

Milk production and fatty acid profile of milkfat by dairy cows fed a winter oats (*Avena sativa* L.) pasture only or a total mixed ration

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Abstract Milk production and milk fatty acid (FA) composition were determined in 12 Holstein dairy cows in mid-lactation fed winter oats pasture only (WOP) or total mixed ration (TMR) in a single cross-over design. The WOP treatment cows received a high quality winter oats (*Avena sativa* L.) pasture rotationally grazed, while the TMR treatment cows were fed a corn silage-based TMR feed *ad libitum* once daily. Milk production tended to be lower (14.9 versus 16.3 kg day⁻¹; $P = 0.15$), and milkfat (32.2 versus 35.5 g kg⁻¹; $P < 0.01$), and total protein (35.8 versus 37.8 g kg⁻¹; $P < 0.01$) concentration were significantly lower for the WOP fed cows than for the TMR fed cows. The cows fed WOP lost liveweight and body condition score, but the cows fed

TMR gained liveweight. Cows fed WOP had a lower saturated:unsaturated FA ratio (1.85 versus 2.22; $P < 0.02$). The *cis-9 trans-11* CLA content was 2.6-fold higher (1.41 versus 0.55% of total FA; $P < 0.01$) for the WOP cows. These results indicated that the nutritive value of the milk could be improved by feeding cows on high quality pasture; however, milk production was lower for grazing dairy cows.

Keywords winter oat; total mixed ration; conjugated linoleic acid

Abbreviations: ADF, acid detergent fibre; BCS, body condition score; LW, liveweight; CLA, conjugated linoleic acids; CP, crude protein; DMI, dry matter intake; EE, ether extract; FA, fatty acids; FCM, 4% fat corrected milk; IVDMD, *in vitro* DM digestibility; MUN, milk urea nitrogen; NDF, neutral detergent fibre; NE_L, net energy of lactation; NEFA, non-esterified fatty acids; OM, organic matter; PUN, plasma urea nitrogen; TMR, total mixed ration; VA, vaccenic acid; WOP, winter oats pasture only; WSC, water soluble carbohydrates.

INTRODUCTION

Dietary manipulation of fatty acid (FA) composition in milk has become in an important issue in the last decade, with the goal of obtaining healthier dairy products (Chouinard et al. 1999). The main objectives have been to reduce the saturated:unsaturated FA ratio and the content of C_{12:0}–C_{16:0}, and increase the content of conjugated linoleic acids (CLA) (Hu et al. 1999). Conjugated linoleic acid is a term that includes several isomers of C_{18:2}, which originate from ruminal biohydrogenation of dietary FA and by the action of the Δ^9 -desaturase enzyme in the mammary gland (Griinari et al. 2000; Lock & Garnsworthy 2002). Conjugated linoleic acids have potential beneficial effects for human health. These effects include: anticarcinogenic, antioxidative, and antiatherogenic effects, reduction in body fat accretion, and stimulation of the immune system (Pariza

1999). The isomer *cis*-9, *trans*-11 CLA represents more than 85% of the total CLA in milk and it is responsible for many of the biological activities observed (Pariza 1999).

Previous studies have reported that the content of *cis*-9, *trans*-11 CLA in milk of cows fed pasture-based diets is enhanced when compared with that milk of cows fed total mixed rations (TMR) based on conserved forage plus concentrate (Kelly et al. 1998; Schroeder et al. 2003, 2004). Kelly et al. (1998) reported a two-fold increase in *cis*-9, *trans*-11 CLA concentration in the milk in high-producing dairy cows fed pasture only compared with cows fed TMR. The concentration of *cis*-9, *trans*-11 CLA was also higher in the milk of dairy cows grazing pasture and supplemented with a corn-based concentrate compared with that of cows consuming a TMR (Schroeder et al. 2003). Dhiman et al. (1999) observed that as the amount of pasture dry matter intake (DMI) decreased from 100 to 33% of total intake, the concentration of *cis*-9, *trans*-11 CLA in milk decreased linearly from 2.21 to 0.89%. Stockdale et al. (2003) also observed a linear and positive relationship between the *cis*-9, *trans*-11 CLA concentration in milk and the amount of pasture DMI. These results suggest that the highest levels of *cis*-9, *trans*-11 CLA would be achieved by feeding cows with pasture only diets. However, energy intake in dairy cows of high genetic merit fed pasture was lower than those fed TMR, resulting in lower milk and milk solids production (Kolver & Muller 1998; Bargo et al. 2003).

Milk production systems in countries like Argentina, Australia, and New Zealand are based on the use of pastures as main components of the diets for lactating cows to reduce costs and increase profit per cow. These production systems have a potential competitive advantage with respect to systems based on high-concentrate diets to obtain dairy products with a FA profile more beneficial for human health. However, information on milkfat composition of dairy cows of moderate genetic merit fed TMR or grazing high quality pasture without supplementation is limited. A key factor in grazing feeding systems is the type and quality of pasture. Previous research on milk concentration of *cis*-9, *trans*-11 CLA in grazing cows was conducted with perennial pastures composed of either temperate (Kelly et al. 1998) or subtropical (White et al. 2001) species. Differences among pasture species may be of sufficient magnitude to influence FA composition of the milk (Thomson et al. 2002b). Annual winter oats pastures are commonly used in Argentina for

lactating dairy cows from late fall to early spring to compensate for the low biomass yield of alfalfa (*Medicago sativa*) pastures during this period. In addition, winter oats have good adaptation to well-drained clay and sandy loam soils, simple cultivation procedure, rapid development, and high dry matter yield (Arelovich et al. 2003). However, there is little information on *cis*-9, *trans*-11 CLA concentration in milk of dairy cows grazing annual pasture species such as winter oats. Therefore, the objective of this study was to compare the milk production and milk FA composition of dairy cows fed winter oats pasture only (WOP) or TMR.

MATERIALS AND METHODS

Cows and diets

The experiment was conducted at the National Institute of Agriculture Technology (INTA) in Balcarce, Argentina. Twelve multiparous Holstein cows in mid-lactation (588 ± 77 kg liveweight (LW), 117 ± 6 days in milk) (mean \pm SD) were paired according to milk production, LW, and body condition score (BCS) registered during the previous 30 days, and randomly assigned to one of two treatments in a single cross-over design. Each experimental period was 30 days in length (21 days for adaptation to the diets and 9 days for data collection). Dietary treatments were a winter oats (*Avena sativa* L.) pasture only (WOP treatment), or a corn silage based TMR (TMR treatment). The TMR was formulated according to the NRC (2001) recommendations and fed once daily (09:00 h) outdoors in individual stalls with permanent access to feed and water to ensure at least 20% refusals (Table 1). Cows on WOP treatment grazed the winter oats pasture at a herbage allowance of approximately 27 kg DM cow⁻¹ day⁻¹ in daily strips (Table 1). The amount of pasture offered was weekly calculated throwing a 0.1 m² quadrat randomly across each paddock at 20 sites per date. Plants were hand-clipped to 5 cm height and dried at 105°C in a forced-air oven for 24 h. Based on these results, the area of the strips were adjusted weekly using temporary electric fencing.

Data collection and samples analysis

Samples of pasture were taken every 10 days by hand plucking at random transects to determine the dry matter (DM) content and chemical composition of the pasture apparently consumed. Samples of the TMR offered and refused were taken weekly. Pasture

and TMR samples were dried at 60°C in a forced-air oven, ground through a 1 mm screen (Wiley mill, Philadelphia, PA), and analysed for DM (105°C in a forced-air oven for 24 h), organic matter (OM) (450°C for 8 h), neutral detergent fibre (NDF), and acid detergent fibre (ADF) (Van Soest et al. 1991), crude protein (CP) (AOAC 1990), *in vitro* DM digestibility (IVDMD) using the two-stage procedure (Tilley & Terry 1963), water-soluble carbohydrate (WSC; AOAC 1990), starch (AOAC 1990), and ether extract (EE; AOAC 1990).

Cows were milked twice daily (06:00 and 17:00 h) and individual milk production recorded daily. Milk samples were taken every 2 days during the data collection periods from the morning and evening milkings, composited by weight, and analysed for fat, protein, and lactose concentration by infrared spectrophotometry (Milko Scan, Foss Electric, Hillerød, Denmark), and milk urea nitrogen (MUN) (Wiener Laboratory, Rosario, Argentina). Subsamples were

frozen (−25°C) for later analysis of FA profile. Milk FA were extracted and subsequently transmethylated as described by Baumgard et al. (2002). Fatty acid methyl esters were quantified by gas chromatography (Supelco, Bellefonte, PA). The column was 100 m in length with an inner diameter of 0.25 mm and a film thickness of 0.2 µm. Oven temperatures were initially at 80°C and then ramped at 2°C min^{−1} until 180°C and held for 15 min. Helium was the carrier gas and flowed at 1.1 ml min^{−1} (17 cm s^{−1}, velocity). Airflow was set at 400 ml min^{−1} and the hydrogen make-up gas flow at 45 ml min^{−1}. Inlet and detector temperature were at 250°C. Retention times were determined with pure methyl ester standards (Nu Check Prep., Elysian, MN; GLC-60, *cis*-9, *trans*-11 CLA, and *trans*-10, *cis*-12 CLA) as described by Schroeder et al. (2003).

On the last day of each experimental period, blood samples were taken after the morning milking from the jugular vein. The samples were collected into vacuum tubes (Becton Dickinson, Franklin Lakes, NJ), and centrifuged for 15 min at 1000 × g. The resulting plasma was analysed for non-esterified FA (NEFA) (Wako Pure, Chemical Industries USA, Inc., Dallas, TX), urea nitrogen (PUN), and glucose (GLU) (Wiener Laboratory, Rosario, Argentina) concentrations. Intra-assay coefficients of variation were 5.2, 2.6, and 3.4% for NEFA, PUN, and GLU analysis, respectively.

Liveweight was determined after the morning milking on 2 consecutive days at the beginning of the study and at the end of each experimental period. The same day that LW was determined, BCS was estimated by three independent observers using a 1 (thin) to 5 (fat) point scale. Dry matter intake and energy balance was estimated using the equations of the NRC (2001) that have been validated for grazing dairy cows by Bargo et al. (2003). The inputs used for each cow during each period were diet composition (Table 1), milk production and composition (Table 2), and actual LW and BCS. After the model estimation, DMI was modified in 0.1 kg steps to achieve the observed LW gain/loss (Table 2).

Statistical analysis

Analyses of variance was performed using the GLM procedure of SAS (1996) according to the following model: $Y_{ijk} = \mu + T_i + C_j + P_k + e_{ijk}$, where Y_{ijk} = response variable, μ = population mean, T_i = effect of the treatment ($i = 1$ to 2), C_j = effect of cow ($j = 1$ to 6), P_k = effect of period ($k = 1$ to 2), and e_{ijk} = experimental error. Significant differences were reported at $P < 0.05$ unless otherwise noted.

Table 1 Composition of the winter oats pasture (*Avena sativa* L.) and the total mixed ration (TMR) (mean ± SD). DM, dry matter; nd, non-determined. Numbers within brackets indicate percentage of total diet (DM basis).

Ingredients (kg DM cow ^{−1} day ^{−1})	Treatment	
	Pasture ^a	TMR
Ground corn	–	5.6(17.7)
Corn silage	–	18.6(59.0)
Sunflower meal	–	6.9(21.9)
Urea	–	0.15(0.5)
Mineral (vitamin premix ^b)	–	0.29(0.9)
Total offered	27 (100)	31.5(100)
Chemical composition	229 ± 18	408 ± 21
DM (g kg ^{−1})	(g kg DM ^{−1})	
Organic matter	898 ± 34	926 ± 35
<i>In vitro</i> DM digestibility	805 ± 45	736 ± 35
Crude protein	195 ± 12	165 ± 10
Neutral detergent fibre	333 ± 21	306 ± 12
Starch	nd	169 ± 09
Ether extract	58 ± 02	46 ± 02
Water soluble carbohydrates	202 ± 09	143 ± 03

^aHand-plucked samples.

^bContained 210 g kg^{−1} Ca(PO₄)₂, 46 g kg^{−1} P₂O₅, 60 g kg^{−1} MgO, 30 g kg^{−1} molasses, 1.5 g kg^{−1} FeSO₄, 4 g kg^{−1} Cu SO₄, 3 g kg^{−1} ZnSO₄, 0.04 g kg^{−1} MnSO₄, 0.2 g kg^{−1} Na₂SeO₃, 0.1 g kg^{−1} I, 6 500 000 IU kg^{−1} vitamin A, 1 600 000 IU kg^{−1} vitamin D, 12 500 IU kg^{−1} vitamin E, 645 g kg^{−1} excipient.

RESULTS AND DISCUSSION

Feed quality

Pregrazing pasture biomass was 1806 ± 138 kg DM ha⁻¹ and 1647 ± 185 kg DM ha⁻¹ (mean \pm SD) for periods 1 and 2, respectively. These values were below those (2000 kg ha⁻¹) recommended to maximise pasture intake (Minson 1990), suggesting that WOP cows could have been restricted to below *ad libitum* pasture intake. The chemical composition and IVDMD of pasture and TMR are presented in Table 1. Variation in pasture quality between periods was minimal. The CP content of pastures (195 g kg⁻¹) was in the range (150–250 g kg⁻¹) at which the pasture digestion is maximised (Minson 1990). The NDF content was below values reported by Muller & Fales (1998) for temperate pastures. The content of EE in the pasture (58 g kg⁻¹) was higher than the values compiled by Schroeder et al. (2004) for high-quality pastures. Total mixed ration was lower in NDF, CP, and EE than winter oats pasture (Table 1)

and was adequate to cover the requirements for dairy cows in mid-lactation (NRC 2001).

Milk production and composition, liveweight and body condition score, and plasma metabolites

Milk production tended to be lower (14.9 versus 16.2 kg day⁻¹; $P = 0.15$) and the concentration of fat, protein, and lactose were lower ($P < 0.05$) when the cows were fed WOP (Table 2). Also, 4% fat-corrected milk (FCM), fat and protein yields were lower ($P < 0.05$) on WOP compared with TMR (Table 2). These results are consistent with previous studies that compared milk production and composition in high-producing dairy cows fed TMR versus pasture without (Kolver & Muller 1998) or with (White et al. 2001; Bargo et al. 2002) concentrate supplementation.

Cows fed WOP lost LW, whereas cows fed TMR gained LW and BCS (Table 2). Similar results were found by Kolver & Muller (1998), who observed

Table 2 Milk production and composition, liveweight (LW) and body condition score (BCS), and plasma metabolites of dairy cows fed winter oats pasture only (WOP) or total mixed ration (TMR). FCM, 4% fat corrected milk; MUN, milk urea nitrogen; GLU, glucose; PUN, plasma urea nitrogen; NEFA, non-esterified fatty acids; DMI = dry matter intake.

	Treatments		SEM	P
	WOP	TMR		
Milk production				
Milk (kg day ⁻¹)	14.9	16.2	0.57	<0.15
FCM (kg day ⁻¹)	13.1	15.3	0.54	<0.02
Fat (g kg ⁻¹)	32.2	35.5	7.1	<0.01
Fat (kg day ⁻¹)	0.47	0.59	0.02	<0.01
Protein (g kg ⁻¹)	35.8	37.8	4.3	<0.01
Protein (kg day ⁻¹)	0.53	0.63	0.03	<0.05
Lactose (g kg ⁻¹)	48.1	50.4	3.4	<0.05
MUN (mg litres day ⁻¹)	20.2	20.1	1.53	<0.98
DMI (kg day ⁻¹) ^a	15.6	18.3	0.46	<0.01
Energy balance (MJ NE _L day ⁻¹) ^a	-11.0	24.7	1.96	<0.01
Liveweight and BCS				
Initial LW (kg)	588	588	24	<0.98
LW daily change (kg)	-0.77	1.11	0.19	<0.01
Initial BCS (1–5 scale)	2.61	2.74	0.32	<0.77
BCS total change ^b	-0.1	0.2	0.01	<0.09
Plasma				
GLU (mg litres dl ⁻¹)	57.2	53.6	1.37	<0.10
PUN (mg litres dl ⁻¹)	11.4	14.3	0.53	<0.01
NEFA (mg litres dl ⁻¹)	164.8	148.9	10.2	<0.28

^aDry matter intake estimated using the equation of NRC (2001) validated for grazing dairy cows (Bargo et al. 2003).

^bInitial-final of each 30-day period.

LW and BCS losses when high-producing cows fed only pasture. Reduction in milk production and body reserves have been attributed to a limitation in energy intake of grazing dairy cows (Kolver & Muller 1998; Bargo et al. 2002). In our study, a possible restriction in pasture intake because of the sub-optimal pasture allowance could affect gut fill in WOP cows, explaining part of the differences in LW changes. Furthermore, as changes in LW and BCS were small (Table 2), and the NEFA concentrations in blood were not affected by the treatments (Table 2), the biological significance of LW changes are difficult to interpret.

The DMI predicted by the NRC (2001) model was 15.6 and 18.3 kg day⁻¹ for WOP and TMR, respectively ($P < 0.05$). The estimated energy balance was positive (24.7 MJ of net energy of lactation day⁻¹) for TMR but negative (-11.0 MJ of net energy of lactation day⁻¹) for WOP ($P < 0.05$). These results suggest that the decrease in milk production and the loss of LW and BCS in grazing cows (Table 2) could

be explained by a lower energy intake that led to a negative energy balance. Under the conditions of our study, feeding dairy cows WOP was not enough to maintain milk production even when the production level was moderate (Table 2) and the quality of the pasture was high (Table 1).

Plasma glucose concentration tended ($P = 0.10$) to be higher (57.2 versus 53.6 mg litre dl⁻¹) on WOP compared with TMR (Table 2). Although WOP cows consumed a diet higher in CP (Table 1), PUN was lower (11.4 versus 14.3 litre mg dl⁻¹; $P < 0.05$), supporting evidence of a reduced DMI.

Milk fatty acid composition

Total concentration of short- (C₄-C₁₂), medium- (C₁₄-C₁₆), and long- (\geq C₁₇) chain FA in milk were not affected ($P > 0.05$) by treatment (Table 3). However, the production of *de novo* synthesised FA (C₄-C₁₄) was lower (166 versus 244 g day⁻¹; $P < 0.01$) on WOP, which was expected due to the negative energy balance and potentially reduced acetate and butyrate

Table 3 Fatty acids (FA) composition of the milkfat of dairy cows fed winter oats pasture only (WOP) or total mixed ration (TMR). CLA, conjugated linoleic acid.

FA (% of total FA)	Treatments			SEM	P
	WOP	TMR			
C _{4:0}	4.30	4.09	0.18	<0.59	
C _{6:0}	2.32	2.40	0.08	<0.41	
C _{8:0}	1.32	1.43	0.06	<0.19	
C _{10:0}	3.15	3.58	0.20	<0.24	
C _{12:0}	3.28	3.28	0.36	<0.91	
Total short chain FA	14.4	15.0	0.55	<0.38	
C _{14:0}	10.12	10.99	0.32	<0.07	
C _{14:1}	0.99	0.97	0.04	<0.65	
C _{15:0}	0.92	1.05	0.03	<0.02	
C _{16:0}	23.67	25.29	0.98	<0.34	
C _{16:1}	1.56	1.16	0.09	<0.01	
Total medium chain FA	37.3	39.2	1.41	<0.34	
C _{17:0}	0.26	0.45	0.08	<0.15	
C _{18:0}	12.03	13.85	0.66	<0.05	
C _{18:1, cis-9}	27.22	24.90	0.71	<0.03	
C _{18:2 cis-9, cis-12}	1.38	2.22	0.19	<0.01	
C _{18:3, cis-9, cis-12, cis-15}	0.51	0.17	0.04	<0.01	
<i>cis-9 trans-11</i> CLA	1.41	0.55	0.12	<0.01	
Total long chain FA	43.4	42.0	1.47	<0.50	
Unknown	5.56	3.66	0.60	<0.05	
Total saturated	61.3	66.2	1.29	<0.02	
Total unsaturated	33.8	30.0	0.98	<0.02	
Ratios					
Long chain:short chain	3.06	2.78	0.17	<0.27	
Saturated:unsaturated	1.85	2.22	0.09	<0.02	

supply because of the lower DMI. The concentration of C_{18:0} and C_{18:2} FA were higher ($P < 0.05$) on TMR (Table 3), which is possibly due to the high level of corn grain in the TMR diet (Table 1). This agrees with previous studies that compared TMR and pasture-based diets (Kelly et al. 1998; White et al. 2001; Loor et al. 2003). The concentration of C_{18:3} increased three-fold (0.51 versus 0.17 g 100 g⁻¹ of total FA, $P < 0.05$) on the WOP. Similar results were found in previous studies (Kelly et al. 1998; Loor et al. 2003; Schroeder et al. 2003), which could be expected because the C_{18:3} is the most abundant FA in high-quality pastures (430–950 g kg⁻¹ of total FA; Schroeder et al. 2004). The apparent greater mobilisation of adipose tissues observed in WOP cows (Table 2) could be another source of long-chain FA for the mammary gland, increasing C_{18:1} concentration and reducing the concentration of *de novo* synthesised FA (Thomson et al. 2002a).

The saturated:unsaturated FA ratio was lower (1.85 versus 2.22; $P < 0.05$) when the cows were fed WOP (Table 3). Milk with a lower saturated:unsaturated FA ratio would be beneficial for human health since saturated FA have been associated with the increase in cholesterolemia and the probability of heart diseases (American Heart Association 1996; Hu et al. 1999).

The *cis-9 trans-11* CLA concentration was 156% higher ($P < 0.05$) on WOP compared with TMR (Table 3), in agreement with previous research that reported that *cis-9 trans-11* CLA concentration was 137% higher for cows fed only pasture (Kelly et al. 1998). Summarising seven studies that compared the *cis-9 trans-11* CLA concentration in milk of cows grazing pastures or cows fed with TMR, Schroeder et al. (2004) found a mean increase of 134% when cows grazed high-quality pastures. Increasing levels of alfalfa hay and concentrate supplementation to grazing cows from 0 to 660 g kg⁻¹ of total DMI, resulted in a linear decrease in *cis-9 trans-11* CLA concentration in milkfat (Dhiman et al. 1999). The high concentration of *cis-9 trans-11* CLA observed in our study was in agreement with those treatments without supplementation (Dhiman et al. 1999). Stockdale et al. (2003) found a significant ($P < 0.05$) positive linear relationship between pasture DMI and *cis-9 trans-11* CLA concentration in milk, suggesting that a potentially healthier milk FA composition is obtained with diets high in pasture and low in cereal grain supplementation.

The increase in *cis-9 trans-11* CLA concentration in WOP treatment could be partially explained by an enhancement of dietary precursors such as

C_{18:3}, which was also higher in milk (Table 4). This is the major unsaturated FA present in fresh grass (Schroeder et al. 2004), which is partially biohydrogenated to *trans-11* C_{18:1} or vaccenic acid (VA) in the rumen (Griinari et al. 2000; Loor et al. 2003). This could explain the positive relationship ($R^2 = 0.74$; $P < 0.01$) between C_{18:3} and *cis-9 trans-11* CLA in milkfat (Fig. 1), supporting the idea that a higher intake of pasture C_{18:3} and its incomplete ruminal biohydrogenation represent key factors involved in the increase of *cis-9 trans-11* CLA concentration in milkfat of grazing cows as was indicated by Loor et al. 2003. Ruminal saturation of VA to C_{18:0} is the limiting step in the ruminal biohydrogenation, leading to accumulation of VA in the rumen and its absorption in the small intestine (Griinari et al. 2000). The absorbed VA may be converted to *cis-9 trans-11* CLA by the mammary Δ^9 -desaturase. This endogenous synthesis of *cis-9 trans-11* CLA in the mammary gland from VA may produce more than 75% of the total *cis-9 trans-11* CLA found in milk (Griinari et al. 2000; Lock & Garnsworthy 2002). Modifications in the ruminal biohydrogenation of long-chain FA by different types of carbohydrate, rate of passage, fluid dilution, and feeding frequency between the two diets could also modify the ruminal metabolism and microbial population affecting CLA and VA production in the rumen (Kelly et al. 1998; Stockdale et al. 2003). Finally, the negative energy balance and greater body mobilisation on WOP might play some role in the increased concentration of *cis-9 trans-11* CLA in milk. Jiang et al. (1996) observed increased *cis-9 trans-11* CLA (+43%) and VA (+72%) concentration in milkfat of cows whose intake of TMR was restricted and were in negative energy balance in comparison with cows whose intake was unrestricted. In grazing dairy heifers, it has been observed that greater BCS and LW losses were associated with increases in long-chain unsaturated FA in milk, and these changes in the FA profile persisted until the heifers reached a positive energy balance (Thomson et al. 2002a). In our study, although WOP cows seemed to be in a negative energy balance and losing BCS (Table 2), these losses were small and there were no changes in plasma NEFA concentrations (Table 2). These results may suggest that the differences in the FA profile in milk were more related to effects of the treatments on the intake and metabolism of the dietary FA rather than effects on body reserve mobilisation. More research is needed to develop a better understanding of the effects of body reserve mobilisation and pasture intake on FA profile in milkfat of grazing cows.

Fig. 1 Relation between milkfat concentration of C_{18:3} and *cis*-9 *trans*-11 conjugated linoleic acid (CLA) of dairy cows fed pasture only (▲) or total mixed ration (○). CLA (g 100 g⁻¹ FA) = 0.197 + 2.434 C_{18:3} (g 100 g⁻¹ FA); R² = 0.75; P < 0.01.

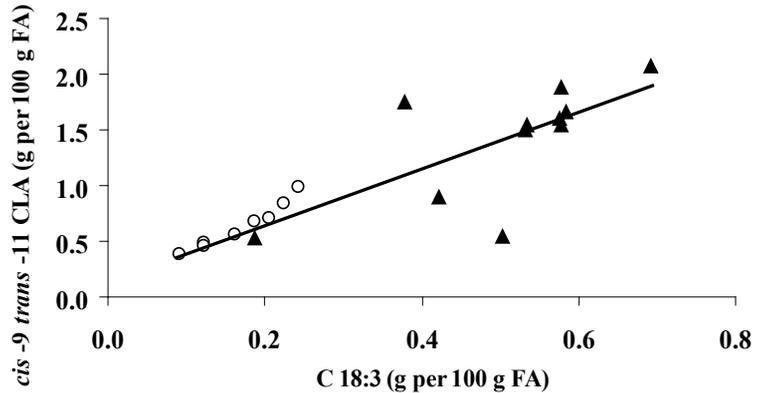
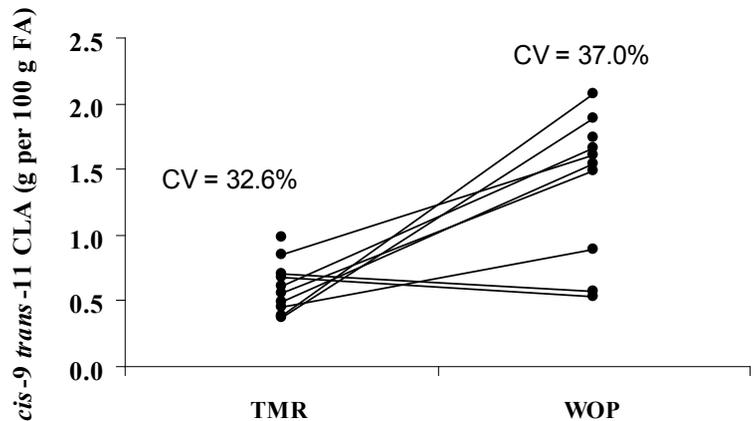


Fig. 2 Individual cow variation in the content of *cis*-9 *trans*-11 conjugated linoleic acid (CLA) of dairy cows fed winter oats pasture only (WOP) or total mixed ration (TMR).



A large variation among cows in the concentration of *cis*-9 *trans*-11 CLA in milkfat has been reported for both TMR and pasture-fed cows (Kelly et al. 1998; Schroeder et al. 2003; Stockdale et al. 2003). In the present study, the variation in *cis*-9 *trans*-11 CLA concentration was high in both treatments (Fig. 2). Regardless of the individual variation, all cows but two responded with a significant increase in *cis*-9 *trans*-11 CLA concentration when fed WOP compared with the concentration found in the same cow when fed TMR (Fig. 2). However, the magnitude of response was not the same for all cows (Fig. 2), suggesting individual variation in other factors affecting ruminal metabolism and/or endogenous production of *cis*-9 *trans*-11 CLA (Stockdale et al. 2003).

CONCLUSION

Dairy cows that grazed an annual winter pasture without supplementation had a lower saturated:unsaturated FA ratio and a higher *cis*-9 *trans*-11 CLA concentration than when consuming a TMR. These changes in FA composition may produce more beneficial dairy products in terms of human health. However, the cows fed WOP seemed to have a lower energy balance, which led to a reduction in milk and milk solids production. Although the effects of high-quality pasture intake on milk FA composition could be maximised with WOP, supplementation strategies are needed to avoid reduction in production and reproduction performance. Future research should be focused on finding those strategies that

increase energy intake of the cows while maintaining the beneficial effects of the pasture intake on milk FA composition.

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