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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 × 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 (57.4% 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 (18:2*cis*-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 18:2*cis*-9, *trans*-11 in intramuscular fat increased with the duration of time on the CLA-promoting diet (1.02% vs 1.34% of total fatty acids).

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 & Griinari, 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 conditions (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

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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, Poulson, 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 housed and randomly assigned to four groups of 10 lambs each. The trial started after one week of adaptation. Lambs were fed *ad libitum*, and the diets used in the trial were commercial concentrate plus 10% of hay (C), dehydrated lucerne pellets (L), and pellets consisting of 90% lucerne and 10% soybean oil (O). The diet O was prepared in an industrial unit, and oil was added to dehydrated lucerne prior to pelletization. The chemical composition of the diets is presented in Table 1 and the ingredient composition of the commercial concentrate is the same as reported by Bessa et al. (2005).

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).

Table 1
Chemical composition (% of dry matter) and fatty composition (% of total FA) of experimental diets

	C	L	O
Crude protein	17.0	14.4	13.0
Ether extract	3.2	2.7	12.1
NDF	21.3	51.5	46.8
Ash	6.8	12.8	11.3
FA composition			
16:0	12.3	14.9	11.3
18:0	1.0	3.1	3.1
18:1 *cis*-9	13.1	11.5	18.1
18:2 $n-6$	35.0	31.3	47.6
18:3 $n-3$	3.3	13.6	8.3

C – Commercial concentrate; L – dehydrated lucerne; O – dehydrated lucerne with 10% of soybean oil; NDF – neutral detergent fibre.

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 °C for 24 h and were later chilled at 0 °C 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, 2002) 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 °C until further analysis. The *Longissimus lumborum* between the 2nd and the 4th lumbar *vertebrae*, was vacuum packed, and frozen at −20 °C, 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% (R^2 = 0.94), SCF% = 0.145 + 0.81 * SCF (chump + shoulder) (R^2 = 0.95) and M/B = 0.03 + 0.87 * M/B (chump + shoulder) (R^2 = 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