Animal 17 (2023) 100698

Contents lists available at ScienceDirect

Animal

The international journal of animal biosciences

When to shear dairy ewes: before breeding, during pregnancy or let them unshorn?

S. González-Luna [a,b], L. Cordón [a], A.A.K. Salama [a], X. Such [a], E. Albanell [a], A. Contreras-Jodar [a,1], J. de Lucas-Tron [b,†], G. Caja [a,*]

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

[b] Departamento de Ciencias Pecuarias, Facultad de Estudios Superiores Cuautitlán, Universidad Nacional Autónoma de México, 54714 Cuautitlán Izcalli, México

ARTICLE INFO

Article history:
Received 24 April 2022
Revised 7 December 2022
Accepted 9 December 2022
Available online 16 December 2022

Keywords:
Colostrum
Dairy sheep
Milk composition
Milk yield
Wool trimming

ABSTRACT

Shearing dairy ewes may improve their fitness and heat tolerance during late pregnancy, with positive effects on lambs and lactation performances. To test this hypothesis, two Mediterranean breeds (**MN**, Manchega, n = 43; **LC**, Lacaune, n = 28), differing in lactation performances and fleece traits, were submitted to three shearing strategies: (i) shorn before breeding (**SBB**), (ii) shorn at day 100 of pregnancy (**S100**) and (iii) unshorn (**CO**). Ewes were bred in spring and gestated during summer. Fleece traits and respiratory rate were measured on pregnant (107–121 days) resting ewes at different barn temperatures. Blood and colostrum were sampled at lambing. Ewes suckled their lambs (28 days) and were machine-milked until 180 days of lactation. Lamb and ewe weights, and condition score of the ewes, were recorded throughout the experiment. Milk yield was assessed during suckling (fortnightly) and milking (daily), and milk was sampled for composition (fortnightly). Fleece extension and wool weight at S100 were 13 and 45% greater in MN than in LC ewes, respectively, but the ewe's respiration rate at late pregnancy, between 20 and 25 °C, did not vary among shearing treatments nor breeds. Nevertheless, S100 ewes had a 37% lower respiration rate than SBB and CO ewes at 28 °C. At lambing, SBB and S100 ewes had 86% higher glycaemia than CO in MN, but LC ewes did not vary. Shearing treatment had no effect in plasma insulin, β-hydroxybutyrate or non-esterified fatty acids (**NEFAs**) at lambing in both breeds. Lamb's birthweight and growth during suckling did not differ by shearing treatment in both breeds. Colostrum composition and milk yield during suckling were not modified by shearing treatment in either breed, although S100 suckling milk composition increased in MN (protein and casein, 6%) and LC ewes (total solids, 8%; fat, 18%), compared to CO and SBB. No effects were detected in milk yield or composition during milking, but S100 tended to yield 28% more milk than CO in the LC ewes. The S100 treatment improved the body reserves in late pregnancy, when compared to CO and SBB in both breeds. In conclusion, shearing dairy ewes in late pregnancy was a recommendable management practice under summer conditions, because alleviated heat stress and improved the weight of the ewes, without detrimental effects on lambing and lactational performances, the last tending to increase milk yield in high-yielding dairy ewes.

Implications

Optimizing management-welfare practices is crucial in dairy sheep. Thus, providing evidence of pregnancy shearing positive effects could aid in the decision-making process (i.e., when and how often) in dairy sheep farms. This study demonstrated that shearing at late pregnancy (day 100) is a suitable practice in dairy ewes because it alleviates the impact of heat stress during summer and reduces the loss of body reserves during pregnancy. No negative effects of pregnancy shearing are expected on the performances of the subsequent lactation, and an increase in milk yield may also occur in high-yielding dairy ewes.

Introduction

Shearing is a husbandry practice economically important for fine-wool sheep farms, but negligible in dairy sheep (<0.8%;

* Corresponding author.
E-mail address: gerardo.caja@uab.es (G. Caja).

[1] Present address: Animal Welfare Program, Institut de Recerca i Tecnologia Agroalimentàries, 17121 Girona, Spain.

[†] Prof. José de Lucas-Tron deceased (13 of July 2022) during the late peer-review process of this article. The rest of co-authors are deeply grateful to his valuable contributions.

https://doi.org/10.1016/j.animal.2022.100698
1751-7311/

Milán et al., 2014). Shearing season varies according to climatic conditions and production systems. In dairy ewes, it is usually done during the dry period and addressed to enhance the ewe's fitness before parturition, but no negative effects on milk yield and composition were reported when ewes were shorn in mid-lactation during winter (Elhadi et al., 2019).

Rutter et al. (1971) reported increases in birthweight and lamb survival in sheep shorn during late pregnancy, without differences in feed intake (Rutter et al., 1972). Ewes shorn 56 days before lambing (Symonds et al., 1986) or 107 days of pregnancy (Rosales-Nieto et al., 2020) performed better by improving fat catabolism, without changes in carbohydrate or protein metabolism, leading to lower insulin secretion and greater glycaemia during late pregnancy. The effects were more marked in twin- than single-bearing ewes (Revell et al., 2000), but Rosales-Nieto et al. (2020) did not observed changes in the placental endocrine response of the ewes. Pregnancy shearing has also been proposed as a strategy for improving lamb survival and suckling growth when prolificacy increases (Kenyon et al., 2003), with possible effects on mammogenesis and lactation. Nevertheless, Knight et al. (1993) reported no effect on milk yield of Dorset ewes shorn at late pregnancy (day 115) and machine-milked from parturition, although fat, protein and total solids contents in milk improved. On the contrary, Cam and Kuran (2004) and Sphor et al. (2011) reported greater milk yield during suckling, without changes on milk composition, in Karakaya and Polwarth ewes shorn pregnant (day 100 and day 53, respectively). Furthermore, Banchero et al. (2010) did not find differences in colostrum quality between shorn (days 70 or 120 of pregnancy) and unshorn Corriedale ewes. It should be stressed that all the previously cited data were obtained in meat and wool sheep breeds, where milk performances are difficult to extrapolate to dairy breeds.

In dairy sheep, García-Rodríguez et al. (2012) did not detect changes in milk yield and composition of Latxa ewes shorn at day 110 of pregnancy and machine-milked from the weaning of the lambs. In this case, twin-lamb birthweight and ewe's feed intake increased in the shorn group. García-Rodríguez et al. (2012) carried out their experiment during winter and with a moderate milk yield because of the weaning of the lambs. Interestingly, Leibovich et al. (2011) compared the effects of pregnancy shearing (day −30) in high-yielding Assaf dairy ewes that were machine-milked from lambing and during summer. They reported increased lamb's birthweight and ewe's intake, milk yield and composition, when shearing was combined with cooling the barn.

With all this in mind, our testing hypothesis was that shearing the ewes during late pregnancy and summer conditions improves their fitness and milk yield or/and milk composition because of the metabolic and hormonal benefits of a greater heat dissipation during peripartum. To test this hypothesis, different shearing strategies were compared in two breeds of dairy ewes, having similar semi-fine wool type and body frame, but differing in fleece traits and lactational performances.

Material and methods

Animals, feeding and management conditions

The research was carried out in the experimental farm of the Servei de Granges i Camps Experimentals (**SGCE**) of the Universitat Autònoma de Barcelona (**UAB**) in Bellaterra (Barcelona, Spain). A total of 71 multiparous ewes of two dairy breeds (Manchega, **MN**, n = 43; Lacaune, **LC**, n = 28) managed as a single flock, were used. The ewes had similar frame and semi-fine (down) wool type, but slightly differ (MN and LC, respectively) in BW (73.0 ± 1.3 and 76.5 ± 1.8 kg BW; *P* = 0.031) and body condition score (2.68 ± 0.07 and 2.51 ± 0.05 **BCS** units; *P* = 0.054), with no differences in age (4.4 ± 0.3 and 3.8 ± 0.3 years; *P* = 0.39) at enrollment. All ewes wore plastic ear tags (Allflex Europe, Vitré, France) and ceramic rumen mini-boluses (20 g, half-duplex technology; Datamars, Bedano, Switzerland) for visual and electronic identification, respectively.

Ewes grazed (6 -h daily) on cultivated Italian ryegrass (*Lolium multiflorum* L.; DM, 16.9%; CP, 30.7%; NDF, 50.0%; and ADF, 24.9%; on DM basis), during winter and spring, and on Mediterranean natural pastures and bushy areas during autumn. Estimated intake of the ewes during grazing was approximately the half of their daily voluntary intake (Caja et al., 2009). Grazing was replaced by green chopped sorghum forage (DM, 33.5%; CP, 10.3%; NDF, 53.6%; and ADF, 27.1%; on DM basis) fed ad libitum in the shelter, during summer. After grazing, the ewes were sheltered in straw-bedded pens and fed alfalfa hay *ad libitum* (*Medicago sativa* L.; DM, 85.0%; CP, 16.3%; NDF, 53.9%; and ADF, 36.1%; on DM basis) and concentrate according to their requirements (INRAtion v.4.07 software; Educagri éditions, Dijon, France). Corn whole grain (0.2 to 0.8 kg/d, as fed; DM, 87.1%; CP, 8.2%; NDF, 8.1%; and ADF, 2.3%; on DM basis) and a farm-produced concentrate (0.4 to 1.0 kg/d, as fed; ingredients: soybean hulls, 60%; barley grain, 10%; oat grain, 10%; gluten feed, 10%; soybean oil, 4%; di-Ca phosphate, 2.5%; sugar cane molasses, 2%; Vitafac ovino-0.3% [DSM Nutritional Products, Madrid, Spain], 1%; and sodium chloride, 0.5%; as fed), were offered in two portions in the feeders of the pens (dry ewes) or in the milking parlour (suckling and milking ewes) according to requirements. All ewes had free access to water and salt-micromineral blocks (Multi-Block; Agrària Comarcal del Vallès, Llerona, Spain).

Breeding was done by rams, after ram-effect (i.e., rams in contiguous pens for 10 days) in spring, and lambing occurred in autumn. Litter sizes in MN and LC were 67 and 47 (1.57 and 1.68 lambs/ewe), respectively. Ewes and lambs were isolated in lambing pens for 5 days to reinforce their maternal-offspring bond and joined to the flock thereafter. Ewes suckled their lambs during the sheltering time (i.e., evening and night) until 28 days of age (abrupt weaning).

Milking was performed twicedaily (0700 and 1700 h) by using a double-12 stall parallel milking parlour (Amarre Azul I; DeLaval Equipos, Alcobendas, Spain) consisting of a central high milk pipeline to which 12 milking clusters (SG-TF100 DeLaval, Tumba, Sweden) with milk flow and recording units (MM25-SG, DeLaval) were connected. Machine-milking settings were 40 kPa, 120 pulses/min and 50% pulsation ratio. Milking routine included automatic cluster detachment and teat dipping with an iodine solution (P3-ioshield; Ecolab Hispano-Portuguesa, Barcelona, Spain), as described by Elhadi et al. (2019). Suckling ewes went every day to the milking parlour to be fed with concentrate and to adapt to machine-milking.

Experimental treatments

Ewes were blocked in three balanced groups by breed, age, and milk yield from the previous lactation, to which the treatments were randomly allocated. All ewes were unshorn from the previous year (last shearing in early May), and ewe assignment to experimental groups was done randomly. Treatments were: (i) let unshorn as a control (**CO**), (ii) shorn 15 days before breeding (**SBB**), and (iii) shorn at day 100 of pregnancy (**S100**). The SBB group was shorn before introducing the rams (mid-May), and the S100 group was shorn at day 100 of pregnancy (mid-August).

Shearing was done by the same person using the un-tied Bowen's technique and machine-shears (Evo-Heiniger three speeds machine with flexible drive-200 cm and an Icon handpiece with Quasar shearing comb-95 mm wide; Heiniger, Herzogenbuchsee, Switzerland). Treatments are summarized in Supplementary Fig. S1.

Measurements, sampling, and analyses

Fleece extension and wool weight

Fleece extension of all ewes was individually scored at day 100 of pregnancy using a three-point scale (score: 1, bare; 2, medium, 3; woolly; accuracy, 0.5 points) according to Elhadi et al. (2019). Moreover, the wool of each ewe after S100 was weighed using a digital scale (AND FV-60K; A&D Company, Tokyo, Japan; accuracy, 0.02 kg) and recorded.

Respiratory frequency in late pregnancy

Respiratory rate (**RR**) of the ewes was measured at morning (0800 to 1000 h) and afternoon (1200 to 1400 h) from day 107 to day 121 of pregnancy, on average, under indoor and Mediterranean summer conditions (August). With this aim, groups of 15 ewes per treatment, were randomly chosen among those that were under resting conditions (i.e., lying down after eating), and their flank movements associated to breathing were counted for 15 s, then multiplied by four and RR expressed as breaths/min (bpm). Measurement of rectal temperature was not done to avoid the stress and hyperthermia induced by handling. At each RR measurement, ambient temperature was also recorded using an aerial probe hung in the middle of the pens (STC 2020; Sertic, Lleida, Spain).

Body reserves of the ewes and lamb's growth

Ewe's weighing was done using an electronic scale (Tru-Test AG500; Auckland, New Zealand; accuracy, 0.2 kg) at different dates pre- (days −43, −33, −27, −21, −14 and −4) and post-lambing (days 0, 10, 36 and 68). Ewes' BCS was also measured at the same time using the 0–5 points score (accuracy, 0.25 points) described by Russel et al. (1969). Lamb crop by ewe group was: MN (CO, 23; SBB, 22; S100, 22 lambs) and LC (CO 16; SBB, 17; S100, 14 lambs). Lambs were weighed at birth and at days 15, 21 and 28 (weaning) using a portable electronic scale (AND FV-60 K), and average daily gain was calculated.

Blood indicators after lambing

Blood samples of the ewes were taken from the jugular vein (10 mL vacutainer tubes with sodium heparin 170 IU; BD, Belliver Industrial Estate, Plymouth, United Kingdom) approximately 6 h after lambing. Plasma was obtained from blood by centrifugation (15 min, 1 500*g* and 4 °C) and stored at −20 °C in 1.5 mL Eppendorf tubes until analysis. Concentrations of glucose, non-esterified fatty acids (**NEFAs**) and β-hydroxybutyrate (**BHB**) were determined using an Olympus AU480 analyzer (Olympus Europa, Hamburg, Germany) by using the analytical methods and reagents previously described by Elhadi et al. (2019). Plasma samples were also analysed for insulin by ELISA sandwich type (Ovine Insulin; Mercodia, Uppsala, Sweden), and the stopped plates read at 450 nm in an automatic reader (iEMS Reader MF V.2.9-0; Labsystems España, Barcelona, Spain). Detection limit, intra- and interassay coefficients of variation for insulin were 0.025 ng/mL, 3.7 and 6.5%, respectively.

Colostrum analyses

Colostrum samples were collected by hand-milking and from both udder sides immediately after blood sampling. Mixed samples (50 mL) were collected in duplicate and stored at −20 °C until analysis. One sample was thawed at room temperature and conditioned to 40 °C for total solids, fat, total protein (N × 6.38), true protein and casein analysis by near-infrared spectrophotometry (**NIRS**) using a NIRS spectrometer (Foss Electric, Nordersted, Germany). Calibrations were performed using data obtained by standard methods including total solids (oven at 103 °C), fat (Gerber method) and total protein (Kjeldahl method). For colostrum density, a total of 10 mL of colostrum were poured into a measuring cylinder (10 ± 0.1 mL) and weighed (Sartorius CP64, Gottingen, Germany; accuracy, 0.1 mg) at 20 °C. Density was calculated by the ratio between mass and volume. The remaining 50 mL of colostrum were thawed at 4 °C and centrifuged (2 000*g* for 15 min) at 4 °C (Hettich Zentrifugen, D-78632 Tuttlingen, Germany). The supernatant and bottom fractions were discarded, and the obtained skim milk was preserved in 1.5 mL Eppendorf tubes and stored at −20 °C until insulin (Ovine insulin, Mercodia, Uppsala, Sweden) and Immunoglobulin G (**IgG**) (Calokit Ovino, ZeuLAB, Zaragoza, Spain) analysis using ELISA sandwich kits. Detection limit, intra- and interassay coefficients of variation for the IgG were 0.0051 mg/mL, 2.6 and 8.0%, respectively. Milk yield and composition were reported during suckling.

Milk yield during suckling was individually estimated at days 5, 14 and 28 of lactation by using double milking with the help of oxytocin and 4-h interval. With this aim, lambs and ewes were removed at 0800 h and the ewes moved to the milking parlour where they were injected with oxytocin (2 IU/ewe; Facilpart, Laboratorios Syva, León, Spain) into the jugular vein and machine-milked. The ewes returned to the pens after milking where they were fed but remained isolated from their lambs. After 4-h, the oxytocin injection and machine milking were repeated, and milk was individually collected and weighed (AND FV-60K). Daily milk secretion was expressed (×6) as daily milk yield. Milk samples were taken (100 mL), preserved with an antimicrobial tablet (Bronopol, Broad Spectrum Micro-tabs II, D&F Control Systems, San Ramon, California, USA) and stored at 4 °C until analyses. Conditioned milk samples were analysed by NIRS, as previously indicated for colostrum.

Milk yield and composition during machine milking

Milk yield at each milking was recorded from day 29 to day 180 of lactation using automatic milk-flow and milk-recording units (MM25-SG, DeLaval). Data were uploaded in the Alpro software 7.2 (DeLaval) and reviewed daily for outlier values. Representative milk samples (100 mL) of each ewe were taken at each milking at days 35, 49, 63 and 77 for composition analyses. Samples were composited according to the daily milking interval (14- and 10-h, respectively), added an antimicrobial tablet (Bronopol) and stored at 4 °C until analysis by NIRS.

Statistical analysis

Data analyses were performed using SAS v. 9.4 (SAS Inst. Inc.; Cary, North Carolina, USA) according to the nature of variables. The differences on fleece extension by the effect of breed and shearing treatments were assessed by using the CATMOD procedure. Wool weight was compared between breeds using the Student's t-test. Respiratory rate was analyzed by the MIXED procedure for repeated measurements including in the model the effects of breed, shearing treatment, ambient temperature, litter size, and the random effect of the animal and the shearing treatment × temperature, litter size × temperature interactions. For the rest of variables, considering the differences between breeds, the data of both breeds were analyzed separately. Blood indicators of the ewes, colostrum composition, lamb birthweight and weaning weight during suckling, were analyzed using the MIXED procedure of SAS containing the fixed effects of shearing treatment, litter size and the litter size × shearing treatment interaction. Data of lamb weight, milk yield and milk composition, and ewe BW and BCS, were analyzed using the MIXED procedure for repeated measurements of SAS containing the fixed effects of shearing treatment, litter size, recording (or sampling) time and the random effects of the animal and the litter size × shearing treatment interaction. For ewe's BW and BCS, the interaction of shearing treatment × time recording was also included. Pearson correlation coefficients were calculated using the CORR procedure of SAS. Differences between least square means were determined with the PDIFF option of SAS. Significances were declared at $P < 0.05$ and tendencies were considered when $0.05 < P < 0.10$. Statistical models used for each variable were summarized in Supplementary Table S1.

Results

Fleece traits and thermal comfort

At day 100 of pregnancy, after approximately 15 months of the previous yearly shearing, fleece evaluation in all ewes covered 13% more of the body surface of MN than LC ewes, as indicated by their extension scores (2.11 ± 0.06 vs 1.87 ± 0.06 points, respectively; $P < 0.001$). No interaction shearing treatment × breed was observed ($P = 0.92$). After shearing, clipped wool weight of the S100 ewes was 45% greater in MN than in LC (2.43 ± 0.20 vs 1.68 ± 0.32 kg/ewe, respectively; $P = 0.048$). Wool production indices were 3.33 ± 0.04 and 2.20 ± 0.05 kg wool/100 kg BW for MN and LC, respectively ($P = 0.048$). Correlations between wool weight and fleece extension score for the S100 ewes were similar ($P = 0.45$) and positive for both MN and LC ($r = 0.68$; $P = 0.003$), which produced 1.03 kg of raw wool per point of fleece score, on average.

Summer ambient temperatures had marked effects on RR of our pregnant ewes, which increased exponentially with temperature ($r^2 = 0.90$; $P < 0.001$) in late pregnancy. No differences in RR were found between breeds ($P = 0.68$), and their results were presented jointly (Fig. 1). As shown in Fig. 1, values of RR increased by 124%, when ambient temperature increased from 20 to 28 °C (42 ± 2 to 98 ± 5 bpm, respectively; $P < 0.001$). On the other hand, shearing treatment affected RR ($P = 0.037$) and an interaction was observed between shearing treatment × temperature ($P < 0.001$). Thus, no differences on RR by shearing treatment were detected at 20 °C and 25 °C, whereas RR values were 37% lower in S100 than in SBB and CO ewes at 28 °C (68 ± 7 bpm vs 108 ± 8 bpm, on average; $P < 0.001$), the last no differing between them ($P = 0.11$). Moreover, a litter size × temperature interaction was detected on RR ($P < 0.001$), the twin-bearing ewes reaching panting conditions at a lower temperature (25 °C; 92 ± 5 bpm) than single bearing ewes (28 °C; 104 ± 9 bpm). No differences in lambing size of MN and LC ewes (1.63 ± 0.10 lambs/ewe, on average; $P = 0.23$) and between experimental groups within each breed ($P = 0.66$ to 0.99) were detected.

Blood indicators at lambing

Plasmatic values at lambing for each breed are shown in Table 1 and Supplementary Fig. S2. Most shearing treatment × litter size interactions were not significant for blood indicators (Table 1). The SBB and S100 treatments increased glycaemia by 86% in MN ewes ($P = 0.008$), when compared to CO ewes, but the difference was not significant in LC ewes ($P = 0.13$). No effects in maternal glycaemia were detected due to litter size ($P = 0.73$ and 0.30) or shearing treatment × lambing size interactions ($P = 0.15$ and 0.51) in our MN and LC ewes, respectively.

Regarding insulinaemia, shearing treatment × litter size interaction was significant in MN ewes ($P = 0.027$). No differences were detected on plasmatic insulin values according to shearing treatments in both breeds (MN, $P = 0.11$; LC, $P = 0.96$; Table 1 and Supplementary Fig. S2) but MN ewes experienced lower insulin values in twin-(−157%) than single-bearing ewes (0.439 ± 0.108 ng/mL vs 1.130 ± 0.111 ng/mL; $P < 0.001$; data not shown). This decrease in insulin was consistent in LC (−98%) when twin- were compared to single-bearing ewes (0.690 ± 0.160 ng/mL vs 1.363 ± 0.241 ng/mL, respectively; $P < 0.001$). Moreover, insulin decreases between single- and twin-bearing MN ewes at lambing were larger in SBB (−302%, 0.407 ± 0.153 ng/mL vs 1.635 ± 0.229 ng/mL; $P < 0.001$) and CO (−267%, 0.269 ± 0.173 ng/mL vs 0.988 ± 0.187 ng/mL; $P = 0.008$) ewes, than in S100 that were not significant (0.640 ± 0.229 ng/mL vs 0.767 ± 0.153 ng/mL; $P = 0.65$), respectively, as shown in Fig. 2. No differences in the plasmatic values of NEFA ($P = 0.37$ to 0.91) or BHB ($P = 0.72$ to 0.98) were also detected among treatments in both breeds (Table 1).

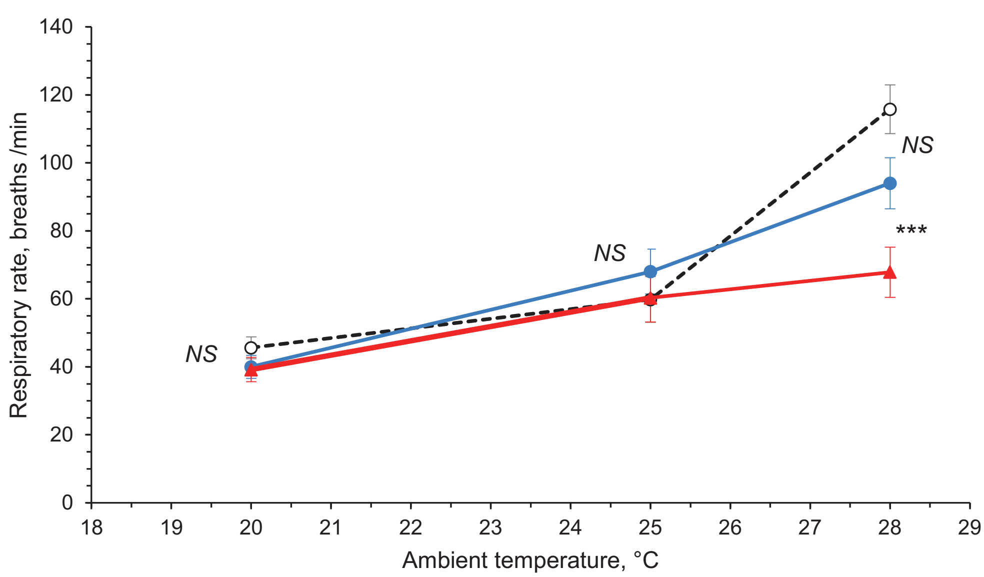

Fig. 1. Respiratory rate of dairy ewes (breeds confounded) according to shearing treatment and ambient temperature (○: CO, control, open circle and dashed line; ●: SBB, shorn before mating, closed circle and solid blue line; ▲: S100, shorn at day 100 of pregnancy, closed triangle and solid red line). Values are means with the SEM indicated by vertical bars.

Table 1
Effects of shearing treatments on the metabolic indicators of the plasma of two breeds of dairy ewes at lambing (data are least-square means).

Breed and item	Shearing treatments[1]			Mean ± SE	*P*-value	
	CO	SBB	S100		ST[1]	LS[2]
Manchega						
Ewes, n	14	13	16	–	–	–
Glucose, mg/dL	59[b]	113[a]	107[a]	93 ± 14	0.008	0.73
Insulin, ng/mL	0.629	1.021	0.703	0.784 ± 0.137	0.11	0.001
NEFA[3], mmol/L	0.717	0.927	0.740	0.795 ± 0.116	0.37	0.10
BHB[4], mmol/L	0.597	0.610	0.612	0.606 ± 0.084	0.98	0.007
Lacaune						
Ewes, n	9	10	9	–	–	–
Glucose, mg/dL	69	89	113	90 ± 15	0.13	0.30
Insulin, ng/mL	0.974	1.070	1.036	1.027 ± 0.271	0.96	0.032
NEFA[3], mmol/L	0.613	0.568	0.607	0.596 ± 0.086	0.91	0.041
BHB[4], mmol/L	0.524	0.507	0.450	0.494 ± 0.072	0.72	0.23

ST × LS interactions were not significant, except for insulinaemia in Manchega ewes (*P* = 0.027).
[1] Shearing treatment (CO = Control; SBB = Shorn before breeding; S100 = Shorn at day 100 of pregnancy).
[2] Litter size.
[3] Non-esterified fatty acids.
[4] β-hydroxybutyrate.
[a,b] Values within a row with different superscripts significantly differ at *P* < 0.05.

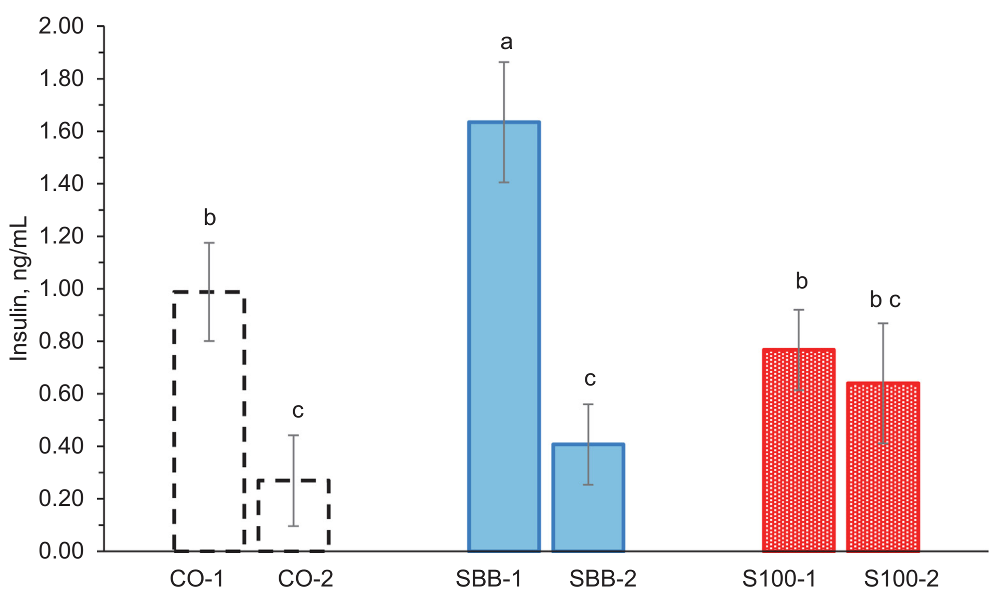

Fig. 2. Plasmatic insulin at lambing of Manchega dairy ewes according to shearing treatment and litter size (CO, control, dashed line; SBB, shorn before breeding, and S100, shorn at day 100 of pregnancy; 1, single bearing ewes; 2, twin bearing ewes). Values are means with the SEM indicated by vertical bars. [abc]Different superscript letters indicate differences at *P* < 0.05.

Lamb weight and growth

No effects of shearing treatments were detected on the lamb's birthweight in either breed (*P* = 0.17 to 0.63; Table 2) and no shearing treatment × litter size interaction effects were detected (*P* > 0.10). Additionally, no effects of shearing treatments were detected on growth performances during suckling and weaning weight of the lambs of either breed. Moreover, treatment × litter size interactions were not significant, except for weaning weight (*P* = 0.043) and average daily gain (*P* = 0.041) in the case of MN ewes, where no differences were observed between singletons and twins in the S100 ewes. Lambs of MN and LC breeds were weaned at the same age (28 days old).

Colostrum composition

Shearing treatments did not affect colostrum composition in either breed (*P* = 0.11 to 0.71; data not shown), and no effect of shearing treatment × litter size interactions were detected (*P* = 0.35 to 0.76; data not shown). Although no direct comparison was done between breeds, colostrum of MN (density, 1.075 ± 0.005 g/mL; fat, 8.28 ± 0.71%; protein, 20.32 ± 1.32%, true protein, 20.05 ± 1.40%; casein, 6.90 ± 0.35%; lactose, 2.36 ± 0.22%; total solids, 31.9 ± 1.5%; on average) had richer composition than of LC (density, 1.060 ± 0.005 g/mL; fat, 4.55 ± 0.71%; protein, 13.45 ± 1.22%; true protein, 12.91 ± 1.24%; casein, 5.04 ± 0.49%; lactose, 2.79 ± 0.24%; total solids, 22.4 ± 1.5%; on average). Moderate correlations (*P* < 0.05) were obtained for density with total solids (MN, *r* = 0.51; LC, *r* = 0.45), true protein (MN, *r* = 0.70; LC, *r* = 0.58), casein (MN, *r* = 0.33; LC, *r* = 0.50) and lactose contents (MN, *r* = –0.45; LC, *P* = 0.35).

Most importantly, colostrum IgG content did not vary by shearing treatments in both breeds (MN, 30.6 ± 4.7 mg/mL, *P* = 0.50; LC, 20.8 ± 3.7 mg/mL, *P* = 0.29). Mean IgG values correlated positively (*P* < 0.05) with protein content in both breeds (MN, *r* = 0.58; LC, *r* = 0.58). Moreover, in MN ewes, twin- showed lower IgG content than single-bearing (24.0 ± 3.2 mg/mL vs 37.2 ± 3.8 mg/mL, *P* = 0.023). No differences were detected in LC (*P* = 0.76).

Table 2
Effects of shearing treatments on the weight and growth of the lambs during suckling in two breeds of dairy ewes (data are least square means).

Breed and item	Shearing treatment[1]			Mean ± SE	*P*-value	
	CO	SBB	S100		ST[1]	LS[2]
Manchega						
Litter size[2], lambs/ewe	1.64	1.69	1.38	1.56 ± 0.12	0.66	–
Birthweight, kg	4.62	4.67	4.23	4.51 ± 0.21	0.17	0.027
Weaning weight[3], kg	12.72	12.10	11.60	12.14 ± 0.57	0.30	0.001
Average daily gain, g/d	255	264	258	259 ± 16	0.92	0.001
Lacaune						
Litter size[2], lambs/ewe	1.78	1.70	1.56	1.68 ± 0.08	0.67	–
Birthweight, kg	3.95	4.20	4.19	4.11 ± 0.22	0.63	0.006
Weaning weight[3], kg	12.32	12.23	12.92	12.49 ± 0.60	0.66	0.001
Average daily gain, g/d	279	287	285	284 ± 30	0.98	0.007

ST × LS interactions were not significant, except for weaning weight ($P = 0.043$) and average daily gain ($P = 0.041$) in Manchega ewes.
[1] Shearing treatment (CO = Control; SBB = Shorn before breeding; S100 = Shorn at day 100 of pregnancy).
[2] Litter size.
[3] Weaned at constant age (28 days).

Insulin content in colostrum was high, compared to plasma but did not differ between shearing treatments in MN (16.96 ± 2.81 µg/L, on average, $P = 0.52$) and LC (13.66 ± 4.93 µg/L, on average, $P = 0.40$) ewes. Colostrum insulin content in twin-bearing MN ewes was lower than in single-bearing MN ewes (13.22 ± 1.88 µg/mL vs 20.69 ± 2.50 µg/L, respectively, $P = 0.042$), but no differences were detected in the LC ewes ($P = 0.92$).

Milk yield and composition

Suckling period

The effects of shearing treatments on the amount of milk produced during suckling are shown in Fig. 3. Shearing treatment × litter size interactions were not significant on milk yield, in MN ($P = 0.07$) and LC ($P = 0.63$) ewes, during suckling. Milk yield measured until the weaning of the lambs did not vary by shearing treatment in MN (2.47 ± 0.14 kg/day, $P = 0.60$; Fig. 3a) and LC ewes (2.76 ± 0.26 kg/day, $P = 0.83$; Fig. 3b).

Regarding milk composition during suckling, shearing treatment × litter size interactions were not significant in MN ($P = 0.15$ to 0.75), although significant effects were detected in the protein fraction of LC ewes (total protein, $P = 0.032$; true protein, $P = 0.043$; casein, $P = 0.020$) as shown in Table 3.

The S100 treatment increased milk protein (6%, $P = 0.049$), casein (6%, $P = 0.037$) and tended to increase true protein (6%, $P = 0.07$) compared to CO ewes, in the MN ewes, without differences with SBB ewes ($P = 0.32$–0.44; Table 3). No differences were detected in milk contents of total solids, fat or lactose by shearing treatment ($P = 0.28$–0.93). On the other hand, the S100 treatment increased total milk solids content in the LC ewes (8%, $P = 0.040$) and milk fat content (18%, $P = 0.031$) when compared to SBB treatment (Table 3) but, as indicated by the significant interactions, no differences between treatments were detected in the LC ewes for protein fractions and lactose contents ($P = 0.36$–0.46).

Milking period

Shearing treatment × litter size interactions were not significant on milk yield, in MN ($P = 0.65$) and LC ($P = 0.17$) ewes, during the milking period. The effects of shearing treatments on milk yield during the milking period (after the weaning of the lambs) by breed are shown in Fig. 3. First, no different lactation curves and average milk yield among shearing treatments were observed in the MN ewes (1.23 ± 0.09 kg/d, on average, $P = 0.52$). Second, in the case of LC ewes (Fig. 3b), the S100-treated ewes tended to yield 28% more milk than CO (2.19 ± 0.17 kg/day vs 1.71 ± 0.17 kg/day, respectively, $P = 0.08$). Nevertheless, no differences were detected between SBB (1.99 ± 0.17 kg/day) and the CO and S100 treatments in the LC ewes.

Regarding milk composition during milking, shearing treatment × litter size interactions had significant effects in the protein fraction of MN ewes (total protein, $P = 0.005$; true protein, $P = 0.007$; casein, $P = 0.032$), but they were not significant in LC ($P = 0.13$–0.40), as shown in Table 3. Moreover, no effects were detected on milked-milk composition (Table 3) according to shearing treatments in either breed (MN, $P = 0.15$–0.34; LC, $P = 0.23$–0.42).

Body reserves

Shearing treatment × litter size interactions were not significant on body reserves (i.e., BW and BCS) of MN ($P = 0.08$ and 0.36) and LC ($P = 0.35$ and 0.38), respectively. Considering the differences in fleece weight and gravid uterus accretion according to prolificacy (Table 2), MN ewes gained BW during late pregnancy (days −43 to −4, 3.7 ± 0.4 kg/ewe; $P < 0.001$) but this gain did not vary by shearing treatment ($P = 0.09$–0.86; Fig. 4a). Nevertheless, differences in the BCS of the MN ewes by shearing treatment were observed in the S100 ewes that were fatter (3.16 ± 0.11 BCS units, $P = 0.001$–0.004, respectively) than the CO and SBB ewes (2.71 ± 0.11 and 2.75 ± 0.12 units, respectively) during late pregnancy (Fig. 4a). Differences between shearing treatments disappeared after lambing (MN, 2.60 ± 0.07 units, on average; $P = 0.32$). At lambing, all MN ewes lost BW (10.6 ± 0.5 kg/ewe, on average, $P < 0.001$) and the CO were heavier than SBB (69.9 ± 2.3 kg BW vs 62.3 ± 2.5 kg BW, respectively, $P = 0.030$) but did not differ from S100 ewes (65.3 ± 2.2 kg BW, $P = 0.16$). The BCS of MN ewes also continued to decrease during lactation, without differences between shearing treatments (−0.24 ± 0.06 units, on average), except at day 36, where S100 ewes were fatter (2.17 ± 0.11 units, $P = 0.041$ and 0.036, respectively) than CO and SBB ewes (1.83 ± 0.12 units, on average, $P = 0.91$), as shown in Fig. 4a.

Similar effects of shearing treatments on body reserves were observed in the LC ewes, although in this case, the differences between S100 and CO were greater during late pregnancy (Fig. 4b). Thus, despite their lower fleece weight and slightly greater gravid uterus accretion according to prolificacy (Table 2), the LC ewes also gained BW during late pregnancy (days −43 to −4; 4.58 ± 0.88 kg BW, $P < 0.001$) and overall pre-lambing BW averaged 77.1 ± 1.7 kg, with differences due to shearing treatment ($P = 0.006$–0.47; Fig. 4b). The BW of CO ewes were greater than SBB during late pregnancy ($P = 0.006$–0.014), at lambing ($P = 0.052$) and post-lambing ($P = 0.027$–0.044) periods, but only differed punctu-

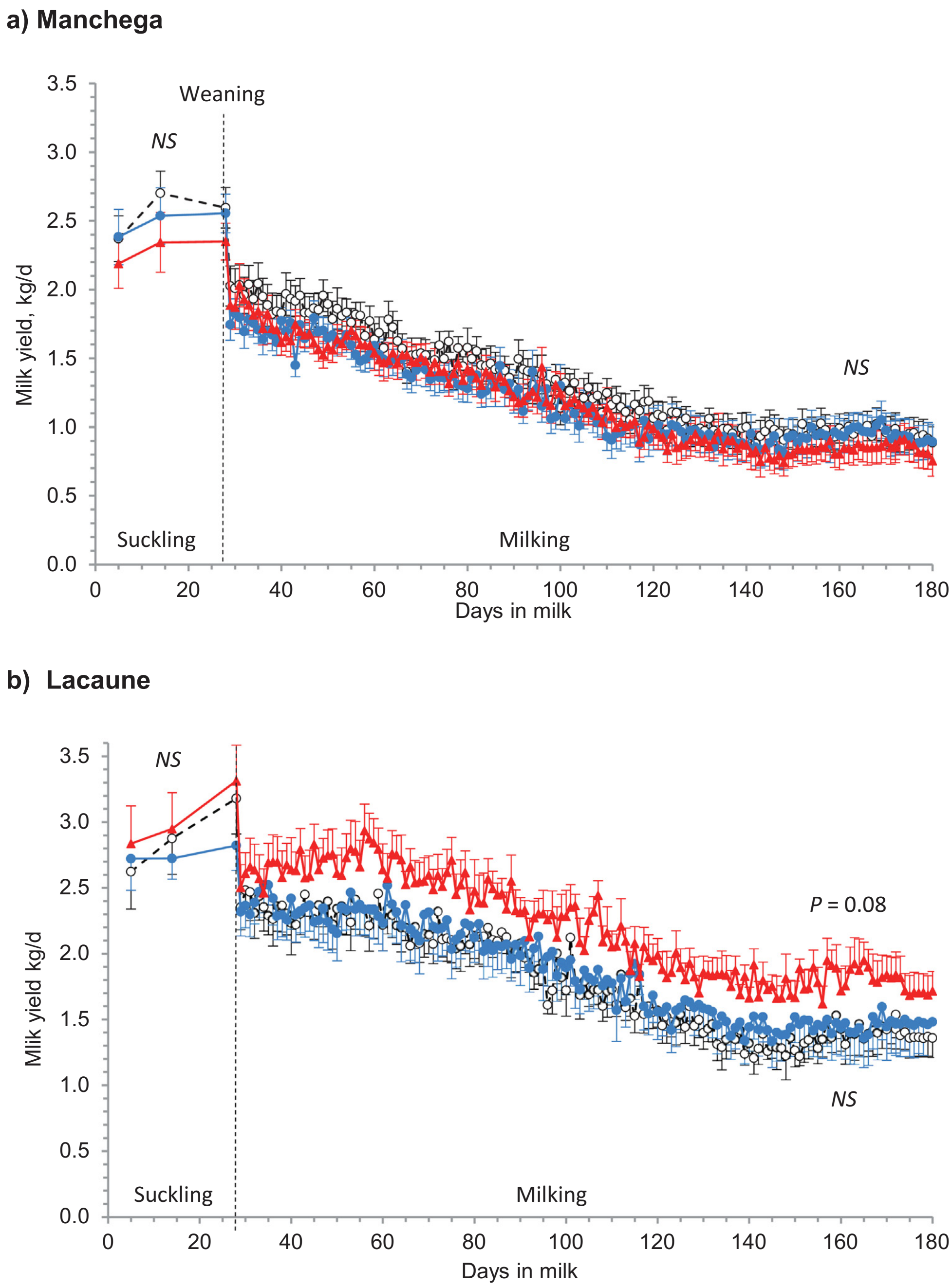

Fig. 3. Milk yield during lactation (180 days) of two breeds of dairy ewes (Manchega and Lacaune) according to shearing treatment (○: CO, control, open circle and dashed line; ●: SBB, shorn before breeding, closed circle and solid blue line; ▲: S100, shorn at day 100 of pregnancy, closed triangle and solid red line). Values are means with the SEM indicated by vertical bars.

ally (days −27 and −4, $P = 0.039$) or tended to differ from S100 ewes during the rest of the periods ($P = 0.06–0.37$) in the LC ewes. The differences in BW observed at lambing were maintained throughout the whole lactation period showing a negative trend from lambing (71.6 ± 1.7 kg BW, on average) to day 68 of lactation (65.1 ± 1.7 kg BW, on average) for all ewe groups (Fig. 4b). Regarding BCS, differences by shearing treatment were observed in the S100 ewes, that had greater BCS (3.22 ± 0.13 units) than the CO (2.71 ± 0.17 units, $P = 0.008$) and SBB ewes (2.72 ± 0.14 units, $P = 0.001$), during late pregnancy (Fig. 4b). After lambing, LC ewes lost BW (9.41 ± 0.65 kg/ewe, on average, $P < 0.001$), although the CO were heavier than SBB at lambing (75.9 ± 3.2 kg BW vs 67.5 ± 2.8 kg BW, $P = 0.050$) and did not differ from S100 (71.4 ± 2.8 kg BW, $P = 0.29$). Moreover, the BW of CO ewes continued being heavier than SBB ($P = 0.027–0.044$) until day 68 post lambing but did not differ from S100 throughout the whole lactation (Fig. 4b, $P = 0.19–0.37$).

The obtained results showed greater body reserves of S100 during late pregnancy in both MN and LC ewes, but the differences disappeared after lambing.

Discussion

Ambient temperatures greater than 25 °C had a marked impact on the ewe's RR in late pregnancy and the S100 ewes showed less

Table 3
Effects of shearing treatments on milk composition during suckling and milking periods in two breeds of dairy ewes (data are least square means).

Breed and item	Shearing treatment[1]			Mean ± SE	*P*-value	
	CO	SBB	S100		ST[1]	LS[2]
Manchega						
Suckling (5–28 days)						
Total solids, %	18.70	18.52	18.58	18.54 ± 0.38	0.93	0.34
Fat, %	8.39	8.15	8.02	8.16 ± 0.37	0.73	0.46
Total protein, %	4.99[b]	5.19[ab]	5.29[a]	5.10 ± 0.09	0.049	0.06
True protein, %	4.50[y]	4.68[xy]	4.77[x]	4.60 ± 0.09	0.07	0.08
Casein, %	3.72[b]	3.86[ab]	3.95[a]	3.81 ± 0.07	0.037	0.11
Lactose, %	4.33	4.17	4.26	4.25 ± 0.07	0.28	0.18
Milking (35–77 days)						
Total solids, %	17.73	18.14	18.21	18.01 ± 0.25	0.25	0.092
Fat, %	6.75	7.06	7.14	6.98 ± 0.21	0.30	0.41
Total protein, %	5.68	5.73	5.94	5.77 ± 0.15	0.15	0.001
True protein, %	5.35	5.41	5.60	5.44 ± 0.11	0.18	0.001
Casein, %	4.42	4.45	4.60	4.48 ± 0.09	0.19	0.002
Lactose, %	4.33	4.25	4.20	4.26 ± 0.06	0.34	0.036
Lacaune						
Suckling (5–28 days)						
Total solids, %	17.68[ab]	16.96[b]	18.30[a]	17.68 ± 0.55	0.040	0.11
Fat, %	7.59[ab]	6.65[b]	7.85[a]	7.44 ± 0.37	0.031	0.032
Total protein, %	5.11	5.15	5.35	5.14 ± 0.14	0.36	0.91
True protein, %	4.64	4.71	4.87	4.68 ± 0.14	0.45	0.89
Casein, %	3.81	3.82	3.99	3.82 ± 0.11	0.38	0.60
Lactose, %	4.00	4.17	4.11	4.09 ± 0.10	0.46	0.21
Milking (35–77 days)						
Total solids, %	16.82	16.41	17.08	16.79 ± 0.42	0.42	0.70
Fat, %	5.80	6.34	6.25	6.18 ± 0.33	0.40	0.35
Total protein, %	5.29	5.22	5.60	5.34 ± 0.25	0.23	0.80
True protein, %	4.98	4.89	5.27	5.02 ± 0.25	0.23	0.82
Casein, %	4.08	4.03	4.28	4.11 ± 0.19	0.31	0.81
Lactose, %	4.19	4.38	4.23	4.27 ± 0.10	0.30	0.34

ST × LS interactions were not significant, except for protein fractions in Manchega ewes during milking (total protein, $P = 0.005$; true protein, $P = 0.007$; casein, $P = 0.032$), and in Lacaune ewes during suckling (total protein, $P = 0.032$; true protein, $P = 0.043$; casein, $P = 0.020$).
[1] Shearing treatment (CO = Control; SBB = Shorn before breeding; S100 = Shorn at 100 days of pregnancy).
[2] Litter size.
[a,b] Values within a row with different superscripts differ at $P < 0.05$.
[x,y] Values within a row with different superscripts tended to differ at $P < 0.10$.

panting than those of SBB and CO treatments, without differences between breeds. Moreover, wool production indices of our specialised dairy ewes were like the values reported for the wool specialised Rambouillet and Corriedale (Smoliak and Slen, 1972), indicating that no differences due to breed specialization should be expected. Since wool blocks heat loss by radiation and convection, making sweating less effective (Marai et al., 2007), woolled sheep under hot conditions appeal to increase respiratory evaporation, paying a greater energy cost for thermoregulation (Collier et al., 2019). The greater energy availability in the shorn ewes may benefit the development of foetus and mammary gland, which already have metabolic priorities under homeorhetic and homeostatic controls during pregnancy (Bauman and Currie, 1980). Shearing at late pregnancy improved the ewe's thermal comfort more markedly in twin- than in single bearing ewes and supported our hypothesis on the advantages of shearing at late pregnancy under hot summer conditions.

No apparent negative impact of S100 treatment was detected during late pregnancy or at lambing. Despite weight gain during late pregnancy was moderate in our ewes and not affected by shearing treatments, S100 ewes were fatter and showed greater BCS than the CO and SBB ewes during this period, with similar trends in the MN and LC breeds. The positive effect of S100 agreed with the greater glycaemia after lambing and with the improved metabolic adaptations to fat mobilization without NEFA increase, as reported by Symonds et al. (1989) and Rosales-Nieto et al. (2020), and with our hypothesis. Values of BCS at lambing for MN and LC ewes of all treatments fit in the recommended range of 2.5–3.0 units (Kenyon et al., 2014), which may explain the lack of differences on lamb birthweight between treatments.

The obtained results support our hypothesis that shorn ewes are better adapted to utilise body fat reserves during late pregnancy, reducing their risks of clinical ketosis. Nevertheless, as the differences disappeared after lambing, few effects should be expected throughout lactation. Even though S100 ewes were fatter at lambing, no differences were detected on plasmatic insulin values by shearing treatments in both breeds. To our knowledge, there are no data available on plasmatic insulin after the parturition of shorn-pregnant ewes. Interestingly, the plasmatic insulin of our S100 ewes did not differ by the number of lambs, while a large insulin drop was observed at lambing between single- and twin-bearing ewes of SBB and CO treatments in the MN breed. This result is new and was the only physiological adaptation detected in our pregnant ewes, in which the stability of insulin in the S100 twin-bearing ewes, as growth factor and lipogenic hormone (Etherton and Evock, 1986; Qaid and Abdelrahman, 2016), may explain their greater fatness and support the use of pregnancy shearing.

Midbody reserves and hot summer conditions seem to have modified the increasing effects of shearing on the birthweight of singleton (Cam and Kuran, 2004; Rosales-Nieto et al., 2020) and twin lambs (García-Rodríguez et al., 2012) reported under winter conditions. Agreeing on this, Leibovich et al. (2011) only detected differences in lamb birthweight when pregnant Assaf dairy ewes (−30 days to lambing) were shorn during summer with barn cooling.

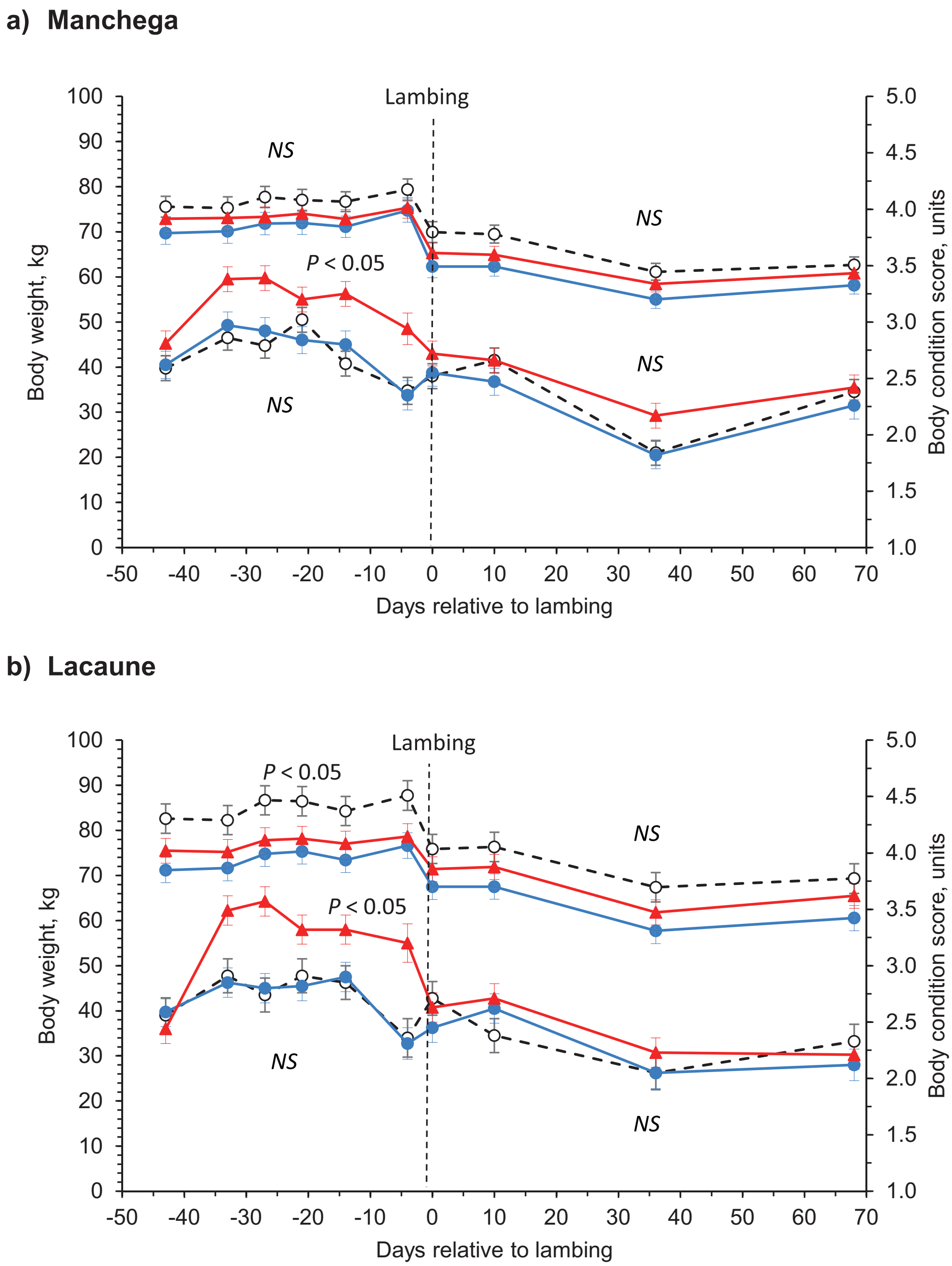

Fig. 4. BW and body condition score of two breeds of dairy ewes (Manchega and Lacaune) according to shearing treatment (○: CO, control, open circle, and dashed line; ●: SBB, shorn before breeding, closed circle, and solid blue line; ▲: S100, shorn at day 100 of pregnancy, closed triangle and solid red line). Values are means with the SEM indicated by vertical bars.

The previously mentioned positive effects of S100 did not affect colostrum and IgG content in either breed, similarly to the findings of Banchero et al. (2010) in Corriedale ewes and did not support our hypothesis of improving the mammary development and the subsequent immunity and nutritional status of the lambs.

According to the few expectancies of effects in early lactation above indicated, the estimated amount of milk produced during suckling did not vary by shearing treatment in either breed. Only small increases in milk protein components were observed for the S100 ewes, compared to CO and SBB ewes, but no differences were detected in the rest of milk components in the MN ewes. On the other hand, the S100 treatment also increased the total milk solids and milk fat contents of the LC ewes but no differences between treatments were detected for milk protein components. These results seem to support a modified partition of nutrients to the mammary gland in early lactation accounted for by endocrine changes (e.g., increased growth hormone or decreased insulin), as Symonds et al. (1990) reported. In our ewes of both breeds, the differences detected in milk composition during the suckling period were not enough to trigger changes in lamb growth during suckling or in weaning weight as we hypothesised.

Responses to shearing treatments during the milking period varied by ewe's breed. No differences in milk yield among shearing treatments were observed in the MN ewes, agreeing with García-Rodríguez et al. (2012) in Latxa ewes shorn at late pregnancy (day 110). In LC ewes, the positive trend detected in the S100 ewes was consistent with the boosting effect of shearing reported by Elhadi et al. (2019; 10%) in high-yielding LC ewes shorn during milking and winter conditions.

The lack of effects on milk composition by shearing treatments in either breed were in accordance with García-Rodríguez et al. (2012) and disagree with the increases in fat, protein and total solids observed by Knight et al. (1993) in the milk of Dorset ewes shorn in late pregnancy. Nevertheless, as previously indicated, shearing was done under different season and temperature conditions. Agreeing on this, Leibovich et al. (2011) reported fat (3%) and protein (11%) increases in Assaf ewes which were shorn pregnant during summer, as our ewes, but machine-milked under barn cooling conditions, which was not in our case.

The above discussed results on milk yield and composition did not support the hypothesis of wide-ranging positive effects of late pregnancy shearing in the lactation of dairy ewes, although improvements on milk composition in early lactation, and on milk yield in high-yielding ewes and under cold conditions, may be expected.

Conclusions

In conclusion, the use of pregnancy shearing is recommended as a husbandry practice to improve the welfare of dairy ewes because it alleviates the impact of heat stress during summer and reduces the loss of body reserves until lambing. Moreover, pregnancy shearing reduced insulin decrease in twin bearing ewes at parturition, compared to single bearing ewes, with no negative effects on the performances of subsequent lactation (i.e., colostrum and milk yield and composition, birthweight and growth of the lambs), where increased milk yield may be also expected in early lactation and in high yielding ewes.

Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.animal.2022.100698.

Ethics approval

The experimental procedures and husbandry practices reported in this study did not require approval of the Ethic Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona (CEEAH-2013), were under veterinary supervision and agreed the Spanish RD 53/2013 on the protection of animals used for experimental purposes, and the codes of recommendations for the welfare of dairy sheep of the Ministry of Agriculture, Alimentation and Environment of Spain.

Data and model availability statement

None of the data were deposited in an official repository. Data that support those study findings are available upon request.

Author ORCIDs

S. González-Luna: https://orcid.org/0000-0001-8011-9463.
A.A.K. Salama: https://orcid.org/0000-0003-2065-9702.
X. Such: https://orcid.org/0000-0002-9712-4477.
E. Albanell: https://orcid.org/0000-0002-6158-7736.
A. Contreras-Jodar: https://orcid.org/0000-0003-0565-2887.
J. de Lucas: https://orcid.org/0000-0002-3056-3774.
G. Caja: https://orcid.org/0000-0001-8606-3587.

Author contributions

S. González-Luna: Investigation, Formal analysis, Data Curation, Writing–Original Draft, Editing.
L. Cordón: Investigation, Data Curation, Writing–Original Draft.
A.A.K. Salama: Investigation, Methodology, Resources, Visualisation, Review.
X. Such: Investigation, Methodology, Resources, Visualization.
E. Albanell: Formal analysis.
A. Contreras-Jodar: Methodology, Data Curation.
J. de Lucas-Tron: Conceptualization, Methodology, Supervision, Review & Editing.
G. Caja: Conceptualization, Methodology, Investigation, Writing–Review & Editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of interest

No conflict of interest was declared.

Acknowledgements

The authors are grateful to the reviewers for the improvement of the manuscript, the CONACYT (Ciudad de México, México) for the doctoral scholarship provided to Sandra González Luna, to Ramon Costa and the team of the SGCE (Servei de Granges i Camps Experimentals) of the Universitat Autònoma de Barcelona (Bellaterra, Barcelona, Spain) for the care of the animals and to Sixto Rius (Caldes de Montbui, Barcelona, Spain) for shearing the ewes.

Financial support statement

This study was supported by a grant of the Plan Nacional (Project AGL2013-44061-R) of the Spanish Ministry of Economy and Competitiveness (Madrid, Spain).

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