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Pasture feeding strategy and milk fatty acid profile in small-scale dairy systems

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ABSTRACT

The effect of the pasture feeding strategy on the milk fatty acid profile of lactating cows in small-scale dairy farms was evaluated. Ten farms participated in the study, five farms grazed pastures a minimum of 8.0 h/d, and five were fed cut herbage. Supplementary feeds were similar. Results were analysed with Student "t" test. There were no statistical differences when fatty acids were grouped by chain length, or in the proportion of saturated fatty acids (SFA) or monounsaturated fatty acids (MUFA), but there were differences for polyunsaturated fatty acids (PUFA). Alpha-Linolenic acid (C18:3 n-3) was significantly higher in milk of grazing cows than in cows fed cut herbage. There were no differences in atherogenicity index nor in the Δ^9 desaturase activity between pasture management strategies. In conclusion, grazing pastures results in milk with a more beneficial lipid profile for human health.

Keywords: Dairy, Fatty acid profile, Feeding, Grazing, Highlands, Mexico, Mono-saturated fatty acids, Pasture, Poly-unsaturated fatty acids, Saturated fatty acids

There is an increasing worldwide interest for foods with attributes that benefit health, like in India (Saroj *et al.* 2017) and Mexico (Rojas-Rivas *et al.* 2019). Fatty acids like conjugated linoleic acid (CLA) in milk are beneficial for human health (Saroj *et al.* 2017). Therefore, there is an interest in feeding strategies for dairy cows that may increase the concentration of these compounds in milk (Saroj *et al.* 2017, Vicente *et al.* 2017).

Grazing has been shown to increase the concentration of CLA in milk (Saroj *et al.* 2017, Vicente *et al.* 2017). In India, Tyagi *et al.* (2015) reported higher CLA and monounsaturated fatty acids (MUFA) in cows and buffaloes when fed fresh berseem clover forage compared to feeding concentrates and straw.

Conventional feeding strategies in small-scale dairy farms in areas with access to irrigation in central Mexico are based on cut-and-carry pastures of temperate grasses associated with white clover, maize straw, maize grain and cobs, and a third of farmers ensile maize, all complemented with purchased feed inputs (Martínez-García *et al.* 2015).

The implementation of grazing pastures in small-scale dairy systems in the highlands of central Mexico has resulted in lower feeding costs, higher profitability, and therefore enhanced sustainability compared to conventional cut-and-carry pastures (Prospero-Bernal *et al.* 2017), and grazing in these systems results in high concentrations of beneficial fatty acids in milk (Plata-Reyes *et al.* 2018). However, there are farmers who continue their cut-and-carry management of their pastures (Prospero-Bernal *et al.* 2017).

Although evidence shows higher concentrations of beneficial fatty acids in milk from grazing cows (Vicente *et al.* 2017), there is little evidence contrasting fatty acid profiles in milk from cows fed fresh herbage from cut-and-carry pastures compared to milk from cows grazing pastures.

Villar *et al.* (2018) reported from Northern Spain a similar fatty acid profile of milk from cows grazing or fed cut herbage, except for alpha-linolenic acid (C18:3 n3) and eicosapentaenoic acid (EPA C22:5 n-3) that were higher in milk from grazing cows, as well as in the total sum of n-3 isomers that was also higher in milk from grazing cows, and the relationship n6/n3 that was significantly lower in milk from grazing cows when compared to milk from cows fed cut herbage. Saroj *et al.* (2017) clearly stated the need to document the fatty acid profiles of milk for humans, "that may be useful to modulate the quality for the health benefits".

The objective was to assess the effect of pasture feeding strategy, restricted day grazing or cut-and-carry, on the fatty acid profile of milk from cows in small-scale dairy systems.

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MATERIALS AND METHODS

Study area: The work was undertaken in the central highlands of Mexico, with a mean altitude of 2,440 m, a sub-humid temperate climate with a marked rainy season (May to October) and dry season (November to April) with an annual rainfall between 700 and 1,000 mm, and a mean temperature of 13.5°C with frosts from October to February (Plata-Reyes *et al.* 2018).

Participating small-scale dairy farms: A participatory livestock research approach was followed with ten small-scale collaborating dairy farmers. Five farms based their feeding strategy on daytime grazing of their pastures, and five followed the conventional cut-and-carry of pastures.

Work was carried out during the rainy season between June and July. At each farm, 50 ml samples were taken from bulk milk from the herd, kept refrigerated, and transported to the laboratory for analyses.

Fatty acid profile determination: The determination of the fatty acid profile of milk was done as per the techniques described by Christie (1982) modified by Chouinard *et al.* (1999) with hexane as organic solvent after milkfat extraction by centrifugation following Feng *et al.* (2004).

Methylated esters were quantified by gas chromatography (Perkin-Elmer Clarus 500) with a 100 m × 0.25 mm × 0.2 μm capillary column (SUPELCO TM-2560), nitrogen as carrier gas, and the detector and injector kept at 260°C. The furnace initial temperature was 140°C for 5 min increasing 4°C/min till reaching 240°C. Fatty acids were identified from retention time peaks form standard methylated esters (Supelco 37 Component FAME Mix, trans-vaccenic acid and conjugated linoleic acid from SIGMA-ALDRICH).

Fatty acids were reported as g/100 g from total fatty acids as per the procedures described by Plata-Reyes *et al.* (2018).

Calculation of the atherogenic index was done as per the equation given by Ulbricht and Southgate (1991), derived from the C12:0, C14:0 and C16:0 fatty acids.

*Statistical analyses:*Results were analysed as independent samples by a Student t-Test comparing grazing against cut-and-carry results for each fatty acid and other variables (Schefler 1979).

RESULTS AND DISCUSSION

Table 1 shows the characteristics of participating farms. Cows in grazing farms remained on pasture from 8 to 14 h/day and were supplemented with 3.3–6.6 kg fresh weight/cow/day of a commercial compound concentrate with 18% crude protein. Grazing was complemented, during the evening confinement in pens, with various other feeds as oat hay, soya bean hulls, maize straw, maize silage, ground maize grain, and maize bran, as is usual practice in the area (Martínez-García *et al.* 2015).

In the five farms under cut-and-carry of pastures, cows were kept confined in tie-stall barns and open pens all day and provided with between 8.0–9.0 kg DM/cow/day of cut pasture. Cows were supplemented with 4.0–8.0 kg (fresh basis) of 20% CP commercial concentrate, and pasture was complemented similarly as the grazing farms.

Table 2 shows fatty acid profile for the two pasture management strategies. The only statistically significant difference ($P<0.05$) was for alpha-linolenic acid (C18:3 n-3), with milk from grazing cows containing almost 80% more alpha-linolenic acid than in milk from cows fed cut herbage.

Besides the differences in alpha-linolenic acid, fatty acid profiles were mostly similar between the two pasture management strategies, given both have similar amounts of fresh herbage intake, grazed or cut, and the complement feeds provided.

Fresh herbage has higher concentrations of linolenic (C18:3) and linoleic (C18:2) fatty acids so that intake of these acids is higher in grazing cows than for cows fed conventional mixed rations high in maize silage and starchy concentrates. Higher intakes of C18:3 and C18:2 increase CLA (C18:2 c9, t11) and vaccenic acid (C18:1 t11) concentrations in milk (Plata-Reyes *et al.* 2018), from the bio-hydrogenation processes and the activity of Δ^9 Desaturase in the mammary gland.

Table 3 shows fatty acids grouped by length of the carbon chain, saturation, atherogenicity index and the Δ^9 desaturase activity.

There were no statistical differences ($P>0.05$) when fatty acids were grouped by chain length, and there were no statistical differences ($P>0.05$) in the proportion of saturated fatty acids (SFA) or mono-unsaturated fatty acids (MUFA), but there were statistical differences ($P<0.05$) for poly-unsaturated fatty acids (PUFA), such that milk from grazing cows had a 24% higher PUFA concentration. There were no differences ($P>0.05$) in atherogenicity index nor in the Δ^9 desaturase activity between pasture management

Table 1. Characteristics of participating farms

Pasture management strategy	Grazing						Cut-and-carry					
Farm	1	2	3	4	5	Mean	1	2	3	4	5	Mean
Farm size (ha)	6.3	7.8	13.0	9.0	12.5	9.7	4.5	2.0	3.5	2.5	7.8	4.1
Total pastures (ha)	1.5	3.0	4.0	2.0	2.5	2.6	1.5	1.0	1.5	1.0	3.0	1.6
Milking cows	7.0	7.0	8.0	6.0	17.0	9.0	17.0	10.0	8.0	13.0	7.0	11.0
Dry cows	1.0	1.0	2.0	2.0	5.0	2.2	3.0	1.0	1.0	2.0	1.0	1.6
Milk yield (L/cow/day)	15.3	13.9	17.0	14.9	16.4	15.5	13.8	18.0	11.0	14.9	13.9	14.3
Milk fat (g/kg milk)	33.0	38.0	35.0	34.0	34.0	34.8	35.0	33.0	32.0	35.0	38.0	34.6
Protein (g/kg milk)	32.0	32.0	33.0	33.0	32.5	32.5	32.0	33.0	32.0	33.0	32.0	32.0

Table 2. Fatty acid profile of milk from grazing or cut-and-carry pasture management strategies

Fatty acid	Common Name	Pasture Management Strategy		SED	P
		Grazing	Cut-and-Carry		
C12:0	Lauric	2.52	2.56	0.35	0.907 ^{NS}
C13:0	Tridecanoic	0.10	0.13	0.04	0.556 ^{NS}
C14:0	Myristic	10.61	11.23	0.87	0.518 ^{NS}
C14:1	Myristoleic	0.53	0.59	0.06	0.342 ^{NS}
C15:0	Pentadecanoic	0.86	0.93	0.20	0.743 ^{NS}
C15:1	Pentadecenoic	0.19	0.23	0.04	0.287 ^{NS}
C16:0	Palmitic	30.01	31.22	0.71	0.161 ^{NS}
C16:1	Palmitoleic	1.43	1.61	0.29	0.566 ^{NS}
C17:0	Heptadecanoic	0.48	0.54	0.09	0.595 ^{NS}
C17:1	Heptadecenoic	0.20	0.21	0.08	0.877 ^{NS}
C18:0	Stearic	13.38	11.95	0.74	0.126 ^{NS}
C18:1 trans 11	Vaccenic	2.36	1.52	0.71	0.304 ^{NS}
C18:1 cis n-9	Oleic	24.42	25.01	1.65	0.738 ^{NS}
C18:2 trans9, trans12 n-6	Linoelaidic	0.11	0.13	0.04	0.640 ^{NS}
C18:2 cis9, cis12 n-6	Linoleic	1.48	1.20	0.24	0.318 ^{NS}
C18:3 cis9, cis12, cis15 n-3	Alpha-Linolenic	0.34	0.19	0.028	0.005*
C18:2 cis-9, trans 11 (CLA)	Rumenic	1.01	0.91	0.13	0.470 ^{NS}
Other fatty acids		0.59	0.49	0.12	0.448 ^{NS}

SED, Standard error of the difference; ^{NS}, P>0.05; *, P<0.05.

Table 3. Grouping of fatty acids

Fatty acid category	Pasture management strategy		SED	P
	Grazing	Cut-and-carry		
Carbon chain length				
Short chain (C4 : 0 – C12 : 0)	11.82	11.83	0.46	0.29^{NS}
Medium chain (C13 : 0 – C18 : 0)	57.79	58.63	1.60	0.57^{NS}
Long chain (C18 : 1 t11 – C23 : 0)	30.39	29.54	1.99	0.68^{NS}
Saturation				
% SFA	67.42	67.96	2.06	0.80^{NS}
% MUFA	29.24	29.31	2.05	0.97^{NS}
% PUFA	3.36	2.71	0.19	0.02*
[1]Atherogenicity index	1.86	1.90	0.19	0.83^{NS}
[2]Δ^9 Desaturase				
C14	0.05	0.15	0.09	0.35^{NS}
C16	0.04	0.10	0.04	0.29^{NS}
C18	0.65	0.67	0.02	0.29^{NS}
CLA	0.33	0.32	0.08	0.90^{NS}

SFA, Saturated fatty acids; UFA, Unsaturated fatty acids; MUFA, Mono-saturated fatty acids; PUFA, Poly-unsaturated fatty acids; SED, Standard error of the difference; NS, P>0.05; *, P<0.05. [1]From Ulbricht and Southgate (1991) (C12 +4 × C14 + C16)/ (Σ unsaturated fatty acids). [2]Calculated for each pair of fatty acids following Kelsey *et al.* (2003) as (product of Δ^9-desaturase)/ (product of Δ^9-desaturase + substrate of Δ^9-desaturase); for example, for C14 : C14 : 1/ (C14 : 1 + C14 : 0).

strategies.

Differences for PUFA concentrations were significantly higher (P<0.05) in grazing cows. The higher levels of PUFA in the rumen modify the bio-hydrogenation of C18:2 leading to higher levels of C18:1 t11, C18:2 c9, t11, and C18:3 in milk (Hernández-Ortega *et al.* 2014).

Interesting to note the significant difference (P<0.05) where Alpha-Linolenic acid (C18:3 cis9, cis12, cis15 n-3) was ~80% higher in the milk of grazing cows than in cows fed cut herbage; similar to that reported by Villar *et al.* (2018) who found higher Alpha Linolenic concentration of milk from grazing cows compared to cows fed cut herbage, although levels in milk in that report from Northern Spain were 2.4 times higher for grazing cows and 3.0 times higher for milk from cows fed cut herbage, probably due to cows receiving a much higher proportion of their diets from fresh herbage (grazed or cut).

Results coincide with findings of Tyagi *et al.* (2015) who compared a diet based on fresh berseem clover against concentrates and wheat straw in crossbred cows and buffaloes. These authors reported higher CLA and MUFA concentration in milk and ghee from the berseem clover diet.

It is concluded that grazing pastures for a minimum of 8.9 h/day results in milk with higher concentration of poly-unsaturated fatty acids and in alpha-Linolenic acid compared to cows fed cut-and-carry pasture representing a lipid profile beneficial to human health.

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