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Influence of the type of forage supplied to ewes in pre- and post-partum periods on the meat fatty acids of suckling lambs

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ABSTRACT

The aim of this study was to evaluate the use of forage diets (grazing vs. hay) around the time of ewe parturition, on the fatty acids profile of suckling lamb meat (10–12 kg body weight). Forty-eight multiparous single-bearing ewes were used. The experimental treatments were conducted during the last 5 weeks of pregnancy and the 5 weeks of lactation in a 2×2 factorial design. Ewes were fed ad libitum on pastures or hay in the autumn. Results showed that milk from grazing ewes during the pre-partum period had a higher content of PUFA and CLA ($P<0.05$) and VA, CLA in their suckling lambs' meat ($P<0.05$). The effect in post-partum feeding was greater, revealing higher CLA, PUFA/SFA, PUFA n-3 and PUFA n-6/n-3 in milk and meat ($P<0.05$). The CLA, VA and PUFA n-6/n-3 ratios are those that are most affected by grazing. Pre-partum grazing, regardless of post-partum feeding, improves FA composition, increasing CLA content in both milk and meat.

1. Introduction

Fat composition of meat has long been studied given its implications for human health (De La Fuente et al., 2009). Health professionals recommend reducing the intake of saturated fatty acids (SFA), and increasing polyunsaturated fatty acids (PUFA), especially n-3. Ruminant fats are not considered healthy for humans because of their high SFA and low PUFA content; however such fats are one of the major dietary sources of conjugated linoleic acid (CLA) which is assumed to be a healthy fatty acid. CLA are a group of positional and geometric isomers of octadecadienoic acids with conjugated double bonds. These groups of fatty acids are receiving increasing attention because of their possible beneficial effects on human health, as they have been shown to reduce the incidence of atherosclerosis, diabetes and cancer in animals (Pariza, Park, & Cook, 1999; Park et al., 1997; Park & Pariza, 2007)

Fat content and composition is affected by animal feeding, which can be used to modify the fatty acid composition (FA). Animal feeding studies show that grass-based diets can improve the FA composition of ruminant fat depots by increasing CLA, vaccenic acid (VA) and PUFA n-3 (Cabiddu et al., 2005; Nudda, McGuire, Battacone, & Pulina, 2005). Pasture plays a key role in improving FA composition to ensure healthy benefits. However, not all forages have the same effect, depending on the maturity, variety and preservation of the forage system (Dewhurst, Shingfield, Lee, & Scollan, 2006; Woods & Fearon, 2009). Green grass is a good source of n-3 PUFA, although it varies according to maturity and the forage species. Haymaking processes lead to a loss of FA precursors of CLA (Tsiplakou, Mountzouris, & Zervas, 2006), reducing total FA by over 50%, with a higher loss of linolenic acid (C18:3 n-3) (Doreau & Poncet, 2000). Modest losses are recorded in wilting prior ensiling (Dewhurst et al., 2006).

Suckling lambs are functionally non-ruminant, hence fatty acid hydrogenation in the rumen will be negligible (Osorio, Zumalacarregui, Figueira, & Mateo, 2007). It thus follows that their meat fatty acid profile should reflect the profile of suckled milk (Napolitano, Cifuni, Pacelli, Riviezzi, & Girolami, 2002; Valvo et al., 2005). It is reasonable to state that the production system is responsible for much of the variation in animal product quality (Rhee, Lupton, Ziprin, & Rhee, 2003), mainly in milk products and in suckling lamb meat. Adequate use of feed with a favourable effect on fat composition can, to some extent, be used to modify the FA profile of sheep products in order to optimise the beneficial FA content.

The aim of this study was to evaluate the effect of the ewe feeding system (hay vs pasture grazing) before and after parturition on suckled/maternal milk and meat FA composition of suckling lambs. Furthermore, the relationship between maternal milk FA and meat FA composition was evaluated.

2. Material and methods

2.1. Animal management and experimental design

Forty-eight multiparous single-bearing ewes of the Churra Tensina breed were used (46.5 ± 0.66 kg body-weight (BW), and a body

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condition score (BCS) of 3.0 ± 0.03, on a 1 to 5 scale). Ewes were mated under the male effect during spring (5 May to 15 June) to produce suckling lambs for the autumn-lambing period. Ewes were kept on low mountain pastures (920–1000 m a.s.l) during the mating period (43–49% Neutral Detergent Fibre, 20–26% Crude Protein; (Joy, Alvarez-Rodriguez, Revilla, Delfa, & Ripoll, 2008). In summer (early to mid pregnancy), all ewes grazed on high mountain pastures (1500–2200 m a.s.l.; 68–75% Neutral-detergent fibre, 7–10% crude protein) (Casasus, Sanz, Villalba, Ferrer, & Revilla, 2002).

The experimental treatments were conducted during the last 5 weeks of pregnancy (pre-partum period) and the 5 weeks of lactation (post-partum period) in a 2×2 factorial design. In the last 5 weeks of pregnancy, half of the ewes were fed ad libitum on mountain pastures or eventually fed alfalfa pellets when the snow was limiting pasture availability, and the rest of the ewes were fed pasture hay ad libitum indoors. The pasture was composed of 22% legumes (mainly *Trifolium repens*), 68% grass (the main species were *Festuca arundinacea*, *Festuca pratensis* and *Dactylis glomerata*) and 10% other species (mainly *Rumex acetosa* and *Ranunculus bulbosus*) (Joy, Alvarez-Rodriguez et al., 2008).

After lambing (average 19 October ± 8 d), half of the ewes were exchanged from their initial treatment and the rest remained in it during the 5 weeks of lactation. This factorial arrangement allowed testing the independent effects of pre-partum and post-partum forage type as well as their interactions: pasture grazed pre- and post-partum, hay pre- and post-partum, pasture grazed pre-partum + hay post-partum, and hay pre-partum + pasture grazed post-partum. The four-group division from two original lots was intended to avoid additional residual error resulting from different paddock environment (especially outdoors).

Ewe's BW and parity were taken into account to balance pre-partum groups. Lamb gender and BW of lambs were additionally considered to balance post-partum groups. Pasture biomass on low mountain pastures decreased steadily from 14.4 ± 4.2 cm to 5.1 ± 0.6 cm during the autumn (late pregnancy and lactation periods) but it was overcome by an ad libitum supply of alfalfa pellets (11 days out of the whole experimental period). Outdoor grazing ewes had free access to a sheltered area. The forages supplied met the energy and protein requirements for maintenance, pregnancy and/or milk production at each physiological stage (INRA, 2007). The study finished when lambs reached 10–12 kg BW, which is the target BW for commercial category suckling lamb.

Milk production was recorded weekly by the oxytocin technique proposed by Doney, Peart, Smith, and Louda (1979) and machine milking was carried out with hand finishing (4 h interval). Ewes were returned to their paddock between the two milking sessions while lambs were confined. The milk obtained in the second milking was weighed and the yield was extrapolated to the daily period. Individual milk samples (50 ml) were taken and kept at −20 °C until analysis.

2.2. Slaughter procedure and carcass measurements

When lambs reached 10–12 kg BW they were transported to the experimental abattoir of the Research Institute in Zaragoza, which is located 180 km away from the farm. Immediately after arrival, lambs were slaughtered according to EU legislation (E.U., 1986). Carcasses were chilled at 4 ºC during 24 h and then split. The loin portion from10th to 12th thoracic *vertebra* was taken for fatty acid determination of intramuscular fat. All samples were vacuum-packed and frozen (−20 °C) until analysis.

2.3. Fatty acid analysis

Lipid separation of milk to determine the fatty acid composition was conducted according to Luna, Juarez, and de la Fuente (2005). Fatty acids (FA) were converted to methyl esters according to Official Methods ISO 5509 (2000). They were separated using flame ionisation detector (FID) and HP-6890 gas chromatograph equipped with a H-88 column 100 m × 0.25 mm id; 0.20 μm film thickness (Agilent Technologies, Waldbronn, Germany). Fatty acid content was expressed as a percentage of the total amount of the fatty acids identified. After individual FA determination, the sum of saturated fatty acids (SFA), mono-unsaturated FA (MUFA), and poly-unsaturated FA (PUFA) was calculated. Moreover, the PUFA/SFA and PUFA n-6/n-3 ratios were calculated.

The M. *Longissimus thoracis* portion was minced for FA analysis. Fatty acid methyl esters were obtained using a 20% solution of boron trifluoride in methanol (Rule, 1997). Analysis of fatty acid methyl esters was performed by gas chromatography as in milk and also expressed as a percentage of the total amount of the FA identified.

2.4. Statistical analyses

Data were analysed with the SAS statistical software (SAS, 2002). Ewe milk FA composition was analysed through analysis of variance with a mixed model (MIXED procedure):

$$y_{ijkl} = \mu + \alpha_i + \beta_k + (\alpha\beta)_{ik} + \lambda_l + (\alpha\lambda)_{il} + (\beta\lambda)_{kl} + d_j + \varepsilon_{ijkl}$$

where: y_{ijkl} = milk FA, μ = overall mean, α_i = pre-partum feeding system effect, β_k = post-partum feeding system effect, λ_l = week of lactation effect d_j = animal random effect j, andε_{ijkl} = residual error.

Lamb data were analysed through analysis of variance with a general linear model (GLM procedure):

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \delta_k + (\alpha\beta)_{ij} + (\alpha\delta)_{ik} + (\beta\delta)_{jk} + \varepsilon_{ijk}$$

where: y_{ijk} = dependent variable, μ = overall mean, α_i = pre-partum feeding system effect, β_j = post-partum feeding system effect, δ_k = sex effect and ε_{ijk} = residual error.

Results are reported as least square means and their associated standard errors (SE). Multiple comparisons among treatments were performed by Tukey's method. The level of significance was set at 0.05. Interactions are only commented on in the text when they were significant ($P \leq 0.05$). A stepwise selection procedure was performed using the STEPDISC function in SAS to select variables that would contribute to a discrimination function of lamb origin for dam's milk fatty acids throughout lactation. The analyses were repeated for meat FA as well as for average milk FA composition and meat FA together. This procedure reduced from 27 to 5, from 26 to 5 and from 53 to 6 the number of variables for milk, meat and milk and meat together. These selected variables were used to classify individuals into feeding strategies with the canonical function of the CANDISC procedure of SAS. Canonical correlations with a P-value lower than 0.05 were considered significant. Only first canonical functions had eigenvalues >1 but second canonical functions were used to depict individuals in figures.

3. Results

During the study period there was snow for 11 days (2 days in late October, 30 and 31, and 9 consecutive days in late November–early December, 25 of November to 3 of December), in which 1 kg of alfalfa pellets was fed to each grazing ewe. Permanent pasture was the dietary component of the grazing treatment, except when snow did not allow grazing, whereas meadow hay formed the hay treatment diet. Chemical composition of pasture, hay and alfalfa pellets is done in Table 1. The estimated dietary metabolizable energy (ME) content according to Cannas, Tedeschi, Fox, Pell, and Van Soest (2004) was similar between them (9.1 and 10.2 MJ ME/kg DM for hay and pasture, respectively). Alfalfa pellets supplied similar ME (10.2 MJ ME/kg DM) to grazing ewes when snow prevented pasture grazing. Although both feeding