due to the interaction between grass species and hay inclusion;*e*= Error term.

Cross-over designs as Latin Squares are useful for on-farm experiments with smallholders, as they maximise limited experimental units (cows) (Kaps and Lamberson, 2004); and have been successful in research with a limited number of cows and short experimental periods previously reported by Miguel et al. (2014) from work in Brasil,and Granados-Rivera et al. (2017) from work on tropical dairy production.

This paper reports an on-farm experiment undertaken with a participating farmer who had knowledge of the objectives of the work, was duly informed at all times, and actively participated in planning and undertaking the experiment. His privacy is respected by not disclosing his name. The experiment with dairy cows and collaborating farmers followed accepted procedures by *Universidad Autónoma del Estado de México*.
Authors declare there is no conflict of interests.

Results

Pasture variables

Table 1 shows results for sward heights (cm) and net herbage accumulation by period for each pasture. There were no differences (P>0.05) in sward height or herbage accumulation between pastures.Being the dry season, NHA was limited to 43 kg DM/ha/day which represented a herbage availability of 17.8 kg DM/cow/day.

Table 2 shows the chemical composition of pastures, where there were no significant differences (P>0.05) for any of the variables between pastures or among periods.Mean CP content of herbage was 205.2 g7kg DM, 510.1.1 g/kg DM for NDF and 235.4 ADF, with a mean IVOMD of 744.2 representing and estimated mean ME content of 9.8 MJ ME/kg DM, indicating good nutritional value in both pastures.

Table 1. Sward height and Net Herbage Accumulation (NHA).

Variable	Variety	Periods				Mean
		I	II	III	IV	
Sward height (cm)	Ryegrass	8.0	9.2	8.2	7.4	8.3
	Tall Fescue	5.7	6.1	6.8	9.1	6.9
NHA per period (kg DM/ha/period)	Ryegrass	609.9	795.5	405.5	344.3	559.1
	Tall Fescue	556.0	554.4	848.2	630.5	647.3
NHA per day (kg DM/ha/día)	Ryegrass	49.3	56.8	28.9	24.4	39.9
	Tall Fescue	39.7	39.6	60.5	45.0	46.2

PI= Period I, PII= Period II, PIII= Period III, PIV= Period IV, NHA per period (kg DM/ha/period)

Table 2. Chemical composition, *in vitro* organic matter digestibility (IVOMD) and estimated metabolizable energy content (eME) of pastures.

Variable	Variety	Periods				Mean TX	SEMTx	SEMExP	P-Value
		I	II	III	IV				
OM (g/kg DM)	Ryegrass	870.8	873.1	877.2	870.0	872.8	0.94	1.94	0.190 *NS*
	Tall Fescue	873.4	875.7	877.4	871.6	874.5			
CP (g/kg DM)	Ryegrass	220.5	196.0	192.5	178.5	196.9	3.06	0.54	0.292 *NS*
	Tall Fescue	206.4	192.5	213.5	241.4	213.5			
NDF (g/kg DM)	Ryegrass	493.4	541.6	474.0	459.4	492.1	10.42	1.03	0.161 *NS*
	Tall Fescue	471.7	573.7	543.2	523.5	528.0			
ADF (g/kg DM)	Ryegrass	236.1	236.4	258.7	238.9	242.4	0.46	0.58	0.449 *NS*
	Tall Fescue	174.5	246.4	241.1	251.3	228.3			
IVOMD	Ryegrass	825.6	823.6	760.7	772.5	795.6	6.35	0.61	0.181 *NS*
	Tall Fescue	735.3	666.0	660.2	709.3	692.7			
eME MJ/kg DM	Ryegrass	11.0	11.4	10.9	10.9	11.0	8.7	2.9	0.057 *NS*
	Tall Fescue	10.2	9.5	9.5	9.7	9.7			

OM= Organic matter; CP= Crude proetin; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; IVOMD= *In vitro* organic matter digestibility. ME= Metabolizable energy; SEMTx= Standard Error of the Mean for pasture treatments (main plots); SEMExP= Standard Error of the Mean for experimental periods (split plot); ^{NS}= Not significant (P>0.05).

Table 3 shows the chemical composition of supplements, both for the commercial compound concentrate as well as for the triticale hay. The chemical composition of the concentrate was as expected from the label. Triticale hay had a low CP content but had a good IVOMD given de medium content of NDF and ADF which yielded a good quality forage with an ME content of 10.4 MJ ME/kg DM.

Animal variables

Table 4 shows results for animal variables. There were no significant differences (P>0.05) for animal variables due to pasture type, triticale hay complementation, or the interaction, except for pasture herbage dry matter intake (P<0.05). There was a trend (P<0.07) for higher milk yields when cows grazed the perennial ryegrass pasture.Herbage DMI in the treatments with hay complementation was 4.5 kg DM/cow/day, and 7.5 kg DM pasture herbage/cow/day for treatments without triticale hay.

Table 3. Chemical composition of concéntrate commercial and of hay of triticale.

Chemical composition (g/kg DM)	DM	OM	CP	NDF	ADF	IVOMD	eME MJ/kg DM
Concentrate commercial	929.4	955.6	185.3	282.4	141.1	926.8	12.9
Hay of Triticale	920.4	941.1	66.4	560.1	283.5	713.3	10.4

DM= Dry matter; OM= Organic matter; CP= Crude proetin; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; IVOMD= *In vitro* organic matter digestibility. ME= Metabolizable energy.

Table 4. Animal variables

Variables	Treatment				SEM	P-Value
	TFH	RGH	RGNH	TFNH		
MY (kg/vaca/día)	14.9	15.9	16.1	14.9	0.26	0.072^{NS}
Milk fat (g/kg)	38.3	37.2	38.0	38.5	0.022	0.143^{NS}
Protein (g/kg)	31.4	31.2	31.4	31.5	0.008	0.471^{NS}
Lactose (g/kg)	45.4	45.3	44.8	45.6	0.019	0.265^{NS}
MUN (mg/dL)	11.5	11.9	10.3	14.2	0.36	0.185^{NS}
LW (kg)	537.3	531.3	531.3	534.0	3.19	0.520^{NS}
BCS (1-5)	2.0	2.0	2.0	2.0	0.00	
Herbage DMI (kg DM/cow/day	4.6	4.4	7.4	7.7	0.12	0.367*

MY= Milk yield; MUN= Milk urea nitrogen; LW= Live weight; BCS= Body condition score. SEM= Standard Error of the Mean; TFH= Tall fescue + triticale hay; RGH= Perennial ryegrass + triticale hay; RGNH= Pereennial ryegrass no hay; TFNH= Tall fescue no hay. NS (P>0.05). * (P<0.05).

Discussion

Pasture variables

Minimum sward height, measured with a ruler, established to enable adequate intake at set stocked grazing is between 5 and 8 cm (Mayne et al., 2000), so that sward height in this experiment was not limiting grazing, with mean grass metre sward heights of 8.4 cm for the perennial ryegrass pasture and 6.9 cm for the tall fescue pasture, although in NHA, the tall fescue pasture had 16% higher herbage growth.

Crude protein content and dry matter digestibility, the latter determined to a large extent by the NDF and ADF contents, are two characteristics of forage quality and nutritive value. The chemical composition of herbage in these variables indicates high quality of herbage from both pastures.
The mean CP content of both pastures was 203.7 g/kg DM, was similar to reports by Heredia-Nava et al. (2007) for perennial ryegrass pastures associated with white clover, and higher to reports by Plata-Reyes et al. (2018) for CP content of perennial ryegrass and tall fescue pastures, similar to those in the study herein reported.

Triticale hay showed a low CP content at 66.4 g/kg DM, much lower than 185 g CP/kg DM reported by Santana et al. (2019) for a large-scale dairy operation. Nonetheless, the low CP content of triticale hay did not have a detrimental effect as it was compensated by the CP content of pasture herbage and the concentrate.

NDF and ADF content in pasture herbage was within reports in the literature (Plata-Reyes et al., 2018) that resulted in high IVOMD and high ME content. Herbage from both pastures had a high estimated ME content, although there was a trend (P<0.06) for a higher ME content in the perennial ryegrass pasture than in the tall fescue pasture highlighting the higher nutritive value of perennial ryegrass pastures

NDF and ADF content of triticale hay was slightly above values for the herbages, although lower than reported for triticale silage (González-Alcántara et al., 2020). However, IVOMD was the same for both triticale forages, silage reported by Gonzalez-Alcántara et al. (2020) and triticale hay herein reported. Estimated ME content of triticale hay was high and even higher than the tall fescue pasture herbage (Tables 2 and 3).

Animal variables

Mean milk yield was 15.5 kg/cow/day, similar to reports by Celis-Alvarez et al. (2016) who reported 15.6 kg/cow/day, López-González et al. (2017) who reported 15.7 kg/cow/day, and Plata-Reyes et al. (2018) with mean yields of 14.9 kg/cow/day. Observed yields were however higher than mean milk yields of 13.2 kg/cow/day reported by Martínez-García et al. (2015), and from González-Alcántara et al. (2020) who reported mean milk yields of 12.3 kg/cow/day from cows complemented with triticale silage; although lower than reports by Heredia-Nava et al. (2007), Anaya-Ortega et al. (2009), and Albarrán et al. (2012) who reported milk yields over 18 kg milk/cow/day. All these reports were from work in similar small-scale dairy farms.

Milk fat, protein and lactose content were very similar within treatments, with mean values of 30.7 g/kg for milk fat, 31.3 g/kg for protein, and 45.2 g/kg for lactose content. These values are within Mexican standards for raw milk composition. Milk urea nitrogen (MUN) had a mean value of 12.0 mg/dL, ranging from 11.3 to 14.2 mg/dL, within the accepted range for dairy cows (Powell et al., 2011).

Conclusions

Although complementing cows with 3.0 kg DM of triticale hay/cow/day did not increased milk yields, milk composition or other animal variables, complementing the diet of grazing dairy cows in small-scale dairy farms with triticale hay during the dry season reduces pasture deterioration due to high grazing pressure and decreased herbage growth.

Acknowledgments

Authors express gratitude to the collaborating farmer and his family who participated in this study, whose privacy is respected by not disclosing their names. This work was undertaken thanks to funding by the Mexican National Council for Science and Technology (Consejo Nacional de Ciencia y Tecnología–CONACYT) through grant 129449 CB-2009, and for the postgraduate grant for María Nayeli Marín-Santana. Our thanks also to Ms. Maria de Lourdes Maya-Salazar and Ms. Laura Edith Contreras-Martínez for their assistance in laboratory analyses.

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