Fatty acid profile in milk of cows fed triticale silage in small-scale dairy systems in the highlands of central Mexico

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ABSTRACT
Milk contains fatty acids (FA) beneficial to human health, so there is interest in the effect of feeding strategies on the FA content of milk. Small-scale dairy systems require conserved forages in the dry season. Cow diets of silages and concentrates yield a lower content of beneficial FA in milk. The objective was to determine the FA profile of feeds and milk from dairy cows on daytime grazing of pastures fed two levels of triticale silage and concentrate. Eight Holstein cows grazed pastures of perennial ryegrass or tall fescue. Triticale silage was offered at two levels (7.5 and 5.0 kg DM/d), in addition to 4.65 kg DM/d of concentrate. The experimental design was a 2 × 2 factorial with two pastures and two levels of silage in a repeated 4 × 4 Latin Square. Linolenic, linoleic, and palmitic acids comprised over 85% of FA in forages, and linoleic acid constituted 50% of FA in the concentrate. There were no differences in the milk composition, or the FA content of milk among treatments or periods (P > 0.05). A higher inclusion of triticale silage did not change the fatty acid profile of milk. The content of beneficial FA in milk was similar to that of grazing cows.

1. Introduction
Small-scale dairy systems, defined as small family farms with herds of between 3 and 35 cows plus replacements (Fadul-Pacheco et al. 2013) comprise over 75% of the dairy farms in Mexico and supply around 35% of the national milk production (Prospero-Bernal et al. 2017). These systems are considered a viable option to ameliorate poverty and promote development in rural communities (McDermott et al. 2010).

Herb-feeding strategies in these systems when irrigation is available are based on cut-and-carry pastures and concentrates during the rainy season, but require complementary forages during the dry winter season when herbage growth decreases due to limited irrigation (Martínez-García et al. 2015). The implementation of grazing pastures and maize silage during the dry season reduces feeding costs, increases profitability and improves the sustainability of these farms (Prospero-Bernal et al. 2017).

However, possible effects of climate change in terms of reduced rainfall or a change in the pattern of rains (IPCC 2014) call for the need to research alternative forage sources better adapted to those scenarios (Thornton et al. 2009).

Several studies have shown that small-grain cereal grains have advantages for use as forage, due to their short agronomic cycle and higher resistance to dry conditions (Murillo et al. 2001; Salgado et al. 2013; Celis-Álvarez et al. 2016; Gómez-Miranda et al. 2020).

Triticale (X. Triticosecale Witt.), a hybrid of wheat (Triticum ssp.) and rye (Secale cereale), is a small-grain forage alternative that combines the protein content of wheat with and the characteristics of rye for resistance to drought, low temperatures and fungal diseases (Payne et al. 2008).

Triticale forage is a viable alternative for feeding livestock, given its high dry matter production and multi-purpose utilization, as it can be grazed, made into hay, or ensiled, and has the additional advantage of a slow decrease in nutritive value as the plants progress through their growth stages (Mendoza-Elos et al. 2011; Salcedo et al. 2014).

Triticale has been evaluated as forage for dairy cattle since the 1970s with good results in terms of yield and nutritive value (Fisher 1972). Previous work on the inclusion of triticale silage for dairy cows in small-scale dairy systems has also shown encouraging results (González-Alcántara et al. 2020).

In recent years, however, there has been increasing interest in health issues related to food consumption, in particular in terms of the fat content of foods. Milk and dairy products are an important source of dietary fats and contain unsaturated fatty acids that are beneficial to human health and that are influenced by the cow’s diet (Elgersma 2015).

Around 25% of fatty acids in milk fat are mono-unsaturated fatty acids (MUFA), and 3% are polyunsaturated fatty acids (PUFA); like rumenic acid (C18:2n7, an isomer of

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conjugated linoleic acid) that has positive effects on cardiovascular disease, certain types of cancer and other conditions (Elgersma et al. 2006; Nantapo et al. 2014; Marin et al. 2018).

Milk from dairy cows fed maize silage and concentrates has lower concentrations of beneficial fatty acids than milk from cows that are grazed (Elgersma et al. 2006). Forages used in dairy cattle feeding are usually evaluated in terms of nutritional value and animal performance, but equally important is their fatty acid composition and how this affects the fatty acid profile of milk (Bauman and Griinari 2003; Salcedo et al. 2014). There are few reports on the fatty acid profile of feeds (Khan et al. 2015) and of the milk of dairy cows fed diets with a significant proportion of small-grain cereal forage (Schroeder et al. 2005; Harper et al. 2017).

This experiment addressed the null hypothesis that there are no significant differences in the fatty acid profile in the milk of cows that graze perennial ryegrass or tall fescue pastures supplemented with triticale silage. Therefore, the objective was to determine the fatty acid profile of feeds and milk from dairy cows on daytime grazing of two pastures (8 h/cow/day) that are fed two levels of triticale silage and concentrate.

2. Materials and methods

2.1. Study area

The study was an on-farm experiment with a collaborating small-scale dairy farmer following the guidelines for participatory livestock technology development (Conroy 2005). The farm is in the municipality of Aculco in the State of Mexico (the state that surrounds Mexico City), located between coordinates 20° 00' – 20° 17' North, and 99° 40' – 100° 00' West. Mean altitude is 2440 m, and the climate is sub-humid temperate, with a mean temperature of 13.2°C, a marked dry season from November to April, winter frosts until mid-February, and a summer rainy season from May to October. Rainfall is between 700 and 1000 mm per year. Figure 1 shows the mean values for temperature and rainfall during the experiment.

Crop, pasture and cow performance of this experiment were reported by González-Alcántara et al. (2020); the results reported here concern the fatty acid profile of feeds and milk.

2.2. Animals, pastures and silage

Eight multiparous Holstein cows were used, with pre-experimental mean live weight (LW) of 502 ± 2.77 kg, 129 ± 87 days in milk, and a mean milk yield of 12.0 ± 2.77 kg/cow/day. The experimental design was a repeated 4 × 4 Latin Square with a 2 × 2 factorial arrangement, and cows within squares were randomly assigned to treatment sequence. The experiment took place from 10 April to 4 June, at the end of the dry season.

Daytime gazing of cows was limited to 8 h a day on two 0.83 ha pastures each, at a stocking rate of 4.8 cows/ha. One pasture was established in 2016 with perennial ryegrass (Lolium perenne cv. Bargala) (PRG) and the second pasture was established in 2009 sown to tall fescue (Lolium arundinaceum, formerly Festuca arundinacea, cv. K31) (TFC), both associated with white clover (Trifolium repens cv. Ladino).

Both pastures were well established and in a vegetative stage. The collaborating farmer had used the pastures for his dairy herd for eight years (TFC pasture) and two years (PRG pasture). Maintenance fertilization was with 40 kg N/ha as urea every month.

Botanical composition in the PRG pasture was 56.5% perennial ryegrass, 34.5% white clover and 9.0% dead herbage, and the TFC pasture was 79.8% tall fescue, 12.7% white clover, and 7.5% dead herbage (González-Alcántara et al. 2020). Pasture utilization was 89.6%, estimated following Reinoso-Ortiz and Soto-Silva (2006).

In accordance to the farmers’ usual practice, cows received 4.65 kg DM/cow/day of an 18% crude protein (CP) commercial dairy concentrate, with half the amount provided at each of two (morning and evening) milkings. Cows were milked by hand at 6:00 and 17:00 h and kept overnight in a tie-stall pen, where they were individually fed the silage allocation after the evening milking.

The triticale crop (X. Triticosecale Witt.) was sown and fertilized on 0.65 ha following the advice of local extension agents, with 120 kg seed/ha and a fertilizer rate of 60N - 40P₂O₅ - 00K; and harvested at 98 days after sowing in the anthesis growth stage (Zadoks et al. 1974). The forage was ensiled in a ground silo covered with 600 calibre black plastic sheet and old tyres. The sampling of silage followed the methodology described by Martínez-Fernández et al. (2014).

2.3. Treatments

Triticale silage was included in the diet as a forage source since herbage growth is very scarce in the dry season.

Treatments were day grazing for 8 h/day (from 9:00–17:00 h) of perennial ryegrass (PRG) or tall fescue (TFC) pasture, 4.65 kg DM commercial concentrate (CONC)/cow/day, and 7.5 or 5.0 kg DM of triticale silage (TSL)/cow per day, in a 2 × 2 factorial combination as follows: HTSL-PRG = 7.5 kg DM TSL+ PRG+ 4.65 kg DM CONC; LTSL-PRG = 5.0 kg DM TSL+ PRG+ 4.65 kg DM CONC; HTSL-TFC = 7.5 kg DM TSL+ TFC+ 4.65 kg DM CONC; LTSL-TFC = 5.0 kg DM TSL+ TFC+ 4.65 kg DM CONC.

TSL inclusion levels represented the provision of 50% (T1 and T3) or 33% (T2 and T4) of the estimated 15 kg of
DM intake. The proportion in diets was 43% concentrate and 57% forage.

TSL was individually offered in the tie-stall manger after the evening milking, and the offered silage and refusals the next morning during the last four days of each experimental period were recorded. Estimation of pasture DM intake was from metabolizable energy requirements (AFRC1993) following Hernández-Mendoza and Leaver (2006) as reported by Celis-Álvarez et al. (2016) and Plata-Reyes et al. (2018).

2.4. Chemical composition of feeds and milk

The sampling of feeds and milk took place during the last four days of each experimental period and a composite sample was used for analysis. Results from the wet chemistry analyses of the chemical composition of feeds were reported by González-Alcántara et al. (2020), and followed standard methods (AOAC 1995) for dry matter (DM), organic matter (OM), crude protein (CP) (method 990.03), neutral detergent fibre (NDF) (method 2002.04) and acid detergent fibre (ADF) (method 973.18); in vitro enzymatic digestibility of organic matter (IVEDOM) followed Riveros and Argamentería (1987), and estimated metabolizable energy (ME) content was calculated from AFRC (1993).

The ether extract figures for herbage, triticale silage and concentrate have been included in Table 1. The ether extract of herbage and triticale silage were estimated from Maxin et al. (2013), and as stated in the label of the commercial concentrate.

2.5. Fatty acid analyses

The fatty acid content of feeds and milk was determined following methods described by Sukhija and Palmquist (1988) modified by Palmquist and Jenkins (2003) using 10% methanolic hydrochloric acid for esterification and hexane as the organic solvent, following Morales-Almaráz et al. (2010) and Plata-Reyes et al. (2018).

Extraction of milk fat for fatty acid profile analyses was by ultra-centrifugation (Feng et al. 2004), and methylation followed the method described by Christie (1982) modified by Chouinard et al. (1999).

Table 1. Fatty acid profile of feeds (g/100 g total fatty acids)

| Feed          | Ether extract | Myristic (C14) | Palmitic (C16) | Palmitoleic (C16:1c9) | Stearic (C18) | Oleic (C18:1c9) | Linoleic (C18:2n-6c) | Linolenic (C18:3n3) | Other |
|--------------|---------------|----------------|----------------|----------------------|---------------|-----------------|----------------------|---------------------|-------|
| PRG          | 11.5          | 1.06           | 1.14           | 2.56                 | 1.11          | 1.15            | 10.82                 | 61.26               | 0.80  |
| TFC          | 11.3          | 0.89           | 0.81           | 0.86                 | 1.66          | 1.61            | 12.36                 | 59.39               | 0.73  |
| TSL          | 12.3          | 0.90           | 0.50           | -                    | 2.58          | 1.59            | 15.15                 | 49.92               | 0.49  |
| CONC         | 30.0          | 0.10           | 0.46           | -                    | 1.92          | 4.31            | 20.21                 | 33.38               | 0.00  |

PRG: Perennial ryegrass; TFC: Tall Fescue; TSL: Triticale silage; CONC: Commercial concentrate.

Fatty acid methyl esters in feeds and milk were separated and quantified by gas chromatography (Perkin Elmer Clarus 500) with a capillary column 100 m X 0.25 mm X 0.2 μm (SULPELCO TM-2560), with nitrogen as the carrier gas. Both the detector and the injector were kept at 260 °C, with an initial temperature of the furnace at 140 °C for 5 min, rising 4 °C per minute until reaching 260 °C.

Each fatty acid peak was identified by the retention time of methyl ester standards (Supelco 37 Component FAME Mix, trans-vaccenic acid and conjugated linoleic acid from SIGMA-ALDRICH). Fatty acid content is reported as g/100 g of total fatty acids.

The daily amounts of fatty acids in milk fat were calculated on the basis of the daily fat amount and the concentration of fatty acids in milk as described by Flachowsky et al. (2006).

The atherogenic index was calculated using the equation by Ulbricht and Southgate (1991), derived from lauric (C12:0), myristic (C14:0) and palmitic (C16:0) fatty acids.

2.6. Experimental design and statistical analysis

The experiment was arranged in a 4 X 4 Latin Square design repeated twice. Latin squares and crossover designs are useful for on-farm experiments with small-scale farmers where there is a limited number of animals for trials, as repeated Latin Squares and cross-over designs enable greater precision (Kaps and Lamberson 2004). There were thus eight observations for each treatment. Cross-over experiments with a limited number of cows are well validated in the scientific literature (Miguel et al. 2014; Granados-Rivera et al. 2017).

On-farm research does not usually meet the same experimental conditions as work on a research station, but that is one of the trade-offs in participatory livestock research (Conroy 2005), which nonetheless offers the advantage of working with the conditions faced by farmers, which enables a faster dissemination and adoption of results (Stroup et al. 1993).

Experimental periods lasted 14 days each, with 10 days for adaptation to treatment diets and 4 days for sampling and recording. Short experimental periods are acceptable when changes in diets are not drastic, following Pérez-Ramírez et al. (2012).

The fatty acids in treatments were analysed via ANOVA as a 4 X 4 Latin Square design repeated twice in a 2 x 2 factorial arrangement with two grass species (PRG and TFC) and two levels of inclusion of TSL, where the square, treatments (inclusion levels), experimental period and the interactions were fixed effects and cows within squares were random effects. The following model, used in previous work, was used (Plata-Reyes et al. 2018):

\[ Y_{ijklm} = \mu + s_i + p_k + TSL_j + GS_m + (TSL \times GS)_{lm} + e_{ijklm} \]

where \( \mu \) = general mean; \( s \) = effect due to squares; \( i = 1, 2, 3, 4 \) = effect due to cows within squares; \( j = 1, \ldots, 4 \) = effect due to experimental periods; \( k = 1, \ldots, 4 \) = TSL = effect due to triticale silage inclusion rate \( l = 1, 2 \); \( GS = \) effect due to the grass species in pastures (perennial ryegrass or tall fescue) \( m = 1, 2 \); \( TSL \times GS = \) effect due to the interaction between TSL and GS; and \( e \) = residual error term.
Tukey’s test was applied when significant differences ($P \leq 0.05$) were detected. In the interest of saving space, only results for treatments are presented, as variation effects among experimental periods are a second blocking factor taken into account in the Latin Square design (Kaps and Lamberson, 2004); and the lineal model for Latin Square designs assumes no interactions between periods and treatments.

### 2.7. Compliance with ethical standards

This paper reports results from an on-farm experiment undertaken with a participating farmer who had knowledge of the objectives of the work and was duly informed at all times, and his privacy and that of his family respected by not disclosing their names. Experimental procedures with dairy cows, and research with collaborating farmers followed accepted procedures by Universidad Autónoma del Estado de México.

### 3. Results

Harvesting triticale at an early growth stage (anthesis) enabled a high quality forage with a crude protein content (CP) of 90.6 g/kg DM, and an in vitro enzymatic dry matter digestibility of 71.3 g/kg DM, which represented an estimated metabolizable energy content of 10.7 MJ ME/kg DM. The early growth stage enabled good ensiling conditions reflected in a silage pH of 4.6, indicating good fermentation. The commercial concentrate had 188 g CP/kg DM, an in vitro digestibility of 89.6 g/kg DM, and an estimated metabolizable content of 13.5 MJ ME/kg DM (González-Alcántara et al. 2020).

Both pastures had good quality herbage, although PRG had higher CP content (226.6 g CP/kg DM) than TFC (210.9 g CP/kg DM), lower fibre content with 462 g NDF/kg DM for PRG and 524.7 g NDF/kg DM for TFC, and 215 and 244 g ADF/kg DM for PRG and TFC respectively, which resulted in a higher DM in vitro enzymatic digestibility for PRG (820 g DM/kg DM for PRG and 755 g DM/kg DM for TFC) such that the estimated ME content of PRG was 12.4 MJ ME/kg DM compared to 11.4 MJ ME/kg DM for TFC (González-Alcántara et al. 2020).

In spite of good herbage quality, pasture growth during the experiment in the dry season was low due to dry conditions (Figure 1) and limited irrigation, with mean net herbage accumulations of 30 kg DM/ha/day for PRG and 46 kg/ha/day for TFC, representing a limited daily availability of herbage of cow 6.20 kg DM/cow/day for PRG, and 9.5 kg DM/cow/day for TFC; therefore, pasture DM intakes were low (González-Alcántara et al. 2020).

#### Table 2. Fatty acid profile in milk from cows grazing two pasture species and complemented with two levels of inclusion of triticale silage and concentrate (g/100 g total fatty acids).

| Treatments          | HTSL-PRG | LTLS-PRG | HTSL-TFC | LTLS-TFC | SEM    | P value |
|---------------------|----------|----------|----------|----------|--------|---------|
| MY                  | 12.3     | 12.34    | 11.95    | 12.62    | 0.29§  | 0.44    |
| Milk fat            | 32.21    | 33.53    | 32.73    | 33.79    | 0.70§  | 0.17    |
| Butyric (C4:0)      | 5.72     | 6.05     | 6.11     | 5.93     | 0.21§  | 0.55    |
| Caproic (C6:0)      | 4.24     | 4.33     | 4.46     | 4.28     | 0.14§  | 0.74    |
| Caprilic (C8:0)     | 2.47     | 2.35     | 2.22     | 2.31     | 0.11§  | 0.88    |
| Capric (C10:0)      | 3.79     | 3.74     | 3.70     | 3.90     | 0.15§  | 0.62    |
| Undecanoic (C11:0)  | 0.44     | 0.46     | 0.39     | 0.45     | 0.04§  | 0.43    |
| Lauric (C12:0)      | 3.56     | 3.44     | 3.47     | 3.72     | 0.16§  | 0.69    |
| Tridecanoic (C13:0) | 1.14     | 1.12     | 0.14     | 0.15     | 0.01§  | 0.67    |
| Myristic (C14:0)    | 12.95    | 12.16    | 12.14    | 12.53    | 0.36§  | 0.58    |
| Myristoleic (C14:1) | 0.60     | 0.61     | 0.61     | 0.63     | 0.03§  | 0.23    |
| Pentadecanoic (C15:0)| 0.85    | 0.86     | 0.84     | 0.90     | 0.07§  | 0.60    |
| cis-10-Pentadecenoic (C15:1n5)| 1.12| 1.05 | 1.09 | 1.05 | 0.04§ | 0.15 |
| Palmitic (C16:0)    | 29.36    | 27.48    | 28.18    | 27.87    | 0.33§  | 0.12    |
| Palmitoleic (C16:1n7)| 1.28 | 1.29 | 1.49 | 1.28 | 0.09§ | 0.23 |
| Heptadecanoic (C17:0)| 0.52 | 0.52 | 0.54 | 0.52 | 0.02§ | 0.63 |
| cis-10-Heptadecenoic (C17:1n7)| 0.13 | 0.14 | 0.13 | 0.12 | 0.01§ | 0.06 |
| Stearic (C18:0)     | 9.09     | 9.52     | 9.46     | 9.80     | 0.35§  | 0.95    |
| Vaccenic (C18:1n7t)| 2.19     | 2.43     | 2.09     | 2.16     | 0.15§  | 0.57    |
| Oleic (C18:1n9c)    | 18.08    | 19.80    | 19.75    | 19.28    | 0.40§  | 0.14    |
| Linoleic (C18:2n6)| 0.14    | 0.15    | 0.15  | 0.16     | 0.01§  | 0.94    |
| Linoleic (C18:2n6c) | 1.24    | 1.24    | 1.13    | 1.10     | 0.04§  | 0.77    |
| Araquidic (C20:0)   | 0.08     | 0.08     | 0.08     | 0.09     | 0.01§  | 0.27    |
| cis-11-Eicosenoic (C20:1n9)| 0.07 | 0.07 | 0.07 | 0.07 | 0.00§ | 0.41 |
| Linolenic (C18:3n3)| 0.47     | 0.44     | 0.35     | 0.39     | 0.03§  | 0.33    |
| Rumenic (C18:2n7)  | 1.37     | 1.52     | 1.35     | 1.26     | 0.06§  | 0.07    |
| Eicosadienoic (C20:2n6)| 0.05 | 0.06 | 0.04  | 0.04     | 0.01§  | 0.41    |
| Behenic (C22:0)     | 0.05     | 0.05     | 0.04     | 0.05     | 0.01§  | 0.40    |
| Tricosanoic (C23:0)| 0.07     | 0.07     | 0.07     | 0.11     | 0.02§  | 0.38    |
| SFA                  | 73.31    | 71.21    | 71.80    | 72.57    | 0.47§  | 0.17    |
| MUFA                | 23.44    | 25.40    | 25.22    | 24.57    | 0.46§  | 0.12    |
| PUFA                | 3.26     | 3.40     | 3.00     | 2.93     | 0.09§  | 0.38    |
| n3 total            | 0.47     | 0.44     | 0.35     | 0.39     | 0.02§  | 0.33    |
| n6 total            | 1.43     | 1.44     | 1.31     | 1.29     | 0.04§  | 0.77    |
| n3/n6               | 0.33     | 0.30     | 0.27     | 0.30     | 0.02§  | 0.15    |
| Atherogenic index   | 3.21†    | 2.77b    | 2.86a    | 3.00b    | 1.01** | 0.01    |

MY: Milk yield; HTSL-PRG: 7.5 kg DM TSL+ PRG+ 4.65 kg DM CONC; LTLS-PRG: 5.0 kg DM TSL+ PRG+ 4.65 kg DM CONC; HTSL-TFC: 7.5 kg DM TSL+ TFC+ 4.65 kg DM CONC; LTS-L-TFC: 5.0 kg DM TSL+ TFC+ 4.65 kg DM CONC; SEM: Standard error of the mean; *P < 0.05; **P < 0.01; SFA: Saturated fatty acids; MUFA: Mono-unsaturated fatty acids; PUFA: Poly-unsaturated fatty acids; †: Published in González-Alcántara et al. 2020.
Grazing was continuous (set stocked) at a stocking rate of 4.8 cows/ha, with access to pasture for 8 h/day, and the cows were kept overnight in pens. Results for pasture intake and pasture variables have been published by González-Alcántara et al. (2020).

Table 1 shows the fatty acid profile of pastures, triticale silage and commercial concentrate. In the herbage from both pastures (PRG and TFC), linolenic, linoleic and palmitic acids represented over 90% of total fatty acid content. In TSL these three fatty acids represented over 85% of total fatty acid content. Linoleic acid comprised over 50% of the total fatty acid content in the commercial concentrate.

Milk yield and composition have been reported by González-Alcántara et al. (2020) and are referred to in Table 2. There were no statistical differences (P>0.05) in chemical composition of milk among treatments, with a mean of 33 g milk fat/kg milk and 33.3 g milk protein/kg milk González-Alcántara et al. (2020).

There were no significant differences (P>0.05) in the fatty acid content of milk (Table 2) for pasture treatments and no significant (P>0.05) interactions between pasture treatments (PRG vs. TFC) or levels of triticale silage inclusion.

Sixty percent of total fatty acids were from saturated fatty acids (myristic, palmitic and estearic). Mean vaccenic acid content was 2.22 g/100 g of total fatty acids, and mean rumenic acid content was 1.37 g/100 g of total fatty acids. These two polyunsaturated fatty acids, found only in foods of ruminant origin, have strong beneficial health effects. The atherogenic index was similar in the four treatments, with a mean value of 2.96.

Table 3 shows results of the analyses of variance for fatty acid yield (g/cow/d) with no differences among treatment for the determined fatty acids.

4. Discussion

Fatty acid content in milk does not generally reflect the fatty acid composition of the diet, since those fatty acids will be altered by the microbe metabolism in the rumen (Morales-Almárrez et al. 2018).

Both pasture herbages (PRG and TFC) had a high content of linolenic acid with a mean of 60 g/100 g total fatty acids, which was lower in the triticale silage (TSL), and the concentrate (CONC) had a high proportion of linoleic acid, as has been reported in the literature (Elgersma 2015). The contents of linolenic, linoleic and palmitic acid in TSL were similar to reports by Khan et al. (2015) for common oat (Avena sativa) as the main fatty acids in forage.

The final proportion of concentrate in the diet was 43%, with very low pasture intake due to difficult grazing conditions given the dry climatological conditions (Figure 1), so that DM intakes were lower than expected (González-Alcántara et al. 2020).

Diets high in concentrates and silages produce low polyunsaturated fatty acid content in milk (Elgersma et al. 2006). It is well documented that lipid metabolism from the diets has a direct relationship to milk fat content and the fatty acid profile of milk (Bauman and Grinnari 2003; Morales-Almárrez et al. 2018).

Contents of palmitic (C16:0) and oleic (C18:1n9c) acids in milk were similar in the current study to results from Harper et al. (2017), who evaluated the effect of wheat and triticale silage as alternatives to maize silage in the performance and nutrient utilization by dairy cows, reporting 26.5 g/100 g for palmitic and 18.9 g/100 g for oleic acids in milk, although with values for myristic acid (C14:0) of 10.0 g/100 g, which is lower than the mean of 12.4 g/100 g of fatty acids observed in the present work. Myristic acid is an important saturated fatty acid given its high atherogenic activity (Ulbricht and Samman 2015).

Omega 6 (n-6) and Omega 3 (n-3) fatty acids are essential for human health since these acids enable normal physiological functions and regulatory signals between cells. The balance between n-3 and n-6 fatty acids is critical for good human health (Wijendran and Hayes 2004; Marin et al. 2018), although
some work has questioned the beneficial effect of these fatty acids in milk on human health, especially conjugated linoleic acid (Benjamin et al. 2015).

As Table 1 shows, pasture herbages and triticate silages were rich in linolenic acid (C18:3n3), as is usual in forages (Elgersma et al. 2006). This polyunsaturated fatty acid is hydrogenized to stearic acid (C18:0) by rumen bacteria producing intermediary trans mono-unsaturated fatty acids (Chilliard et al. 2007). Linoleic acid (C18:2n6c) is another essential polyunsaturated fatty acid, which comprised the largest proportion of fatty acids in the concentrate, which is also hydrogenized in the rumen to stearic acid (C 18:0), producing rumenic (C18:2n7) and vaccenic (C18:1n7t) acids as intermediaries in the rumen (Noble et al. 1974).

The process of bio-hydrogenation in the rumen of polyunsaturated fatty acids from the diet is the reason why milk contains low concentrations of linolenic (C18:3n3) and linoleic (C18:2n6c) acids (Table 2).

The degree of bio-hydrogenation of polyunsaturated fatty acids in the rumen is influenced by the type of diet, and therefore, the production of intermediaries that pass through and are absorbed in the small intestine. Conjugated linoleic acid (CLA) has been proven to have several beneficial attributes to human health (Ip et al. 1991), and ruminant products are the main source of this essential fatty acid (Elgersma et al. 2006). The most important isomer of CLA is rumenic acid (C18:2n7) (Harfoot and Hazlewood 1997).

The concentration of rumenic acid (C18:2n7) and its precursor, vaccenic acid (C18:1n7t), were not significantly different among treatments, with a mean of 2.22 g/100 g or vaccenic and 1.37 g/100 g total fatty acids for rumenic acid. These figures are higher than reports by Castro-Hernández et al. (2014) and Vieyra-Alberto et al. (2017) for cows grazing temperate pastures complemented with maize silage, indicating a more beneficial fatty acid profile than when cows are fed maize silage.

It is also noted that the vaccenic and rumenic acid concentrations in milk in the work herein reported, although lower in vaccenic acid, are within the range of values for vaccenic acid reported by Plata-Reyes et al. (2018) from the evaluation of grazing of three temperate grass species and a subtropical grass supplemented with concentrates. Those authors reported a range of 2.9–3.7 g/100 g for vaccenic acid and 1.3–1.6 g/100 g of total fatty acids for rumenic acid, which compares with the 2.2 g/100 g for vaccenic and 1.37 g/100 g for rumenic acid in the present work.

However, given the high proportion of saturated fatty acids, the atherogenic index is much higher in the present work than in the report by Plata-Reyes et al. (2018).

Rumenic acid concentration was similar to that reported by Schroeder et al. (2005) for cows grazing a common oat (Avena sativa) pasture in Argentina.

Rumenic acid is produced mainly by the action of Δ9-desaturase enzyme activity in the mammary gland on the substrate vaccenic acid, which is produced as an intermediary in the ruminal bio-hydrogenation of the polyunsaturated linoleic and linolenic fatty acids (Lock and Garnsworthy 2002), supplied in the diet.

When cows received the lower level of triticale silage, there was a higher pasture intake, which meant a higher intake of linolenic acid (C18:3n3), which would result in a higher synthesis of vaccenic acid (C18:1n7t), but there were no significant differences between the high and the lower inclusion levels of triticale silage in vaccenic acid content.

Lauric (C12:0), myristic (C14:0) and palmitic (C16:0) saturated fatty acids may produce atherosclerosis in humans. Myristic acid has four times the cholesterol-raising potential of palmitic acid (Ulbricht and Southgate 1991), and efforts are being aimed at reducing the concentration of these saturated fatty acids in milk, increasing the levels of polyunsaturated fatty acids to obtain low atherogenic indices (Prieto-Manrique et al. 2016).

It is known that feeding strategies of dairy cows based on silages and concentrates produce milk with a lipid profile less favourable for human health, with higher levels of saturated fat, in particular myristic and palmitic fatty acids, compared to milk with a more favourable fatty acid profile from grazing cows (Elgersma et al. 2004), or even from cows fed total mixed rations of silages and concentrates but that have access to grazing (Bargo et al. 2006; Morales-Almaráz et al. 2010), or from grazing cows complemented with silages and concentrates (Castro-Hernández et al. 2014), as in the work herein reported.

5. Conclusions

A higher level of inclusion of triticale silage at 7.5 kg DM/cow/day, rather than at 5.0 kg DM/cow/day, in the diet of grazing cows did not change the fatty acid profile of milk, which means that supplementing the diet with TSL may be considered a practical option with no ramifications for the FA composition of milk when grazing conditions are difficult in the dry season, restricting dry matter intake. Levels of beneficial fatty acids were similar to milk from grazing cows.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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