Effects of previous diet and duration of soybean oil supplementation on light lambs carcass composition, meat quality and fatty acid composition

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ABSTRACT

Forty Merino Branco ram lambs were used to study the effects of initial diet and duration of supplementation with a conjugated linoleic acid (CLA) promoting diet, on carcass composition, meat quality and fatty acid composition of intramuscular fat. The experimental period was 6 weeks. The experimental design involved 2 initial diets (commercial concentrate (C); dehydrated lucerne (L)), and 2 finishing periods (2 and 4 weeks) on dehydrated lucerne plus 10% soybean oil (O). Data were analysed as a 2 x 2 factorial arrangement with initial diet and time on finishing (CLA promoting) diet as the main factors. The lambs were randomly assigned to four groups: CCO; COO; LLO; LOO according to the lamb’s diet fed in each period. Lambs initially fed with concentrate showed higher hot carcass weights (11.2 vs 9.6 kg) than lambs fed initially with lucerne. The increase of the duration of finishing period reduced the carcass muscle percentage (54.0% vs 55.5%) and increased the subcutaneous fat percentage (5.67% vs 7.03%). Meat colour was affected by initial diet. Lambs initially fed with concentrate showed a lower proportion of CLA (18:2cis-9, trans-11 isomer) (0.98% vs 1.38% of total fatty acids) and most of n-3 polyunsaturated fatty acids than lambs initially fed with lucerne. Initial diet did not compromise the response to the CLA-promoting diet and the proportion of 18:2cis-9, trans-11 in intramuscular fat increased with the duration of the time on the CLA-promoting diet (1.02% vs 1.34% of total fatty acids).

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1. Introduction

The nutritional modulation of the fatty acid (FA) profile of ruminant edible fats is currently an important research topic (Sinclair, 2007). It is well established that dietary FA composition can affect human metabolism and health (Givens, 2005; Ruxton, Calder, Reed, & Simpson, 2005). Some saturated FA, particularly 12:0, 14:0 and 16:0 are hypercholesterolaemic and their intake should be restricted (Givens, 2005). Ruminant edible fats are particularly rich in saturated FA, due to the extensive microbial hydrogenation of dietary polyunsaturated fatty acids (PUFA) in the rumen. However, isomerisation and incomplete hydrogenation of PUFA in the rumen also produce several of octadecenoic, octadecadienoic and octadecatrienoic isomeric FA (Bessa, Santos-Silva, Ribeiro, & Portugal, 2000) and, at least some of them, have powerful biological properties (Nagao & Yanagita, 2005). Conjugated isomers of linoleic acid (CLA) such as rumenic acid (18:2 cis-9, trans-11) and 18:2 trans-10, cis-12 have been extensively studied. Among several biological effects, rumenic acid has anticarcinogenic properties and 18:2 trans-10, cis-12 is a powerful inhibitor of milk fat synthesis (Shingfield & Grinari, 2007). Rumenic acid is produced in the rumen in minor quantities, and most present in tissues or secreted in milk, is produced endogenously by delta-9 desaturation of vaccenic acid (Palmquist, St. Pierre, & McClure, 2004). Vaccenic acid (18:1 trans-11) is also produced by rumen biohydrogenation of PUFA and its output can be considerable in specific dietary circumstances (Bessa et al., 2000). The supplementation of ruminant diets with PUFA rich lipids is the most effective approach to decrease saturated FA and promote the enrichment in potential health benefiting unsaturated FA, including rumenic acid and n-3 PUFA. High levels of PUFA intake can lead to a partial ruminal biohydrogenation resulting in high output of trans-octadecenoic acids to be absorbed and high levels of rumenic acid in animal products. Lamb meat (and beef) production systems are frequently based on concentrate feeding of weaned lambs (or calves). However, the inclusion of high levels of polyunsaturated oils in diets for increasing CLA content in meat is more effective when using forage based diets (Bessa, Portugal, Mendes, & Santos-Silva, 2005). Moreover, depression on fibre and organic matter digestion in the rumen, often observed when high levels of polyunsaturated oils are fed to...
ruminants, are attenuated by high fibre diets (Palmquist, 1988). The isomeric pattern of octadecenoic FA derived from ruminal biohydrogenation is clearly distinct between high concentrate and high forage diets, which frequently leads to a failure to increase rumenic acid when animals are fed high concentrate diets (Beaulieu, Drackley, & Merchen, 2002; Bessa et al., 2005; Engle, Spears, Fellner, & Odle, 2000). Although, high forage and high oil diets (CLA-promoting diets) are effective in modifying the FA composition of ruminant products, they often depress dry matter intake with occasional reduction in animal performance (Bessa, 2001; O’Kelly and Spiers, 1993).

Information about the effect of the diet fed before the finishing period on muscle CLA deposition in ruminants is scarce. Some studies indicate that, after a finishing period with a high grain diet, cattle previously fed with forages have higher muscle CLA content than others previously fed with grain based diets (Laborde, Mandell, Tosh, Buchanan-Smith, & Wilton, 2002). Conversely, Poulsouin, Dhiman, Ure, Cornforth, and Olson (2004) suggested that using grain based diets previously to a finishing period on pasture, compromises the expression of the mechanism responsible for the synthesis and deposition of CLA in muscle.

The importance of the duration of n–3 PUFA enriched diets on long chain n–3 PUFA in meat was reviewed and emphasised by Raes, De Smet, and Demeyer (2004) but the knowledge about duration of oil enriched diets on CLA deposition in ruminant meat is scarce. As far as we know, the only direct comparison of two lengths of dietary oil supplementation on intramuscular CLA concentration in ruminants is from Gillis, Duckett, and Sackmann (2004). These authors found no differences in intramuscular CLA concentrations of heifers fed a high grain diet related to the length of the supplementation period with 4% of corn oil (32 vs 64 days).

Our experiment was intended to explore the concept of using a CLA-promoting diet as finishing diet for growing ruminants. Therefore, the main objectives of this trial were to verify if high rumenic acid concentrations in lamb meat can be achieved with short finishing periods with high oil forage based diet administration, and if the type of previous diet affects the response to high oil forage based diet. Soybean oil was used because we already had the experience that it could be incorporated in lucerne pellets up to 10% of DM without digestive disturbances and that was effective in increasing rumenic acid in muscle (Bessa et al., 2005; Santos-Silva, Mendes, Portugal, & Bessa, 2004).

2. Material and methods

2.1. Experimental design and animal management

To perform this trial, forty Merino Branco ram lambs were used. The lambs were raised with their dams on pasture, in a farm in the south of Portugal, and were supplemented with concentrate, fed in the shelter during the night. At weaning when the lambs were 49.8 ± 3.08 days of age and 13.8 ± 1.80 kg live weight they were transported to the Estação Zootécnica Nacional facilities, and were supplemented with concentrate, fed in the last two periods.

The trial lasted for 6 weeks and was divided into 3 periods of 14 days each, with 3 days of transition between diets. The 6 weeks period is a common finishing time on production of Merino Branco light lambs (carcass weights up to 15 kg) preferred in Portuguese market. Experimental groups were named CCO, COO, LLO and LOO according to diet fed in each period (i.e. COO lambs were fed concentrate in the first period and lucerne meal with 10% of soybean oil in the last two periods).

2.2. Slaughter and sampling procedure

Lambs were slaughtered at Estação Zootécnica Nacional. After weighing to obtain the slaughter live weight, lambs were sent to the experimental abattoir where they were stunned and slaughtered by exsanguination. Carcasses were immediately weighed to obtain hot carcass weight (HCW). Carcasses were kept at 10 ºC for 24 h and were later chilled at 0 ºC until the third day after slaughter.

The kidney knob channel fat (KKCF) and the kidneys were removed and the carcasses were split along the spine. The left sides of the carcasses were separated into eight joints (Santos-Silva, Mendes, & Bessa, 2005), and the chumps and the shoulders were dissected into muscle, fat and bone. The colour of longissimus thoracis (Lt) was estimated using a Minolta CR-300 chromometer (Konica Minolta, Portugal) in the L*, a* and b* system at the level of the left 13th thoracic vertebra, after 1 h of exposure to air to allow blooming. After removing the epimysium, samples from the left Lt muscle between the 6th and the 13th thoracic vertebrae, were minced, vacuum packed, freeze-dried and stored at −80 ºC until further analysis. The Longissimus lumborum between the 2nd and the 4th lumbar vertebrae, was vacuum packed, and frozen at −20 ºC, until shear force determination, following the procedure described by Santos-Silva, Bessa, and Mendes (2003).

2.3. Analytical procedures and calculations of variables

2.3.1. Carcass composition

Percentages of carcass muscle, subcutaneous fat (SCF) and muscle/bone ratio (M/B) were calculated from the tissue composition of the chump and shoulder, and from KKCF proportion, according to the equations: Muscle% = 19.35 + 0.69 * Muscle% (chump + shoulder) – 1.41 KKCF% (R² = 0.94), SCF% = 0.145 + 0.81 * SCF (chump + shoulder) (R² = 0.95) and M/B = 0.03 + 0.87 * M/B (chump + shoulder) (R² = 0.86), determined by Santos-Silva and Simões (1999).

2.3.2. Lipid analysis

Muscle lipids were extracted using the method of Folch, Lees, and Stanley (1957) and esterified FA methyl esters were prepared by base catalysed transesterification using sodium methoxide, according to Christie (1993). The FA methyl esters were analysed using gas chromatography, after methyl esters were transesterified with hexane as the solvent.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>L</th>
<th>O</th>
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<tr>
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<tr>
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C – Commercial concentrate; L – dehydrated lucerne; O – dehydrated lucerne with 10% of soybean oil; NDF – neutral detergent fibre.
according to procedures described by Bessa et al. (2005), except for column temperature that was programmed to a constant temperature of 170 °C. Peak identification was based on co-chromatography with known standards of FAME (Sigma, St. Louis, MO, USA).

2.4. Statistical analysis

Data was analysed as a 2 × 2 factorial, considering the initial diet (I), time on CLA-promoting diet (O) and their interactions (I * O), using the GLM procedure of SAS (SAS Institute, Inc., Cary, NC, USA). The models used to study weight gain, carcass traits include covariates. The random allocation of lambs in the experimental groups resulted in significant differences between groups for initial LW which clearly affected the slaughter LW. So, slaughter LW gain and hot carcass weight (HCW) results were adjusted to the same initial LW. For carcass composition variables results were adjusted to the same HCW.

3. Results

Lambs initial and slaughter live weights (LW), total LW gain, carcass composition and meat quality traits are presented in Table 2. In lambs initially fed with concentrate, time on CLA promoting diet decreased total LW gain whereas in lambs previously fed lucerne the effect was opposite. Dressing percentage and adjusted HCW was 5% and 17% higher for lambs initially fed with concentrate than for those initially fed lucerne. Adjusted carcass composition was not affected by initial diet. However, increasing the time on CLA-promoting diet decreased carcass muscle and increased subcutaneous fat. The muscle/bone ratio was not affected by initial diet or time on CLA-promoting diet.

Lambs initially fed concentrate had lower shear force and L* and higher b* than lambs initially fed lucerne. Total FA in Lt were not affected by the treatments.

Fatty acid profile of Lt muscle are presented in Table 3. In all treatments, the major FA were 18:1 cis-9, 16:0, 18:0 and 18:2 n–6, which together contributed about 70% of total FA. Out of 26 FA, only 7 were not affected by either initial diet, time on CLA-promoting diet or their interaction. These include minor FA (<1%) and 14:0, 18:0 and 18:1 cis-11. Lambs initially fed with concentrate had higher proportions of 15:0, 18:1 trans-10 and lower proportions of 18:1 trans-11 (P < 0.06), 18:2 cis-9, trans-11, 20:4n–6, 20:5n–3, 22:5n–3 and 22:6n–3 (P < 0.07) than lambs initially fed with lucerne. Time on the CLA-promoting diet decreased 17:0 and the sum of unidentified FA (other) and increased 18:1 trans-11 and 18:2 cis-9, trans-11.

Significant interactions between initial diet and time on CLA-promoting diet were observed for 12 FA and generally followed two different patterns: (a) 16:0, 16:1 cis-9, 17:1 cis-9, 18:1 cis-9 decreased with time on CLA-promoting diet for lambs initially fed with concentrate, to levels similar to those of LLO and LOO; (b) 18:1 trans-12, 18:1 cis-12, 18:1 cis-15 and 18:2n–6 increased between CCO and COO to levels similar to those of LLO and LOO. The 18:3n–3 was higher in LLO and LOO lambs than in CCO and COO lambs and time on CLA-promoting diet increase it only when the initial diet was concentrate.

The ratios between n–6 and n–3 PUFA (n–6:n–3), PUFA and saturated FA (P:S) were considered to evaluate the effects of the treatments in the nutritional value of fat. Lambs fed initially with lucerne had (P = 0.051) lower (better) values for n–6:n–3 ratio, and the time on CLA-promoting diet increased this variable. The P:S ratio was lower (worst) for CCO lambs than for all the other groups, which did not differ among them.

4. Discussion

4.1. Total weight gain, carcass composition and meat quality traits

The better growth performances of lambs initially fed with concentrate are in accordance with the results of Bessa et al. (2005), obtained in lambs fed with concentrate and with dehydrated lucerne. However, the total LW gain observed in this trial was lower than those reported for Merino Branco lambs fed with concentrate or dehydrated lucerne (Bessa et al., 2005; Santos-Silva & Portugal, 2001; Santos-Silva et al., 2004). The impact of changing diets during the short trial period may explain the lower growth performances observed in this study. This effect might be attenuated in longer finishing periods, possible for the production of heavy lambs and beef. However, 6 weeks is a common finishing period for Merino Branco lambs in order to obtain light carcass preferred by Portuguese consumers (Santos-Silva et al., 2002).

The small increase of fat deposition and reduction of carcass muscle with time on CLA-promoting diet is consistent with effects of lipid supplementation reported by Solomon, Lynch, and Lough (1992), Lough, Solomon, Rumsey, Kahl, and Slyter (1994) or Santos-Silva et al. (2004).

Table 2

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<th>COC</th>
<th>COO</th>
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<th>SEM</th>
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<td>20.7</td>
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<tr>
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<td>0.00</td>
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Table 3

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<th>CCO</th>
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<td>0.443</td>
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Values adjusted to initial live weight; a values adjusted to hot carcass weight; LW – Live weight; HCW – hot carcass weight; M/B – muscle bone ratio; KKCF – kidney knob channel fat; SCF – subcutaneous fat; L* – lightness, a* – redness, b* – yellowness; FA – fatty acids; SEM – standard error; I – initial diet; O – time on CLA-promoting diet. Means in the same row with different superscripts are significantly different (P < 0.05).
The average values obtained for meat shear force ranged between 4.1 and 6.1 and are higher than others reported for Merino Branco lambs with similar carcass weights (Santos-Silva et al., 2002, 2004), probably because the ageing periods were not the same (3 days in the present trial vs 7 days). Bessa et al. (2005) reported that meat from Merino Branco lambs with similar carcass weight and fed concentrate or dehydrated lucerne did not differ in shear force values. Nevertheless, in the present trial lambs fed initially with lucerne showed higher meat shear force than lambs initially fed with corn grains. Other strategies were explored to increase CLA, namely finishing beef cattle on pasture, attempted by Noci, Monahan, French, and Moloney (2005). These authors reported that up to 40 days on pasture, there was no increase of rumenic acid, and even after 99 days on pasture, it increased only 14%. Although, the differences between species on muscle growth, FA deposition and FA turnover must be considered, the results of these trials suggest that lucerne pellets with 10% of soybean oil is more effective than pasture in increasing rumenic acid.

As far as we know, there are no reports about the effect of the time on CLA promoting diets on fatty composition of lambs. Gillis et al. (2004), in a study with heifers fed with high grain diets found no differences in intramuscular CLA concentration related to the length of the supplementation period with 4% of corn oil (32 vs 60 days). Griswold et al. (2003) studied the effect of short-term finishing strategies (6 weeks) on CLA content of beef. The supplementation with soybean oil and the increase of forage:concentrate ratio from 20:80 to 40:60 failed to increase CLA content in muscle, probably because the forage used was corn silage which is rich in starchy corn grains. Other strategies were explored to increase CLA, namely finishing beef cattle on pasture, attempted by Noci, Monahan, French, and Moloney (2005). About 87% of rumenic acid present in tissues results from endogenous desaturation by stearoyl-CoA desaturase (SCD) of 18:1 cis-9, trans-11 concentration in muscle and even after 99 days on pasture, it increased only 14%. Although, the differences between species on muscle growth, FA deposition and FA turnover must be considered, the results of these trials suggest that lucerne pellets with 10% of soybean oil is more effective than pasture in increasing rumenic acid.

The lower concentration of rumenic acid in lambs initially fed concentrate was most probably due to the lower starting point and not to a diminished response to the CLA-promoting diet. Comparing the values obtained for rumenic acid in COO and LLO treatments (0.75% and 1.28% of total FA, respectively) with those previously reported by our group (Bessa et al., 2005) using also Merino Branco lambs fed the same commercial concentrate used in the present trial (0.55% of total FA) and dehydrated lucerne (0.85% of total FA) suggests that feeding the CLA-promoting diet in the last 14 days before slaughter increased rumenic acid concentration in lamb meat about 35% and 50% respectively.

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The response of rumenic acid concentration in muscle to the introduction of the CLA-promoting diet (forage plus oil) was highly effective and was independent of the initial diet (1* O, P = 0.25). This is particularly impressive if we consider the very short period of supplementation in the present trial. These results do not support the suggestion of Poulson et al. (2004) that feeding ruminants with high grain diets previous to a finishing period on pasture, compromises the expression of the mechanism responsible for the synthesis and deposition of CLA in muscle.

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References


