Shearing dairy ewes in mild-winter during lactation

By Elhadi et al.

The effects of shearing (control vs. shorn) were assessed under mild-winter conditions (13.2ºC, on average) in 48 lactating dairy ewes of 2 breeds (Lacaune, LC; Manchega, MN) characterized by having different fleece (heavier in MN) and milk yield (greater in LC). Rectal temperature after shearing only decreased in MN (−0.4ºC). Feed intake and milk yield increased (5% and 10%, respectively) in shorn LC, when compared to control LC, but did not vary in MN. Shearing did not affect milk composition, milk fatty acid profile or physiological indicators, as well as body reserves in both breeds. In conclusion, shearing during lactation was positive for high-yielding ewes, without effects on mid-yielding ewes.

Effects of shearing two breeds of dairy ewes during lactation under mild-winter conditions

A. Elhadi,* A. A. K. Salama,*† X. Such,* E. Albanell,* P. G. Toral,‡ G. Hervás,‡ P. Frutos,‡ and G. Caja*[1]

[*]Group of Research in Ruminants (G2R), Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain

[†]Dairy and Food Science Department, South Dakota State University, Brookings, SD 57007

[‡]Instituto de Ganadería de Montaña (CSIC-Universidad de León), Finca Marzanas, 24346 Grulleros, León, Spain

ABSTRACT

The lactational effects of shearing (CO, control unshorn; SH, shorn) were investigated in 48 dairy ewes of 2 breeds (Lacaune, LC, n = 24; Manchega, MN, n = 24) having similar stage of lactation (120 ± 6 DIM) and body frame (65.1 ± 1.5 kg BW and 2.4 ± 0.1 BCS), but differing in fleece and milk production. Ewes were penned indoors, adapted to the diet (alfalfa hay ad libitum and fixed amount of concentrate) and allocated for 30 d in 8 balanced groups to which the experimental treatments were applied. All ewes were sheared on the same day. Feed intake by pen and milk yield by ewe were recorded daily. Individual samples of milk (d −3, 3, 5, 7 and 15) and blood (d −7, 3, 7 and 15) were collected, as well as BW and BCS measured (d −15, 0

[1]Corresponding author: gerardo.caja@uab.es

and 15), related to shearing. Pooled milk samples per pen were also collected before and after shearing for milk FA analysis (d −3 and 15). Average temperatures in the barn before (12.6 ± 0.7ºC) and after (13.7 ± 0.4ºC) shearing were mild. Fleece was heavier in MN than in LC (1.04 ± 0.10 vs. 0.75 ± 0.09 kg/ewe) and tended to cover more body surface in MN than in LC ewes. Responses to shearing varied according to breed, the rectal temperature after shearing only decreasing significantly in the MN (−0.36 ± 0.09ºC). Feed intake increased in the LC-SH (5%), when compared to LC-CO, but did not vary in the MN ewes. Ingestibility of the alfalfa hay, expressed as filling units for sheep (FUs) and monitored in 2 groups of 6 dry and unshorn ewes of each breed (73.0 ± 2.5 kg BW and 3.1 ± 0.2 BCS), was constant throughout the experiment (0.99 ± 0.03 FUs/kg DM). Regarding milk production, LC-SH ewes yielded 10% more milk (1.38 ± 0.06 vs. 1.52 ± 0.05 kg/d) than LC-CO ewes, but no differences were detected in MN ewes (0.74 ± 0.03 kg/d, on average). No differences in the concentration of major milk components by effect of the shearing treatment were detected in either breed, but LC-SH ewes yielded 9% more milk protein than did LC-CO ewes. No relevant effects of shearing were also detected on milk fatty acid profiles, although MN ewes showed lower C4:0, C6:0, C14:0, *t*-11 and *t*-12 C18:1 contents, than did LC ewes. Moreover, no changes by effect of shearing were detected in plasma glucose, NEFA, cortisol and insulin values in either breed, as well as in BW or BCS. In conclusion, shearing dairy ewes during lactation under mild-winter conditions, is a suitable management option that may increase feed intake and milk production, without deleterious effects on milk composition.

Key words: shearing, dairy sheep, milk composition, fatty acid

INTRODUCTION

Shearing is usually considered to be a necessary practice for flock management in order to improve sheep welfare and production (Swanson and McGlone, 2010). Shearing modifies the limits of the thermo-neutral zone of sheep, increasing the lower critical temperature and inducing adaptive responses to maintain body homeostasis (Russel et al., 1985; Symonds et al., 1988). Shearing boosts the heat transfer between the animal and its environment, especially under cold-weather conditions, resulting in a greater feed demand to cope with the increased energy demand for heat production (18 to 78%, according to temperature; Elvidge and Coop, 1974). Different degrees of cold stress can be expected by breed according to their morphological traits and their physiological and behavioral adaptations. A greater degree of cold stress would result in a greater metabolic rate, thus increasing the amount of feed needed to cope with the requirements.

In the Mediterranean countries, traditional sheep production systems involve shearing at the beginning of the summer to match the onset of hot temperatures. In Spain, sheep are usually shorn around mid-May, before mating and starting traditional grazing on cereal stubbles or transhumance. Nevertheless, intensified production systems (i.e., high milk yield and long lactation length with delayed dry-off) and out-of-season breeding (i.e., increased lambing frequency for extending the harvest of milk in the farm) resulted in the need of shearing the ewes at any time during the year. These intensification practices are currently observed in the dairy farms of many sheep's milk leading countries (Pulina et al., 2018).

When shearing is conducted during winter or early spring, shorn sheep could suffer cold stress as a consequence of the low temperatures and having lost their insulation. Piccione et al. (2002) reported an increase of over 1ºC in the core body temperature of Mediterranean dry ewes (i.e., Comisana, Barbaresca and Pinzirita) after shearing in spring (mild conditions, 16 to 28ºC), as an over-reaction of the ewes to the stress.

Despite the expected effects of environmental temperatures on the thermoregulation of the lactating animals, little is known on the effects of shearing in lactating dairy ewes. So, our hypothesis was that shearing dairy ewes during winter, when they are open and lactating, could cause a thermoregulatory response due to the removal of their fleece, which will increase the metabolic rate and feed intake of the ewes to maintain their body temperature. This catabolic effect may also modify milk yield and milk composition (e.g., increase milk fat or decrease milk protein) by modifying the hormonal profiles and the partitioning of nutrients between the body and the udder. To our knowledge, only Aleksiev (2008) in Tsigai and Rassu et al. (2009) in Sarda dairy ewes, have studied the specific effects of shearing during lactation, with increases in water intake and milk fat composition, respectively. It is unclear if the differences in intake and milk composition observed were breed related.

To test our hypothesis, the effects of shearing on lactational performances (i.e., milk yield and composition including milk fatty acid profile), body reserves and physiological indicators (i.e., main blood metabolites and hormones) were studied in 2 breeds of dairy ewes, similar in frame but differing in milk yield and composition, under mild-winter conditions.

MATERIALS AND METHODS

The experiment was conducted in the experimental farm of the SGCE (Servei de Granges i Camps Experimentals) of the Universitat Autònoma de Barcelona in Bellaterra (Barcelona, Spain) located at N 41º 30’20” and E 2º 05’ 46” (elevation, 162 m) in mid-February and under mild-winter conditions. The ewes were sheltered in a sheep barn enclosed by 3 walls, with the other open to the West and with windbreakers. The roof was thermo-isolated and provided with stack chimneys and fans.

Animal-care conditions and management practices agreed with the Spanish Royal Decree 53/2013, on the protection of animals used for experimental purposes, the codes of

recommendations for the welfare of dairy sheep of the Ministry of Agriculture, Alimentation and Environment of Spain (MAPA, 2007) and the procedures stated by the Ethical Committee of Animal and Human Experimentation of the Universitat Autònoma de Barcelona (UAB).

Ewes Management and Feeding

A total of 48 ewes of 2 dairy breeds (LC, Lacaune, n = 24; MN, Manchega, n = 24) were used in mid-lactation (122 ± 8 and 118 ± 7 DIM, respectively). Ewes of both breeds (LC and MN, respectively) were of similar age (2.4 ± 0.3 and 2.9 ± 0.4 yr), BW (64.6 ± 1.7 and 65.5 ± 1.6 kg) and BCS (2.19 ± 0.10 and 2.52 ± 0.14). All ewes wore plastic ear tags (Allflex Europe, Vitré, France) and ceramic rumen mini-boluses (20 g; Datamars, Bedano, Switzerland) for visual and electronic identification that were used for automatic milk recording (Ait-Saidi et al., 2014).

Machine milking was conducted twice daily (0700 and 1700) in a double, 12-stall parallel-milking parlor (Amarre Azul I; DeLaval Equipos, Alcobendas, Madrid, Spain) with a central high milk pipeline, silicone milking clusters (DeLaval SG-TF100) and automatic milk-flow and milk-recording devices (MM25SG; DeLaval, Tumba, Sweden). Milking was performed at a vacuum of 40 kPa, 120 pulses/min, and 50% pulsation ratio. The milking routine included manual cluster attachment, machine milking and automatic cluster detachment (milk flow rate < 0.1 L/min or milking time > 3 min). Teat dipping with an iodine solution (P3-ioshield; Ecolab Hispano-Portuguesa, Barcelona, Spain) was done at the end of milking.

An adaptation period to the experimental conditions (pen and diet) was applied during 3 wk to all animals. The diet consisted of alfalfa hay fed *ad libitum*, 0.15 kg/d of whole-grain corn and a farm-produced concentrate (ingredients: 50.0% soybean hulls, 10.0% barley meal, 10.0% oats meal, 10.0% gluten feed, 5.0% rapeseed 00 meal, 5.0% soybean oil, 4.0% corn meal, 2.5% bi-calcium phosphate, 2.0% cane molasses, 1.0% VitafacOvino-0.3premix, 0.5% salt, as fed)

fed according to requirements (LC, 0.5 kg/d; MN, 0.3 kg/d, as fed) and distributed altogether after the morning milking. Moreover, all ewes received 100 g of concentrate and 50 g of whole-grain corn in individual feeders in the milking parlor at each milking for a faster bringing in. Nutrient requirements were calculated by INRAtion v.4.06 (Educagri éditions, Dijon, France). Composition and nutritive value of the feeds used in the experiment are shown in Table 1. Ewes had free access to water and to commercial mineral blocks (Multi-Block; Agrària Comarcal del Vallès, Llerona, Barcelona, Spain).

Voluntary intake of the alfalfa hay was assessed to monitor the differences between breeds and the quality of hay bales used during the experiment. With this aim, 2 groups of unshorn, dry and open dairy ewes of each breed (LC, n = 6, 3.0 ± 1.1 yr, 74.4 ± 4.0 kg BW and 3.00 ± 0.19 BCS; MN, n = 6, 3.8 ± 1.6 yr, 71.6 ± 3.6 kg BW and 3.13 ± 0.27 BCS) were used as previously done by Caja et al. (1997) and Flores et al. (2008) in dairy ewes. The ewes were penned in the same building and conditions as the lactating ewes during the experiment, fed the alfalfa hay alone and their voluntary intake was used to calculate the ingestibility according to INRA (2010).

Experimental Treatments

The experimental design consisted of a 2 × 2 factorial (breed × shearing treatment) to which the ewe groups were randomly allocated. Shearing treatments were: control unshorn (CO) and shorn (SH) during lactation. No ewe had been shorn since May of the previous year. Machine shearing of the SH ewes was done in mid-February by a commercial sheep-shearer on the same day. Ewes were allocated in 8 balanced groups of 6 animals according to breed, age, BW, BCS and milk yield, to which the experimental treatments were applied. After the 3-wk adaptation period to pen and diet, the experimental period lasted for approximately 4 wk (from d −15 to 15, centred by the shearing treatment).

Measurements, Sampling and Analyses

Fleece Extension and Wool Weight. Fleece extension at the start of the experiment was scored subjectively in all ewes by 2 operators using a 3-point scale (1, open; 2, medium; 3, extended) with an accuracy of 0.5-points. Wool weight was measured after shearing using an electronic scale (AND FV-60K; A&D Company, Tokyo, Japan; accuracy, 20 g).

Rectal and Environmental Temperatures. Rectal temperatures were recorded at d −1, 1, 3, 7 and 15, relative to shearing, using a digital clinical thermometer (Model ICO; Technology mini color, Barcelona, Spain; reading range, 32.0 to 43.9°C; accuracy, ± 0.1°C). Environmental temperature was recorded every 10 min by using a data logger (Opus 10; Lufft, Fellbach, Germany) and the data downloaded to a computer and processed using the analysis software SmartGraph2 (Lufft).

Milk Yield. Milk yield of individual ewes was recorded daily by weight during the whole experimental period by using the milk-flow and milk-recording automatic units of the milking parlor. Data were uploaded daily using the AlPro software 7.2 (DeLaval) and weekly reviewed and updated in a spreadsheet to avoid missvalues (Nieddu and Caja, 2017).

Milk Composition. Representative milk samples (100 mL) of each ewe were taken before (d −3) and after shearing (d 3, 5, 7 and 15) for compositional analyses. Daily milk samples were composited (60:40) according to the daily milking interval (14 and 10-h), preserved with an antimicrobial tablet (Bronopol; Broad Spectrum Micro-tabs II, D&F Control Systems, San Ramon, CA) and stored at 4°C until analysis. Non-homogenized milk samples were analyzed using a near infrared spectrometer (Foss Electric; Norderstedt, Germany) for fat, total protein (N×6.38), true protein and casein contents, according to Albanell et al. (1999). Calibrations were performed using data obtained by conventional methods including the Gerber method for fat, Kjeldahl method for total protein and oven-drying at 103ºC for total solids content. Samples

were also analyzed for somatic cells count (SCC) in the Dairy Herd Improvement Laboratory of Catalonia (ALLIC, Cabrils, Barcelona, Spain) using an automatic cell counter (Fossomatic 5000; Foss Electric, Hillerød, Denmark).

Milk Fatty Acid Composition. Pool samples of each treatment group, composited according to the milk yield of each ewe, were prepared from individual milk samples at d −3 and 15 for fatty acid (FA) analysis. Milk fat was separated by centrifuging 10 mL of fresh milk (2,000 × *g*, 15 min at 4ºC; Hettich Zentrifugen, Universal 32R, Tuttlingen, Germany) and the obtained fat layer was transferred to 1.5 mL Eppendorf tubes. Milk lipids were extracted from 50 mg of milk fat using diethyl ether and hexane (5:4, vol/vol) and transesterified to FA methyl esters (FAME) using freshly prepared methanolic sodium methoxide (Shingfield et al., 2003). FAME were separated and quantified using a gas chromatograph (Agilent 7890A GC System; Agilent Technologies, Santa Clara, CA) equipped with a flame-ionization detector and a 100-m fused silica capillary column (0.25-mm i.d., 0.2-μm film thickness; CP-SIL 88, CP7489; Varian Ibérica, Madrid, Spain) and using hydrogen as carrier gas. Total FA profile was determined in a 2-μL sample with a split ratio of 1:50 using a temperature gradient program, and C18:1 isomers were resolved in a separate analysis under isothermal conditions at 170°C, according to Shingfield et al. (2003). Peaks were identified based on retention time comparisons with commercially available standards, cross referencing with chromatograms reported in the literature, and by comparison with milk samples for which the FA composition was determined based on gas chromatography analysis of FAME and GC-MS analysis of corresponding 4,4-dimethyloxazoline derivatives (Bichi et al., 2013).

Body Weight and Condition Score. The BW and the BCS of all ewes were evaluated 3 wk before the start of the experiment, to allocate the ewes in balanced groups during the adaptation period, and at d −15, 0 and 15, relative to shearing. Weighing was performed using an electronic

scale (Tru-test A6500; Auckland, New Zealand) and BCS was assessed (0 to 5 points; accuracy, ±0.25 points) according to Russell et al. (1969).

Blood Measures. Blood samples were taken from the jugular vein using 10 mL vacutainer tubes with sodium heparin 170 IU (BD; Belliver Industrial Estate, Plymouth, UK) at d −7, 3, 7 and 15 before the morning feeding. Plasma was obtained by centrifugation of whole blood for 15 min at 2,000 × *g* and 4ºC, and plasma transferred to 0.5 mL Eppendorf tubes and stored at −20°C for glucose, NEFA, insulin, cortisol and IGF-1 analyses. Glucose was determined by the hexokinase method (OSR 6121; Reagent System Olympus, Beckman Coulter, Krefeld, Ireland) and NEFA by the ACS-ACOD colorimetric enzymatic test method (Wako Chemicals; Neuss, Germany), in both cases for all sampling times, using an Olympus AU400 analyzer (Olympus Europa, Hamburg, Germany) reading at 340 and 540 nm, respectively. Samples of d −7 and 3 were also analyzed for insulin by ELISA sandwich type (Ovine Insulin; Mercodia, Uppsala, Sweden) and cortisol by ELISA competitive type (Ovine salivary cortisol; DRG Instruments, Marburg, Germany). The stopped ELISA plates were read in an automatic reader (iEMS Reader MF V.2.9-0, Labsystems España, Barcelona, Spain) at 450 nm for insulin and cortisol.

Feed Intake and Sampling. Feed intake of each group of dairy ewes was assessed daily throughout the experiment by measuring the amount of feed offered and refused in the pens. No refusals of concentrate were observed in the milking parlor. Hay and concentrate offered in the pens and their refusals were sampled daily and composited for pre- and post-shearing periods and preserved at room temperature until analysis.

Ingestibility of the alfalfa hay was assessed by measuring its voluntary dry matter (DM) intake when fed alone in the groups of dry ewes. Ingestibility obtained was expressed as Fill Units for sheep (FUs) by calculating the quotient between the intake of a forage of reference (i.e., standard prairie hay) and the observed intake per metabolic weight (g DM/kg $BW^{0.75}$) according to the INRA (2010), being:

$$\mathbf{FUs} = \frac{\mathbf{75}}{\mathbf{g\ DM/kg\ BW^{0.75}}}$$

Feed Analyses. The DM content was determined by gravimetry, desiccating the sample in an air-forced stove (103ºC for 24 h) and organic matter (OM) content was measured gravimetrically by ashing samples in a muffle furnace (550ºC for 4 h) according to AOAC (1990). Total N was determined by combustion according to the Dumas method using a Leco analyzer (Leco Corporation, St. Joseph, MI), and CP was calculated as N × 6.25. Cellulose was analyzed as crude fiber according to AOAC (1990), and neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined, on an ash-free basis, by adding amylase and sodium sulfite solutions according to Van Soest et al. (1991) and using an Ankom200 Fiber Analyzer incubator (Ankom Technology, Macedon, NY). Crude fat was analyzed as ether extract by the Soxhlet method according to AOAC (1990).

Statistical Analyses

Data were analyzed by the MIXED procedure for repeated measurements of SAS v. 9.1.3 (SAS Institute Inc., Cary, NC). The statistical mixed model contained the breed (LC vs. MN), the shearing treatment (CO vs. SH), the sampling time, and the breed×shearing and sampling-time×shearing interactions as fixed effects, as well as the random effects of the experimental unit (either the animal -for milk yield and composition, and body and plasma indicators- or the pen -for DM intake and FA profile-), and the random residual error. For DM intake and FA profile the random effect of pen(treatment) was used according to St-Pierre (2007). Wool weight and environmental temperature data were analyzed by the GLM procedure for single or repeated measurements of SAS, respectively. In the case of the fleece extension the CATMOD procedure of SAS was used on the basis of the categorical nature of the variable.

For lactational performances (i.e., feed intake, milk yield and composition), body indicators (i.e., rectal temperature, BW, BCS) and physiological plasma indicators (i.e., glucose, NEFA,

cortisol and insulin), the individual measurements taken before shearing were used as covariates and values averaged for their respective sampling dates. Values of variables were discussed as LSM and their means separated by the PDIFF test of SAS v. 9.1.3 (SAS Institute Inc.). Pearson's correlation (r) coefficients were calculated using the CORR procedure of SAS. Significance was declared at $P < 0.05$ and a tendency was considered when $P < 0.10$.

RESULTS AND DISCUSSION

Environmental Temperatures

On average, mean temperatures in the sheep barn were 12.6 ± 0.7°C and 13.7 ± 0.4°C (P = 0.08), for the pre- and post-shearing periods, respectively. The pattern of changes was nearly symmetrical pre- and post-shearing and typical for a Mediterranean mild-winter (Figure 1), as has been habitual in the area over the last several years. Normal mean temperature values during winter (December to February) reported in the area (i.e., Barcelona airport, N 41º 17' and E 2º 4') are in the range of 9.2 to 10.0ºC according to the Spanish Meteorological Agency (AEMET, 2018). After shearing, the barn temperatures steadied, except for the peak reported in Figure 1 between d 13 and 15 (19.1ºC).

Wool Production

Despite having similar BW and according to the breed characteristics, clipped wool weight was lower in the LC than in the MN ewes (0.75 ± 0.09 vs. 1.04 ± 0.10 kg/ewe, respectively; P = 0.038). Fleece also tended to cover less body surface in LC than in MN ewes, as indicated by the extension score of the ewes before shearing (LC vs. MN, 1.39 ± 0.07 vs. 1.95 ± 0.13; P = 0.08). Correlations between wool weight and fleece score were positive for both breeds (r = 0.72 to 0.85; $P < 0.001$). Consequently, we expected to induce greater cold stress by shearing the MN ewes as they had greater wool weight and fleece extension, compared to the LC ewes.

Rectal Temperature

Agreeing with the fleece differences by breed above indicated, differences were observed in the variation of rectal temperatures before and after shearing according to breed (Figure 2). Rectal temperatures in the SH ewes decreased until d 3 in MN and d 7 in LC, and recovered thereafter. The mean temperature drop between CO and SH ewes was greater in the MN (−0.36 ± 0.07°C; $P < 0.001$) than in LC (−0.01 ± 0.09°C; $P = 0.93$).

The observed decrease in rectal temperatures of MN-SH was consistent, although smaller, with the results reported by Aleksiev (2008; −0.9ºC) in lactating Tsigai dairy ewes shorn during winter and maintained at mild ambient temperatures, as in our case. The greater drop in rectal temperatures reported in Tsigai ewes may be a consequence of the small frame and full fleece cover of this Balkan breed. Moreover, our results also agree with those of Leibovich et al. (2011) who sheared pregnant Assaf dairy ewes during the summer, with or without barn cooling, and found that rectal temperature decreased by −0.3°C and −0.2°C, in pregnant and lactating ewes, respectively. On the contrary, Piccione et al. (2002) reported that shearing several Mediterranean sheep breeds in mild-spring conditions (16 to 28ºC), increased their rectal temperature by 1ºC, which was considered to be a result of the hyperthermia induced by shearing stress at warmer temperatures. Although handling at shearing was done carefully in our lactating ewes, the stress-induced hyperthermia, if produced, could also have contributed to alleviate the cold effects observed in our SH-treated ewes.

Feed Intake

Values of voluntary feed intake of the dairy ewes during the experiment are shown in Figure 1. Although the temperatures of the barn varying approximately 10ºC during the pre-shearing

period (d −15 to −10), DM intake values steadied in both LC and MN ewes as a result of the buffering effect of the fleece on thermoregulation.

During the post-shearing period, the buffer effect of the fleece on thermoregulation disappeared and DM intake showed a greater daily variation in both breeds (Figure 1). Nevertheless, the effects of shearing were only significant in the LC ewes in which DM intake increased 5% in the LC-SH ewes, when compared to LC-CO ewes (Table 2; $P = 0.038$). The intake increase found in our LC-SH ewes may have been a result of the increased energy requirements associated with the loss of insulation induced by shearing. No differences between CO and SH groups were observed in the MN ewes ($P = 0.43$), reinforcing the importance of the breed effect in the response to shearing. Ruiz et al. (2008) also reported a 10% increase in the DM intake of lactating Latxa dairy ewes during winter, although the ewes were in this case shorn in late-pregnancy. According to Aleksiev (2008) the increase of intake after shearing, under mild-winter conditions, may not be evident despite a decrease in rectal temperature, as observed in Tsigai ewes and discussed above in the case of our MN ewes.

Breed effect was significant in our results and, on average, LC-CO ewes had 15% greater intake than did MN-CO ewes ($P < 0.001$), and LC-SH ewes had 19% greater intake than did MN-SH ewes ($P < 0.001$). Nevertheless, shearing × breed interaction was not detected on feed intake ($P = 0.51$). Apart from the differences in the fleece, the observed breed effect on intake may be related to the differences in milk production of each breed (Table 2).

Voluntary intake of the dry and open ewes used to monitor the ingestibility of the alfalfa hay steadied during the experimental period and was 0.99 ± 0.03 FUs/kg DM, on average. This value was close to that of the standard prairie hay used as the forage of reference (i.e., 1 FUs = 1 kg DM), and also showed the thermoregulatory buffering effects of the fleece on intake.

Milk Yield

Results of milk yield of the dairy ewes according to breed and shearing treatments, are shown in Table 2 and Figure 3. Milk yield slightly decreased in both breeds as lactation advanced showing small daily changes throughout the experiment. As a response to shearing during lactation the LC-SH ewes increased milk yield by 10%, when compared to LC-CO ewes (P = 0.049), and the effect was maintained until the end of the experiment. On the contrary, no differences were detected in the milk yield of the MN ewes by shearing (P = 0.26) which agreed with the results reported in Suffolk-crossbred (McBride and Christopherson, 1984) and Tsigai (Aleksiev, 2008) ewes shorn during lactation. Moreover, Ruiz et al. (2008) did not find effects of shearing in late-pregnancy on the milk yield of the following lactation in Latxa ewes. It should be stressed that some of the controversial results reported in the literature may be a consequence of the methodology used; McBride and Christopherson (1984) submitted the shorn ewes to cold conditions during lactation and estimated their milk yield by weight-suckle-weight of the lambs, whereas Ruiz et al. (2008) used the oxytocin technique and sheared the ewes in late-pregnancy. In the present study, ewes were selected after the weaning of their lambs, milk was measured directly by machine milking and the shearing took place during mid-lactation.

On the other hand, comparing our breeds of dairy ewes, LC produced on average 82% and 114% more milk than did MN before and after shearing (Table 2; $P < 0.001$), respectively. The differences between our MN and LC ewes agreed with the values previously reported by Rovai et al. (2008) and Castillo et al. (2008), under the same management conditions. Milk yield before shearing did not correlate with wool weight (r = 0.14 to 0.36; P = 0.68) or the fleece extension score (r = 0.07 to 0.25; P = 0.78) in either breed, indicating that, under our mild-winter and intensive-feeding conditions, fleece cover of dairy ewes was not relevant for thermoregulation.

Major Milk Components

There were no dramatic changes or differences between SH and CO treatments in the concentration of major milk components of either breed throughout the experiment (Table 2). Milk composition of all ewe groups steadied on the days immediately after shearing and slightly tended to decrease for fat and protein contents thereafter, whereas lactose content tended to increase. Nevertheless, LC-SH yielded more milk protein (9%; $P = 0.044$) and lactose (12%; $P = 0.012$) than did LC-CO, as a consequence of the greater milk yield of the LC-SH ewes discussed above. Our results did not agree with those reported by McBride and Christopherson (1984), who found that shearing during suckling under cold conditions (i.e., 0ºC) improved milk fat content by 26% in Suffolk-crossbred ewes, nor with those of Rassu et al. (2009) who reported 9% increase in milk fat content of Sarda dairy ewes shorn during lactation in spring and attributed the effect to the cold nights (temperatures non available). The differences may be explained by the fact that, in our case, the lower extreme temperatures of the shelter, observed during the nights, were greater than 5ºC (Figure1). No difference in milk protein content was reported by Ruiz et al. (2008) in Latxa dairy ewes shorn in late-pregnancy.

As expected, agreeing with the milk yield differences and with early reports (Castillo et al., 2008), the breed greatly conditioned milk composition (Table 2). Thus, the concentration of most milk components was greater in MN than in LC but, on the other hand, the lactose content did not vary by breed (4.49 ± 0.07%, on average; $P = 0.88$).

Milk Fatty Acids Profile

Table 3 summarizes the effects of the treatments on the FA profile of the milk fat of our LC and MN dairy ewes, according to their carbon-chain length (C<16, C16 and C>16) or saturation-degree (SFA, saturated FA; MUFA, monounsaturated; PUFA, polyunsaturated) groups. No effects were detected on FA chain-length or saturation-degree groups, the milk of

our ewes being characterized, on average, by high proportions of long chain (C<16:C16:C>16 = 34:28:38) and saturated FA (SFA:MUFA:PUFA = 71:23:6), respectively. All the obtained values were in the range of those reported by Ferrand-Calmels et al. (2014) in a large collection of samples from French dairy ewes mainly fed forage diets. The values also agree with those previously observed in Italian dairy ewes under grazing conditions and supplemented indoors with concentrate and oats as reported by Signorelli et al. (2008). The slightly greater MUFA contents observed in the milk of our ewes, when compared with Signorelli et al. (2008), agreed with the fact of being supplemented with soybean oil in the concentrate, as previously reported by Bouattour et al. (2008) in dairy goats.

No effects of shearing were detected on the detailed SFA profile of the milk fat (Table 4), which mean values agreed with those reported in Assaf dairy ewes fed a diet containing 2% sunflower oil using the same analytical methodology (Toral et al., 2013). Nevertheless, small differences were found in the C14:0 and C16:0 contents that were slightly greater in our ewes than in those of Toral et al. (2013).

On the other hand, breed differences were detected in the specific profile of milk SFA for most medium- and long-chain FA (i.e., C>14:0 to C24:0) as shown in Table 4, the milk of LC having greater C14:0 (4%; $P = 0.044$) and lower odd- and branched-chain FA with 13 to 17 C atoms and C>18:0 than did the milk of MN. Signorelli et al. (2008) also reported similar breed effects when the milk fat SFA profile of Italian dairy breeds was compared. A breed × shearing interaction was detected for the C12:0 values ($P = 0.028$) in our data.

No effects of shearing treatment were observed on the specific unsaturated FA (MUFA and PUFA) profiles of the milk fat of our ewes (Table 5), with the exception of *t*-11 C18:1 (*trans*-vaccenic acid), a bioactive FA with potential healthy effects on human health that originates in the rumen (Palmquist et al., 2005). Differences in its concentration might indicate an effect on the lipid metabolism at rumen or mammary gland levels (Palmquist et al., 2005). However,

the speculative approach presents challenge since almost none of the rumen biohydrogenation metabolites showed differences due to the shearing treatment. Our results did not support those of Rassu et al. (2009) who reported that, in addition to an increase in fat content, shearing lactating dairy ewes in late spring modified the profile of milk FA by increasing the medium-length FA (i.e., C8, C10, C12 and C16) whereas it did not change the content of long-chain FA (>C18). The authors stressed that the increase in milk fat content by effect of shearing was related to the increase of the main FA synthesized in the mammary gland, and not related to fat mobilization by the expected cold stress occurred during the nights. To our knowledge, no other references are available on the effects of shearing on milk yield and composition of dairy ewes.

Regarding the effects of the breed on MUFA profiles, the *c*-12 to *c*-16 and *t*-4 to *t*-15 isomers of C18:1 were the most affected, which were 10 to 48% greater ($P = 0.001$ to $P = 0.029$; Table 5) in the milk of LC, when compared to MN ewes. Signorelli et al. (2008) also found differences in the milk MUFA profile according to breed in Italian dairy ewes.

Similar breed effects were observed with regard to the milk fat profile of PUFA. Although *c*-*c* C18:2 did not vary when LC and MN were compared, most *c*-*t* and *t*-*t* isomers were greater in the LC (16 to 27%; $P = 0.001$ to $P = 0.023$). No CLA contents or isomer partitioning resulted affected by shearing or breed treatments, the mean values of *c*-9, *t*-11 CLA (0.88 ± 0.06%) and *t*-10, *c*-12 CLA (0.008 ± 0.001%) being considered as high and low, respectively, as usually observed in the milk of Assaf dairy ewes using the same analytical methodology (Toral et al., 2013; Frutos et al., 2017).

It must be stressed that some of the breed differences reported in our results may have been a consequence of the different amount of concentrate, and consequently of soybean oil, fed to our ewes according to the breed and its nutritional requirements (i.e., milk yield differences). This statement is supported, for example, by the higher values of *t*-10 and *t*-11 C18:1 observed

in Table 5 for LC, as compared to MN ewes, agreeing with the expected effects of concentrate on FA biohydrogenation (Palmquist et al., 2005).

Physiological Indicators

Mean values of blood metabolites and hormones measured in plasma during the experimental period in the dairy ewes, according to breed and shearing treatment, are shown in Table 2. There were no detectable changes on the days around shearing nor differences between SH and CO treatments of either breed. Despite the lack of differences observed in most physiological blood indicators (glucose, NEFA, cortisol and insulin) in the LC ewes during the experiment (P = 0.12 to 0.89), a 3% increase in the glucose concentration of the MN-SH ewes when compared to MN-CO ewes (P = 0.050) was detected. This increase may be a consequence of the numerically greater intake (Table 2; P = 0.43) observed in the MN-SH ewes that showed a decrease in their rectal temperature after shearing. A similar effect on blood glucose was reported in pregnant ewes shorn under cold stress conditions (Thompson, 1982). Hargreaves and Hutson (1990) reported an acute rise in heart rate, hematocrit and plasma cortisol in Merino ewes, as a response to manipulation during the shearing procedure (i.e., restraint, up-ending, shearing noise and shearing). Nevertheless, the authors stressed that partial or total wool removal itself produced a weak effect that was unlikely to be related to thermoregulatory adjustments. According to Carcangiu et al. (2008), cortisol concentration in blood showed that shearing management also caused severe acute stress in Sarda dairy ewes under in-field conditions. Plasma levels of glucose rose in the shorn ewes immediately before and after shearing as a consequence of handling (i.e., separation, tying and shearing), the rise being directly proportional to the level of cortisol (Carcangiu et al., 2008) and attributed to the hyperglycemic effect of this hormone which stimulates the sympathetic-adrenergic axis and increases glucose production in the liver (gluconeogenesis). These effects were not significant

on the day after (Carcangiu et al., 2008), as also observed in our ewes that showed normal physiological indicators for the feeding conditions and stage of lactation used.

Mears et al. (1999) concluded that shearing itself does not elevate cortisol and β-endorphin above the levels produced by the cumulative stress of handling and processing that accompany shearing. Agreeing with this, no effects of shearing were detected in the case of our LC ewes which did not show changes of rectal temperature, had open and small fleece and are recognized to be calm dairy ewes (Pedernera-Romano et al., 2010), and calmer than MN ewes.

CONCLUSIONS

The results of the present study show that shearing high yielding dairy ewes (i.e., LC) during the milking period and under mild-winter conditions, increased feed intake and lactational performances (i.e., milk yield, protein and lactose yields) in the shorn ewes. In the case of MN ewes, no differences were detected neither in feed intake nor lactational performances after shearing. On the other hand, no differences in physiological indicators were found between shorn and unshorn ewes in either breed. Therefore, shearing dairy ewes during lactation and under mild-winter conditions, is a suitable management option that may improve their lactational performances, more likely to high-yielding ewes as Lacaune under cold conditions, without changes in their physiological indicators or milk composition.

ACKNOWLEDGEMENTS

This work is part of a research project of the Plan Nacional I+D+i Retos 2013 (Project AGL2013-44061-R) funded by the Spanish Ministry of Economy and Competitiveness (Madrid, Spain) and was also supported by a research scholarship to Abdelali Elhadi from the International Centre for Advanced Mediterranean Agronomic Studies (Instituto Agronómico Mediterráneo de Zaragoza, Zaragoza, Spain). The authors are also grateful to Ramon Costa and

the team of the SGCE (Servei de Granges i Camps Experimentals) of the UAB (Bellaterra, Barcelona, Spain) for the care of the animals and to Charles (Chuck) Simmons, native English-speaking University Instructor (Cerdanyola, Barcelona, Spain) for the English language and style revision of the manuscript.

REFERENCES

AEMET. 2018. Agencia Estatal de Meteorología, Ministerio para la Transición Ecológica, Gobierno de España. Valores climáticos normales: Barcelona Aeropuerto. Accessed Sep. 13, 2018. http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/valoresclimatologicos?l=0076&k=cat.

Ait-Saidi, A., G. Caja, A. A. K. Salama, and S. Carné. 2014. Implementing electronic identification for performance recording in sheep: I. Manual versus semiautomatic and automatic recording systems in dairy and meat farms. J. Dairy Sci. 97:7505–7514.

Albanell, E., P. Cáceres, G. Caja, E. Molina, and A. Gargouri. 1999. Determination of fat, protein, and total solids in ovine milk by Near-Infrared Spectroscopy. J. AOAC Int. 82:753−758.

Aleksiev, Y. 2008. Effects of shearing on feed intake and milk yield in Tsigai ewes. Bulg. J. Agric. Sci. 14:87−92.

AOAC. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists. 15th edition, Association of Official Analytical Chemists, Washington, DC.

Bichi, E., G. Hervás, P. G. Toral, J. J. Loor, and P. Frutos. 2013. Milk fat depression induced by dietary marine algae in dairy ewes: Persistency of milk fatty acid composition and animal performance responses. J. Dairy Sci. 96:524–532.

Bocquier, F., F. Barillet, P. Guillouet, and M. Jacquin. 1993. Prévision de l'énergie du lait de brebis à partir de différents résultats d`analyses: proposition de lait standard pour les brebis laitières. Ann. Zootech. 42:57–66.

Bouattour, M. A., R. Casals, E. Albanell, X. Such, and G. Caja. 2008. Feeding soybean oil to dairy goats increases conjugated linoleic acid in milk. J. Dairy Sci. 91:2399–2407.

Caja, G., L. Pérez-Oguez, J. Plaixats, P. Prió, and F. Bocquier. 1997. Validation of the estimated forage fill values obtained either through chemical analysis or directly measured in wethers and dry ewes of a dairy breed. Renc. Rech. Rumin. 4:83.

Carcangiu, V., G. M. Vacca, A. Parmeggiani, M. C. Mura, M. Pazzola, M. L. Dettori, and P. P. Bini. 2008. The effect of shearing procedures on blood levels of growth hormone, cortisol and other stress haematochemical parameters in Sarda sheep. Animal 2:606−612.

Castillo, V., X. Such, G. Caja, A. A. K. Salama, E. Albanell, and R. Casals. 2008. Changes in alveolar and cisternal compartments induced by milking interval in the udder of dairy ewes. J. Dairy Sci. 91:3403−3411.

Elvidge, D. G., and I. E. Coop. 1974. Effect of shearing on feed requirements of sheep. NZ J. Exp. Agric. 2:397−402.

Ferrand-Calmels, M., I. Palhière, M. Brochard, O. Leray, J. M. Astruc, M. R. Aurel, S. Barbey, F. Bouvier, P. Brunschwig, H. Caillat, M. Douguet, F. Faucon-Lahalle, M. Gelé, G. Thomas, J. M. Trommenschlager, and H. Larroque. 2014. Prediction of fatty acid profiles in cow, ewe, and goat milk by mid-infrared spectrometry. J. Dairy Sci. 97:2013−6648.

Flores, C., G. Caja, R. Casals, E. Albanell, and X. Such. 2008. Performance of dairy ewes fed diets with a fibrolytic enzyme product included in the concentrate during the suckling period. Animal 2:962−968.

Frutos, P., P. G. Toral, and G. Hervás. 2017. Individual variation of the extent of milk fat depression in dairy ewes fed fish oil: Milk fatty acid profile and mRNA abundance of candidate genes involved in mammary lipogenesis. J. Dairy Sci. 100:9611–9622.

Hargreaves, A. L., and G. D. Hutson. 1990. Changes in heart rate, plasma cortisol and haematocrit of sheep during a shearing procedure. Appl. Anim. Behav. Sci. 26:91−101.

INRA. 2010. Institut de la Recherche Agronomique. Alimentation des Bovins, Ovins et Caprins. Éditions Quæ, Paris, France.

Leibovich, H., A. Zenou, P. Seada, and J. Miron. 2011. Effects of shearing, ambient cooling and feeding with byproducts as partial roughage replacement on milk yield and composition in Assaf sheep under heat-load conditions. Small Rumin. Res. 99:153−159.

MAPA. 2007. Ministerio de Agricultura, Pesca y Alimentación. Guías de prácticas correctas de higiene Ovino de leche. Accessed Jun.7, 2018. http://www.mapama.gob.es/es/ganaderia/publicaciones/CCAE_tcm30-105306.pdf

McBride, G., and R. Christopherson. 1984. Effect of cold exposure on milk production and energy balance in the lactating ewe. Can. J. Anim. Sci. 64:379−389.

Mears, G. J., F. A. Brown, and L. R. Redmond. 1999. Effects of handling, shearing and previous exposure to shearing on cortisol and β-endorphin responses in ewes. Can. J. Anim. Sci. 79:35–38.

Nieddu, G., and G. Caja. 2017. Eficiencia de identificación electrónica y recogida de datos de leche en un sistema automático para ovejas y cabras lecheras. Pages 33–35 in Proc. XVII Jornadas de Producción Animal of AIDA (Asociación Interprofesional para el Desarrollo Agrario), Zaragoza, Spain.

Palmquist, D. L., A. L. Lock, K. J. Shingfield, and D. E. Bauman. 2005. Biosynthesis of conjugated linoleic acid in ruminants and humans. Adv. Food Nutr. Res. 50:180–217.

Pedernera-Romano, C., J. L. Ruiz de la Torre, L. Badiella, and X. Manteca. 2010. Effect of perphenazine enanthate on open-field test behaviour and stress-induced hyperthermia in domestic sheep. Pharm. Biochem. Behav. 94:329–332.

Piccione, G., G. Caola, and R. Refinetti. 2002. Effect of shearing on the core body temperature of three breeds of Mediterranean sheep. Small Rumin. Res. 46:211−215.

Pulina, G., M. J. Milán, M. P. Lavín, A. Theodoridis, E. Morin, J. Capote, D. L. Thomas, A. H. D. Francesconi, and G. Caja. 2018. Current production trends, farm structures, and economics of the dairy sheep and goat sectors. J. Dairy Sci. 101:6715–6729.

Rassu, S. P. G., M. G. Manca, A. H. Dias Francesconi, A. Mereu, and A. Nudda. 2009. Shearing influences the milk fatty acid profile of dairy ewes. Ital. J. Anim. Sci. 8 (Suppl. 2):462.

Rovai, M., G. Caja, and X. Such. 2008. Evaluation of udder cisterns and effects on milk yield of dairy ewes. J. Dairy Sci. 91:4622−4629.

Ruíz, R., A. García, E. Ugarte, J. Arranz, I. Beltrán de Heredia, and L. Oregui. 2008. Winter shearing in the Latxa dairy sheep: effect on dry matter intake during lactation, milk yield, milk quality and body condition. Page 194 in Proc. 59th Annual Meeting EAAP. Book of abstracts No.14. Wageningen Academic Publishers, Wageningen, The Netherlands.

Russell, A. J., J. M. Doney, and R. G. Gunn. 1969. Subjective assessment of body fat in live sheep. J. Agric. Sci. Camb. 72:451−454.

Russel, A., R. Armstrong, and I. White. 1985. Studies on the shearing of housed pregnant ewes. Anim. Prod. 40:47−53.

Shingfield, K. J., S. Ahvenjärvi, V. Toivonen, A. Ärölä, K. V. V. Nurmela, P. Huhtanen, and J. M. Griinari. 2003. Effect of dietary fish oil on biohydrogenation of fatty acids and milk fatty acid content in cows. Anim. Sci. 77:165–179.

Signorelli, F., G. Contarini, G. Annicchiarico, F. Napolitano, L. Orrú, G. Catillo, G. F. W. Haenlein, and B. Moioli. 2008. Breed differences in sheep milk fatty acid profiles:

Opportunities for sustainable use of animal genetic resources. Small Rumin. Res. 78:24−31.

St-Pierre, N. R. 2007. Design and analysis of pen studies in the Animal Sciences. J. Dairy Sci. 90:E87−E99.

Swanson, J. C., and J. J. McGlone. 2010. The FASS Guide for the Care and Use of Agricultural Animals in Research and Teaching. Federation of Animal Science Societies. 3rd edition. Champaign, IL.

Symonds, M., M. Bryant, and M. Lomax. 1988. Metabolic adaptation during pregnancy in winter shorn sheep. J. Agric. Sci. 111:137−145.

Thompson, G. E., J. M. Bassett, D. E. Samson, and J. Slee. 1982. The effects of cold exposure of pregnant sheep on foetal plasma nutrients, hormones and birth weight. Brit. J. Nutr. 48:59−64.

Toral, P. G., G. Hervás, A. Belenguer, E. Bichi, and P. Frutos. 2013. Effect of the inclusion of quebracho tannins in a diet rich in linoleic acid on milk fatty acid composition in dairy ewes. J. Dairy Sci. 96:431−439.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for animal dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to nutrition. J. Dairy Sci. 74:3583−3597.

Table 1. Chemical composition and nutritive value of the feeds used in the experiment

Item, DM basis	Alfalfa hay	Concentrate mixture	Corn grain
Component, %			
DM	88.5	90.6	87.8
OM	10.7	7.5	1.2
CP	16.8	15.1	8.0
Fat	1.9	8.1	3.9
Cellulose	30.4	21.2	1.7
NDF	46.3	39.4	7.9
ADF	33.4	25.1	1.4
Nutritive value[1]			
NE_L, Mcal/kg	1.16	1.62	1.84
UFL[2]/kg	0.68	0.95	1.08
PDIN[3], g/kg	121	89	64
PDIE[4], g/kg	97	58	84

[1]Estimated according to INRA (2010) tables and PreValim 3.3 software (Educagri éditions, Dijon, France).

[2]Feeding units for lactation (1.7 Mcal EN_L).

[3]Protein truly digested in the small intestine allowed by N.

[4]Protein truly digested in the small intestine allowed by energy.

Table 2. Effect of shearing during mild-winter conditions on the lactational performances and the physiological indicators in the plasma of two breeds of dairy ewes (data are LS means)

	Lacaune		Manchega				Effect (*P*-value)		
Item	Control	Shorn	Control	Shorn	Mean	SEM	Shearing	Breed	Interaction[1]
Intake, kg DM/d	2.86[b]	3.01[a]	2.48	2.52	2.72	0.04	0.038	0.001	0.51
Milk									
Yield, kg/d	1.38[b]	1.52[a]	0.76	0.71	1.09	0.09	0.36	0.001	0.37
ECM[2], kg/d	1.33	1.43	0.87	0.82	1.11	0.09	0.58	0.001	0.67
Fat, g/d	95	101	68	65	82	7	0.64	0.001	0.89
Total protein, g/d	80[b]	87[a]	49	47	66	3	0.47	0.001	0.60
Lactose, g/d	62[b]	70[a]	35	31	50	3	0.57	0.001	0.23
SCC, $\log_{10}$/mL	5.36	5.24	5.09	5.36	5.26	0.16	0.60	0.63	0.18
Milk composition, %									
Fat	6.89	6.65	8.98	9.14	7.92	0.22	0.59	0.001	0.16
Total protein	5.80	5.74	6.50	6.59	6.16	0.21	0.55	0.001	0.15
True protein	5.63	5.44	6.37	6.48	5.98	0.26	0.51	0.001	0.13
Casein	4.31	4.15	4.92	5.27	4.66	0.18	0.56	0.001	0.11
Lactose	4.52	4.58	4.56[a]	4.39[b]	4.51	0.10	0.44	0.41	0.041
Plasma indicators									
Glucose, mg/dL	65.7	66.2	63.2[b]	65.2[a]	65.1	1.1	0.81	0.038	0.73
NEFA, mmol/L	0.125	0.095	0.115	0.100	0.109	0.015	0.47	0.61	0.52
Cortisol, ng/mL	6.5	5.4	5.6	3.8	5.4	1.1	0.73	0.84	0.97
Insulin, ng/L	0.43	0.44	0.34	0.40	0.40	0.08	0.60	0.21	0.53

[a,b]Within a row and breed, values with a different superscript differ ($P < 0.05$).

[1]Shearing × Breed.

[2]Energy corrected milk = Milk yield × [0.071× (Fat, %) + 0.043 × (Total protein, %) + 0.2224], according to Bocquier et al. (1993).

Table 3. Effects of shearing during mild-winter on the major classes of fatty acids (FA) according to carbon chain lengh and saturation degree in the milk of two breeds of dairy ewes

	Lacaune		Manchega				Effect (*P*-value)		
Item, g/100 g total FA	Control	Shorn	Control	Shorn	Mean	SEM	Shearing	Breed	Interaction
Chain length									
<C16	35.9	34.3	34.2	34.6	34.8	0.5	0.47	0.28	0.22
C16	27.4	27.9	27.4	27.7	27.6	0.3	0.20	0.87	0.98
>C16	36.7	37.8	38.4	37.7	37.6	0.6	0.85	0.31	0.30
Saturation degree									
SFA[1]	70.9	70.2	70.2	70.8	70.5	0.6	0.95	0.88	0.38
MUFA[2]	22.8	23.4	23.4	22.9	23.1	0.5	0.94	0.87	0.41
PUFA[3]	6.28	6.38	6.42	6.27	6.34	0.17	0.98	0.96	0.40
Atherogenicity index[4]	2.66	2.55	2.47	2.56	2.56	0.07	0.88	0.30	0.22

[1]Saturated fatty acids.
[2]Monounsaturated fatty acids.
[3]Polyunsaturated fatty acids.
[4](12:0 + 4 ×14:0 + 16:0)/(MUFA + PUFA).

Table 4. Effects of shearing during mild-winter on the saturated fatty acid (SFA) profile in the milk of two breeds of dairy ewes

	Lacaune		Manchega				Effect (*P*-value)		
SFA, g/100 g total FA	Control	Shorn	Control	Shorn	Mean	SEM	Shearing	Breed	Interaction
4:0	3.26	3.33	2.95	2.89	3.11	0.08	0.97	0.009	0.45
5:0	0.02	0.02	0.02	0.02	0.02	0.01	0.88	0.40	0.58
6:0	2.53	2.48	2.37	2.35	2.43	0.08	0.69	0.16	0.92
7:0	0.03	0.03	0.03	0.03	0.03	0.01	0.47	0.52	0.79
8:0	2.40	2.28	2.30	2.28	2.32	0.08	0.39	0.48	0.52
9:0	0.05	0.05	0.05	0.05	0.05	0.01	0.85	0.48	0.60
10:0	7.56	7.04	7.23	7.32	7.29	0.21	0.36	0.90	0.22
11:0	0.08	0.08	0.08	0.09	0.08	0.01	0.77	0.12	0.21
12:0	4.62	4.23	4.30	4.43	4.39	0.08	0.36	0.69	0.12
13:0 *anteiso*	0.010	0.010	0.011	0.012	0.011	0.001	0.59	0.022	0.36
13:0 *iso*	0.031	0.033	0.037	0.037	0.035	0.001	0.30	0.003	0.23
14:0	11.71	11.32	10.98	11.19	11.30	0.15	0.59	0.044	0.11
14:0 *iso*	0.15	0.16	0.18	0.18	0.17	0.01	0.21	0.008	0.74
15:0	1.23	1.28	1.39	1.39	1.32	0.03	0.49	0.015	0.63
15:0 *anteiso*	0.47	0.50	0.55	0.55	0.52	0.01	0.22	0.010	0.33
15:0 *iso*	0.32	0.34	0.37	0.37	0.35	0.01	0.20	0.003	0.29
16:0	25.55	25.87	25.35	25.66	25.61	0.21	0.20	0.37	0.98
16:0 *iso*	0.28	0.29	0.33	0.34	0.31	0.01	0.27	0.002	0.50
8-oxo-16:0	0.029	0.028	0.037	0.035	0.032	0.002	0.62	0.001	0.75
17:0	0.72	0.75	0.85	0.83	0.78	0.03	0.80	0.001	0.40
17:0 *anteiso*	0.44	0.46	0.52	0.52	0.48	0.02	0.48	0.001	0.67
17:0 *iso*	0.36	0.38	0.43	0.43	0.40	0.02	0.57	0.002	0.60
18:0	7.91	8.07	8.44	8.40	8.20	0.36	0.87	0.30	0.79
18:0 *iso*[1]	0.071	0.073	0.082	0.083	0.077	0.002	0.42	0.014	0.84
10-oxo-18:0	0.04	0.04	0.05	0.05	0.05	0.01	0.68	0.10	0.17
13-oxo-18:0	0.02	0.03	0.04	0.03	0.03	0.01	0.46	0.25	0.22
19:0	0.14	0.14	0.15	0.16	0.15	0.01	0.49	0.14	0.82
20:0	0.29	0.30	0.33	0.33	0.32	0.01	0.64	0.014	0.64
21:0	0.11	0.12	0.15	0.14	0.13	0.01	0.96	0.005	0.56
22:0	0.19	0.19	0.24	0.22	0.21	0.01	0.41	0.001	0.24
23:0	0.13	0.13	0.18	0.17	0.15	0.01	0.77	0.001	0.47
24:0	0.077	0.076	0.105	0.099	0.089	0.002	0.30	0.001	0.40

[1] Contains a C17:1 isomer of indeterminate double bond position as a minor component.

Table 5. Effects of shearing during mild-winter on the unsaturated fatty acid (UFA) profile in the milk of two breeds of dairy ewes

	Lacaune		Manchega				Effect (*P*-value)		
UFA, g/100 g total FA	Control	Shorn	Control	Shorn	Mean	SEM	Shearing	Breed	Interaction
MUFA[1]									
c-9 10:1	0.30	0.29	0.31	0.31	0.30	0.02	0.69	0.40	0.73
c-9 12:1	0.10	0.08	0.10	0.10	0.09	0.01	0.49	0.24	0.27
t-9 12:1	0.06	0.05	0.06	0.06	0.06	0.01	0.80	0.72	0.50
c-9 14:1	0.28	0.27	0.27	0.28	0.27	0.03	0.96	0.99	0.73
cis-12 14:1	0.09	0.07	0.09	0.10	0.09	0.01	0.37	0.16	0.16
t-5 + 6 14:1	0.02	0.02	0.02	0.02	0.02	0.01	0.36	0.27	0.72
t-9 14:1	0.01	0.01	0.01	0.01	0.01	0.01	0.11	0.94	0.59
c-9 15:1	0.01	0.01	0.01	0.01	0.01	0.01	0.96	0.09	0.72
t-5 15:1	0.19	0.19	0.23	0.22	0.21	0.01	0.85	0.001	0.62
t-6 + 7 15:1	0.023	0.023	0.028	0.027	0.025	0.001	0.66	0.001	0.49
c-7 16:1	0.24	0.25	0.27	0.26	0.25	0.01	0.76	0.020	0.28
*c*9 16:1	0.93	0.97	0.99	1.00	0.97	0.06	0.73	0.50	0.88
c-13 16:1	0.06	0.06	0.07	0.06	0.06	0.01	0.94	0.09	0.27
c-14 16:1[2]	0.17	0.14	0.16	0.18	0.16	0.01	0.68	0.29	0.24
t-6 + 8 16:1	0.08	0.08	0.08	0.08	0.08	0.01	0.35	0.27	0.31
t-9 16:1	0.10	0.10	0.09	0.08	0.09	0.01	0.59	0.13	0.68
c-9 17:1	0.28	0.29	0.33	0.32	0.30	0.01	0.80	0.012	0.39
c-9 18:1[3]	15.29	15.79	16.16	15.87	15.78	0.38	0.79	0.28	0.35
c-11 18:1	0.36	0.37	0.38	0.36	0.37	0.01	0.67	0.54	0.18
c-12 18:1	0.35	0.36	0.30	0.30	0.33	0.01	0.68	0.001	0.67
c-13 18:1	0.056	0.058	0.047	0.048	0.052	0.002	0.50	0.006	0.94
c-15 18:1	0.056	0.058	0.047	0.048	0.052	0.002	0.48	0.001	0.92
c-16 18:1	0.065	0.067	0.060	0.060	0.063	0.002	0.65	0.023	0.66
t-4 18:1	0.020	0.021	0.018	0.017	0.019	0.001	0.53	0.005	0.21
t-5 18:1	0.018	0.019	0.016	0.015	0.017	0.001	0.69	0.001	0.26
t-6 + 7 + 8 18:1	0.28	0.28	0.23	0.22	0.25	0.01	0.87	0.001	0.40
t-9 18:1	0.27	0.27	0.23	0.22	0.25	0.01	0.82	0.001	0.35
t-10 18:1	0.43	0.44	0.29	0.30	0.36	0.03	0.76	0.001	0.92
t-11 18:1	1.47	1.44	1.34	1.21	1.36	0.03	0.09	0.001	0.47
t-12 18:1	0.40	0.41	0.35	0.34	0.37	0.01	0.81	0.002	0.41
t-15 18:1	0.223	0.225	0.202	0.205	0.214	0.006	0.72	0.029	0.95
t-16 18:1[4]	0.31	0.32	0.30	0.30	0.31	0.01	0.58	0.06	0.70
c-9 20:1	0.01	0.01	0.01	0.01	0.01	0.01	0.30	0.06	0.70
c-13 22:1	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.13	0.80

c-15 24:1	0.016	0.016	0.021	0.020	0.018	0.001	0.72	0.004	0.50
PUFA[1]									
c-9, *c*-12 18:2	2.48	2.55	2.49	2.42	2.48	0.04	0.97	0.27	0.17
c-12, *c*-15 18:2	0.01	0.01	0.01	0.02	0.01	0.01	0.71	0.98	0.72
c-9, *t*-12 18:2	0.053	0.059	0.048	0.046	0.052	0.002	0.58	0.023	0.17
c-9, *t*-13 18:2	0.30	0.30	0.27	0.27	0.28	0.02	0.81	0.06	0.98
c-9, *t*-14 18:2	0.14	0.14	0.13	0.14	0.14	0.01	0.97	0.19	0.96
t-9, *c*-12 18:2	0.037	0.039	0.031	0.032	0.035	0.002	0.48	0.020	0.90
t-11, *c*-15 18:2	0.11	0.12	0.12	0.12	0.12	0.01	0.45	0.94	0.51
t-9, *t*-12 18:2	0.012	0.013	0.011	0.011	0.012	0.001	0.12	0.001	0.026
t-10, *t*-14 18:2	0.052	0.051	0.041	0.041	0.046	0.003	0.90	0.001	0.90
t-11, *t*-15 18:2	0.01	0.01	0.01	0.01	0.01	0.01	0.95	0.08	0.69
c-9, *t*-11 CLA[1]	0.952	0.945	0.850	0.785	0.883	0.060	0.58	0.09	0.65
t-9, *c*-11 CLA	0.021	0.022	0.036	0.019	0.025	0.010	0.43	0.55	0.36
t-10, *c*-12 CLA	0.008	0.009	0.007	0.009	0.008	0.001	0.11	0.39	0.76
t-11, *t*-13 CLA	0.02	0.02	0.01	0.02	0.02	0.01	0.46	0.20	0.67
other *t*-*t* CLA[5]	0.06	0.06	0.06	0.06	0.06	0.00	0.66	0.10	0.58
18:3n-3[6]	1.00	1.04	1.17	1.16	1.09	0.03	0.62	0.008	0.39
18:3n-6	0.049	0.047	0.058	0.052	0.051	0.003	0.15	0.014	0.41
20:2n-6	0.02	0.02	0.02	0.02	0.02	0.01	0.64	0.10	0.99
20:3n-6	0.027	0.028	0.038	0.033	0.031	0.002	0.35	0.015	0.20
20:4n-6	0.17	0.17	0.18	0.18	0.18	0.01	0.86	0.11	0.77
20:5n-3	0.064	0.058	0.072	0.071	0.066	0.003	0.30	0.005	0.48
22:4n-6	0.02	0.02	0.02	0.02	0.02	0.01	0.42	0.14	0.20
22:5n-6	0.01	0.01	0.01	0.02	0.01	0.01	0.21	0.19	0.25
22:5n-3	0.13	0.13	0.16	0.16	0.14	0.01	0.98	0.027	0.95
22:6n-3	0.058	0.059	0.066	0.080	0.066	0.005	0.24	0.049	0.29

[1]MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; CLA, conjugated linoleic acid.
[2]Coelutes with 3, 7, 11, 15-tetramethyl 16:0.
[3]Contains t-13 + 14 18:1 as minor components.
[4]Coelutes with *c*-14 18:1.
[5]Sum of *t*-9, *t*-11 + *t*-10, *t*-12 + *t*-8, *t*-10 CLA.
[6]Contains *c*-11 20:1 as a minor isomer.

FIGURE CAPTIONS

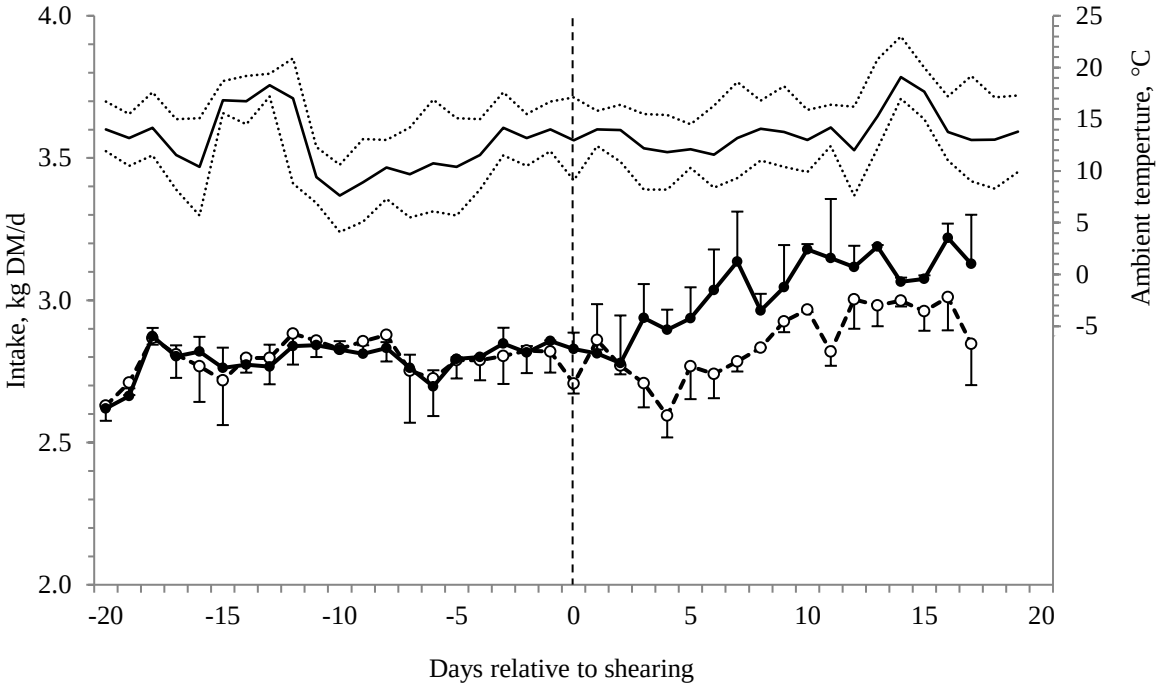
Figure 1. Ambient temperatures (mean in solid line, min and max in dashed lines) and voluntary feed intake recorded during mild-winter before and after shearing (CO, control; SH, shorn) in 2 breeds of dairy ewes: a) Lacaune (LC) breed (○, LC-CO; ●, LC-SH); b) Manchega (MN) breed (□, MN-CO; ■, MN-SH). Values are means with the SEM indicated by vertical bars.

Figure 2. Rectal temperature before and after shearing (CO, control; SH, shorn) under mild-winter conditions in 2 breeds of dairy ewes: a) Lacaune (LC) breed (○, LC-CO; ●, LC-SH); b) Manchega (MN) breed (□, MN-CO; ■, MN-SH). Values are means with the SEM indicated by vertical bars.

Figure 3. Milk yield before and after shearing (CO, control; SH, shorn) under mild-winter conditions in 2 breeds of dairy ewes: a) Lacaune (LC) breed (○, LC-CO; ●, LC-SH); b) Manchega (MN) breed (□, MN-CO; ■, MN-SH). Values are means with the SEM indicated by vertical bars.

Figure 1

a) LC



b) MN

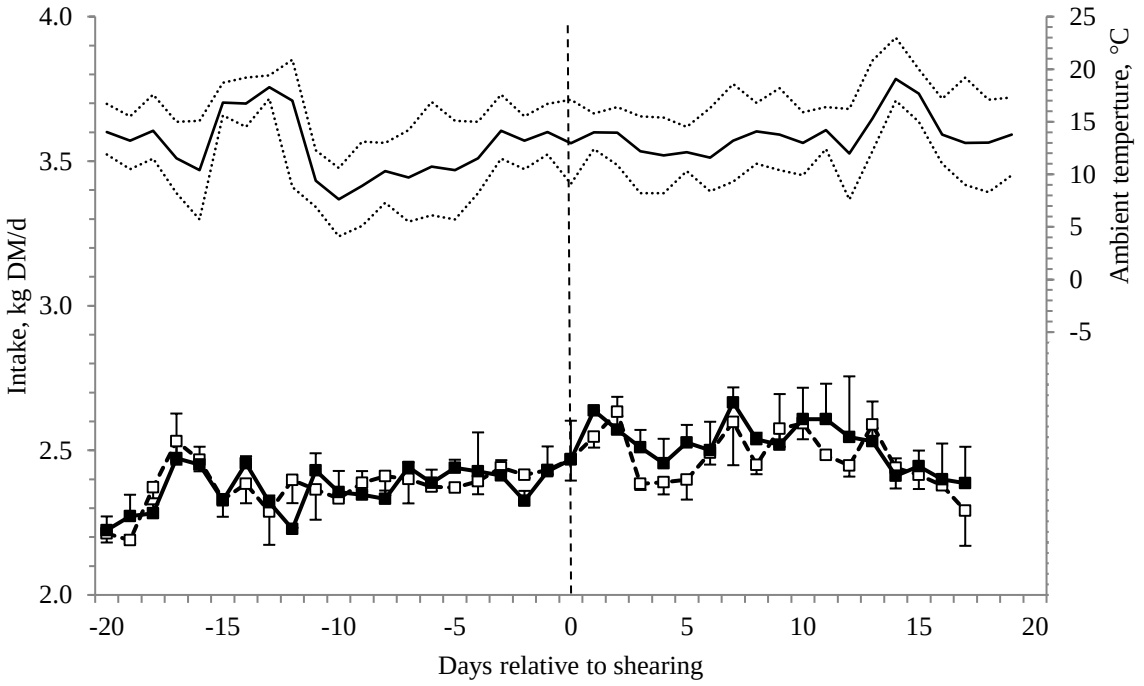
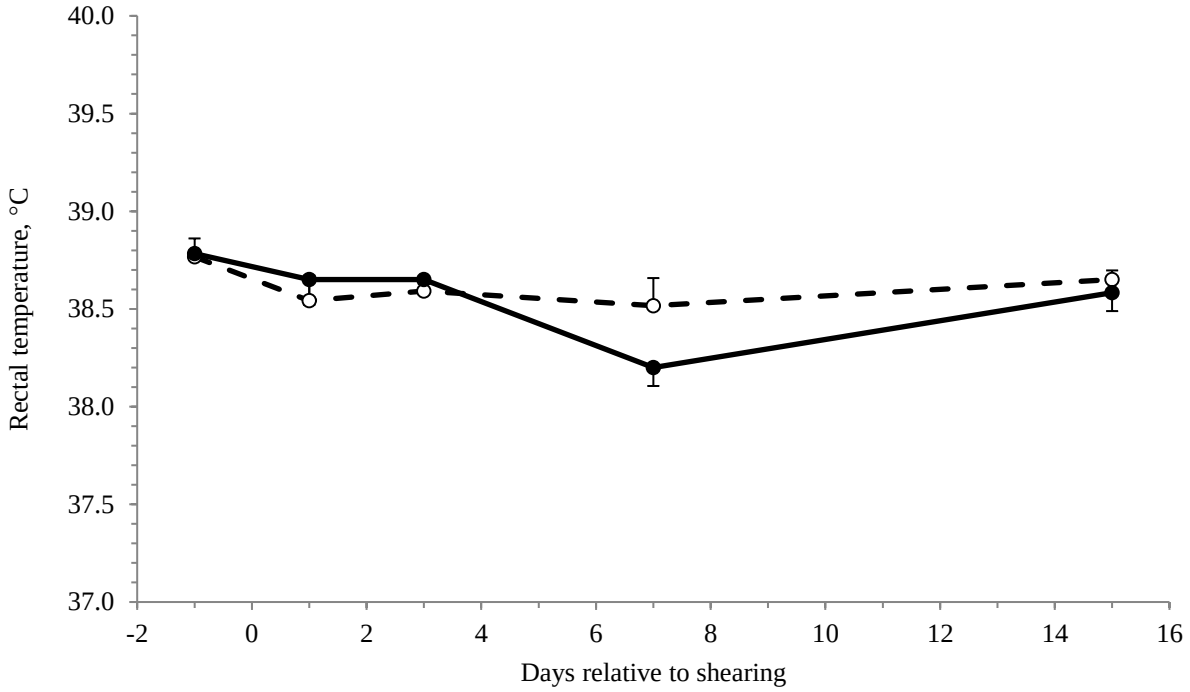


Figure 2

a) LC



b) MN

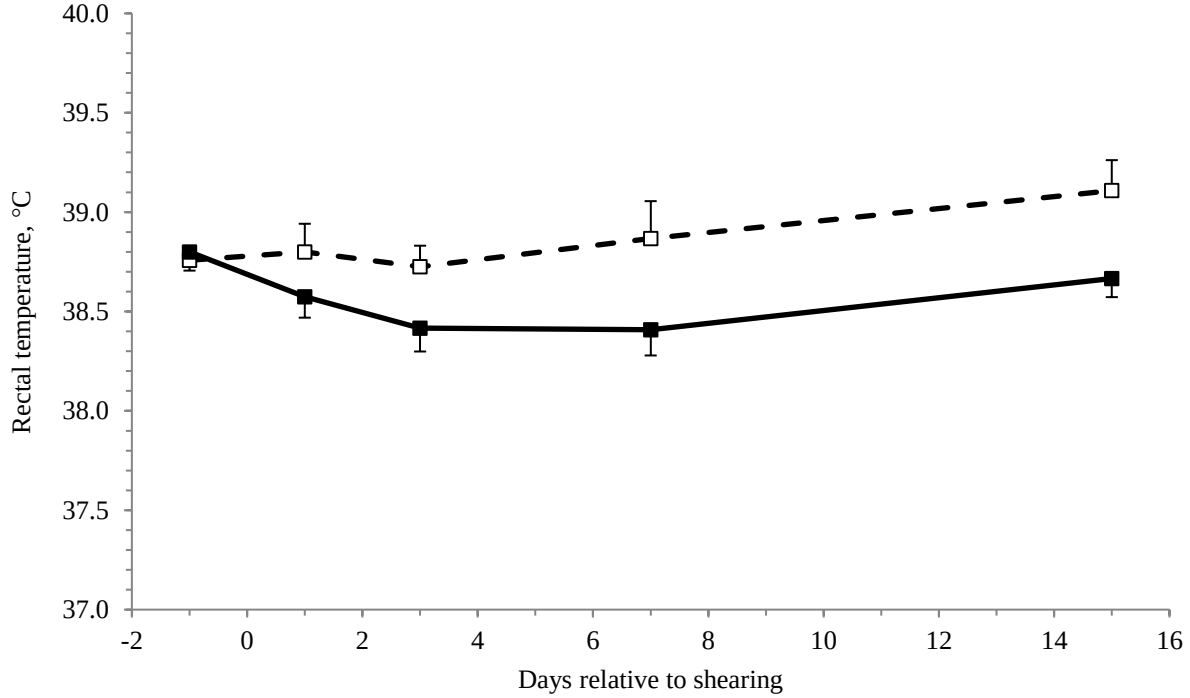
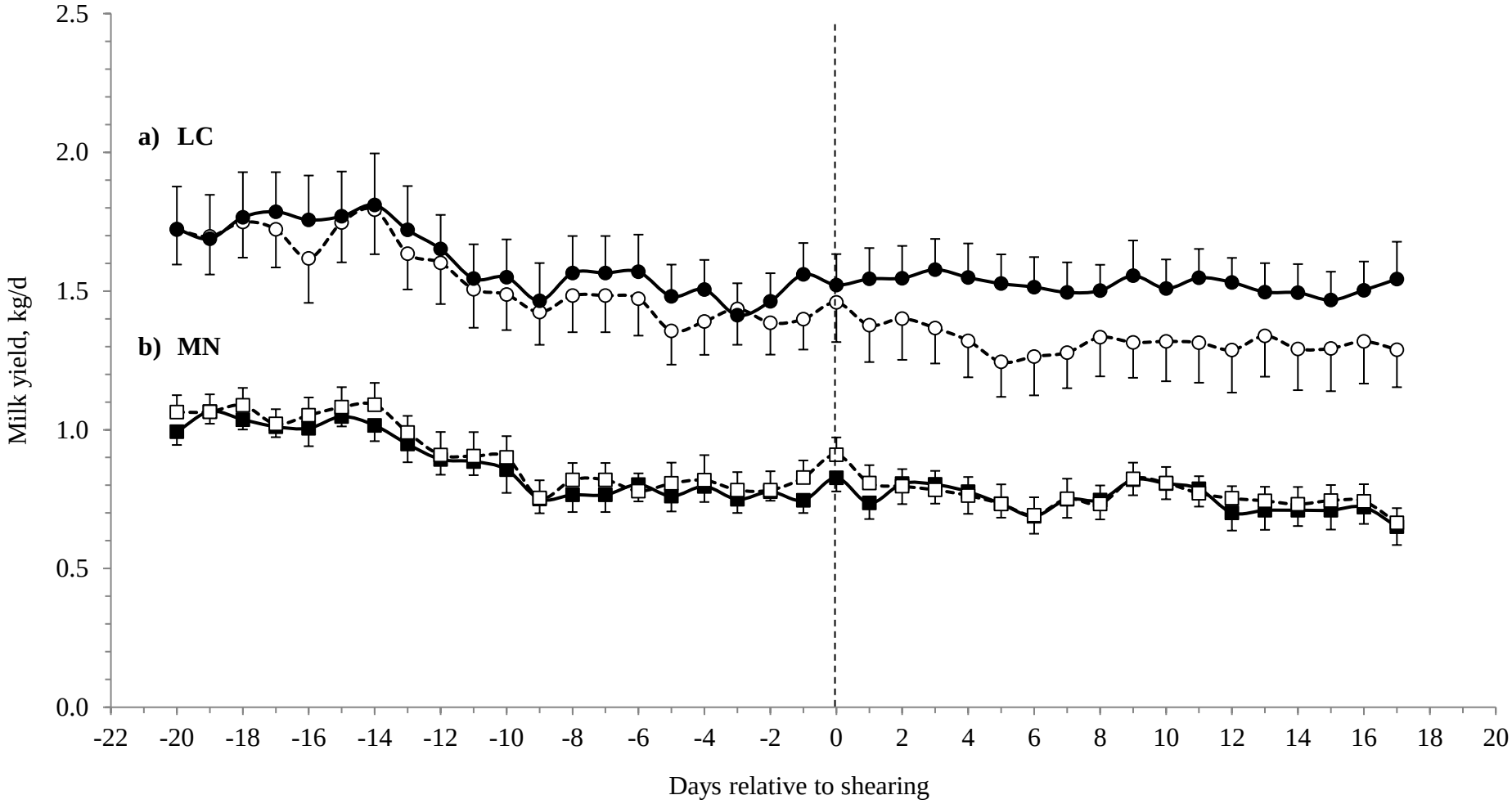


Figure 3


a) LC
b) MN
Milk yield, kg/d
Days relative to shearing
2.5
2.0
1.5
1.0
0.5
0.0
-22
-20
-18
-16
-14
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
20