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Growth performance, carcass and meat quality of lambs supplemented with increasing levels of a tanniferous bush (*Cistus ladanifer* L.) and vegetable oils

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ABSTRACT

The effects of dietary inclusion of *Cistus ladanifer* L. (CL) and a vegetable oil blend were evaluated on growth performance, carcass and meat quality of fifty four lambs that were assigned to 9 diets, corresponding to 3 levels of CL (50, 100 and 200 g/kg DM) and 3 levels of oil inclusion (0, 40 and 80 g/kg DM). Treatments had no effects on growth rate. Oil depressed dry matter intake ($P = 0.017$), carcass muscle ($P = 0.041$) and increased ($P = 0.016$) kidney knob channel fat. Chemical and physical meat quality traits were not affected by treatments. Off-flavour perception was higher for 8% of oil ($P < 0.001$). The level of 100 g/kg DM of CL inclusion improved meat stability after 7 days of storage. Supplementation with linseed and soybean oils (2:1) was a good approach to improve meat nutritional value from feedlot lambs, increasing total n-3 PUFA.

1. Introduction

Ruminant edible fat contains high levels of saturated fatty acids (SFA), low contents of polyunsaturated fatty acids (PUFA) and variable amounts of rumen metabolism derived fatty acids (FA), including *trans* FA and conjugated FA. Increasing meat's content of PUFA (particularly *n*−3 PUFA) and conjugated linoleic acid isomers (CLA) is widely accepted as targets to improve nutritional quality of ruminant meat (Mapiye et al., 2012). Dietary supplementation with PUFA rich oils can be used to increase both *n*−3 PUFA and CLA, but the extensive rumen biohydrogenation of PUFA strongly limits the effectiveness of this nutritional strategy.

Cistus ladanifer L. (CL) is an evergreen spontaneous forage shrub well adapted to semi-arid conditions, poor and acidic soils (Patón, Azocar, & Tovar, 1998) and highly available in marginal fields of most Mediterranean countries. Overall, the CL is considered as a feed resource with low nutritional value, mainly due to its high content on antinutritional compounds, such as condensed tannins (CT) (Dentinho, Navas, & Potes, 2005), being a common field observation that ruminants only browse CL during season of pasture scarcity. Condensed tannins are normally considered as anti-nutritive and toxic compounds due to their adverse nutritional effects for herbivores, especially when they are in a high concentration in plant tissues (>6% DM) (Aerts, Barry, & McNabb, 1999; Butter, Dawson, & Buttery, 1999). Nevertheless, when ingested in balanced doses, the CT may have beneficial effects on ruminants by preventing bloat, increasing digestive utilization of dietary protein, and acting as anthelmintics and as antioxidants (Makkar, 2003; Waghorn, 2008). Condensed tannins might have some potential to interfere with rumen metabolism and modulate the PUFA biohydrogenation, as well as to improve the meat oxidative stability (Vasta & Luciano, 2011). Thus, our research team explored the possibility of achieving these goals by incorporating CL in high oil-high forage diets of finishing lambs (Jerónimo et al., 2010, 2012). In the previous studies we reported that CL modified the rumen biohydrogenation pattern, resulting in a relevant enrichment of CLA in intramuscular fat of oil supplemented lambs (Jerónimo et al., 2010). In addition, CL increased the resistance to induced oxidation in meat, independently of oil supplementation (Jerónimo et al., 2012). Moreover, we were surprised by the fact that the inclusion of CL up to 25% dry matter (DM) did not affect negatively growth, carcass traits and meat quality of lambs (Jerónimo et al., 2010, 2012). In that study, CL replaced dehydrated lucerne in high forage diets and this might be a reason why its inclusion did not result in productive trait depression. However, finishing lambs are commonly fed low forage diets based on cereals, cereals by-products and oilseed meals. Thus, the present experiment was designed to test if the CL effects observed when CL is included in high oil-

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high forage diet are maintained when CL is included in diets with lower forage content. The productive performance, carcass traits and meat quality results are reported here.

2. Materials and methods

2.1. Animals and management

Animal handling followed EU Directive 86/609/EEC concerning animal care. Fifty-four Merino Branco (MB) ram lambs born in spring 2012 were reared with dams on extensive grazing until weaning at approximately 60 days of age. At weaning, lambs were transported to the Unidade Estratégica de Investigação e Serviços em Produção e Saúde Animal, Instituto Nacional de Investigação Agrária e Veterinária (UEISPA-INIAV), located at Vale de Santarém, Portugal. Thereafter, lambs were housed and randomly assigned to 18 pens; 3 lambs per pen and 2 pens per treatment, according to a completely randomized experimental design with a 3 × 3 factorial arrangement of treatments, with 3 levels of CL incorporation (50, 100 and 200 gDM/kg DM) and 3 levels of oil (0, 40 and 80 g/kg), resulting in 9 isoenergetic and isonitrogenous diets: 1) CL5, 5% CL and 0% oil; 2) CL10, 10% CL and 0% oil; 3) CL20, 20% CL and 0% oil; 4) CL5O4, 5% CL and 4% oil; 5) CL10O4, 10% CL and 4% oil; 6) CL20O4, 20% CL and 4% oil; 7) CL5O8, 5% CL and 8% oil; 8) CL10O8, 10% CL and 8% oil; and 9) CL20O8, 20% CL and 8% oil. Leaves and soft stems of CL shrubs were harvested in Portugal (39°30′36″N/8°19′00″W) in March 2012, dried at room temperature, cut in small pieces, and milled. The oil used as supplement was a blend of soybean oil and linseed oil (1:2 vol/vol). The diets were presented as pellets (3 mm diameter). The formulas of the 9 diets and their chemical composition, obtained as the average of the results of three pooled samples of each diet, are presented in Table 1.

After an adaptation period of 7 days to the experimental conditions, in which lambs were dewormed by dosing with Ivomec® (Merial Labs., Spain) and vaccinated against enterotoxaemia (Miloxan, Merial Labs., Spain), the lambs stayed on trial for 6 weeks. The average live weight (LW) at the beginning of the trial was 16.2 ± 2.93 kg (mean ± SD). Feed was offered daily at 9:00 am at a rate of 110% of ad libitum intake calculated by weighing-back refusals daily which were registered and discarded. The animals were weighed weekly just before feeding.

2.2. Slaughter, carcass evaluation and sample collection

At the end of the trial, lambs were weighed and transported to the experimental abattoir of the UEIPSA-INIAV where they were stunned and slaughtered, by sectioning jugular veins and the carotid arteries. After preparation, carcasses were immediately weighed to obtain hot carcass weight (HCW) and were kept at 10 °C for 24 h. After that period carcasses were re-weighed, to obtain the cold carcass weight (CCW) and graded, according to the EUROP classification systems for lamb carcasses weighing less or more than 13 kg (EC regulations N°1234/2007 and N°1249/2008 (EC, 2011a,b)). Then, carcasses were chilled at 2 °C until the third day after slaughter. At that time, the kidney knob channel fat (KKCF) and kidneys were removed. Carcasses were split along the spine and left sides were separated into eight joints as described in Santos-Silva, Mendes, and Bessa (2002). The weight of each joint was recorded to estimate the proportion of the higher-priced joints (leg + chump + loin + ribs). The pH was measured in the *Semimembranosus* muscle (SM) using a Hanna Instruments Hi 9023 device. Chumps and shoulders were vacuum-packed and frozen at −20 °C until being dissected into muscle, subcutaneous and intermuscular fats and bone to determine the tissue composition.

The rib joints of the left half of the carcasses, containing the *Longissimus thoracis* muscle (LT), were vacuum-packed and frozen at −20 °C until shear force determinations. The *Longissimus lumborum* (LL) muscle was removed from loin joints of the left halves of the carcasses and, after the removal of the *epimysium*, was minced with a food processor (3 × 5 s), vacuum-packed, freeze-dried, and stored at −20 °C until further lipid analysis.

In the right halves, two sub-samples with about 1.5 cm thickness of LT were collected and used to evaluate the lipid and colour stability during 7 days of storage at 2 °C in illuminated cooler. At day 0 of storage the colour parameters were determined after 1 h of blooming. The other sample was individually placed on polystyrene trays, over-wrapped with oxygen permeable polyvinyl chloride film and displayed 7 days. At the end of storage time, meat samples were allowed to bloom for 1 h, before the determination of the colour parameters. After that, the samples were vacuum packed and stored at −80 °C until lipid oxidation analysis. The right loins containing LL were vacuum packed and frozen at −20 °C, until being used for sensory analysis.

Table 1
Proximal (%) and chemical composition (g/kg DM) of the experimental diets.

	5CL			10CL			20CL		
	0O	4O	8O	0O	4O	8O	0O	4O	8O
Ingredients									
Maize	5.00	5.00	5.00	26.11	21.34	16.57	23.91	19.71	5.00
Wheat	29.55	24.42	19.30	6.00	6.00	6.00	6.62	6.00	16.68
Soybean meal 48%	12.95	14.08	15.20	15.39	16.16	16.93	16.98	17.79	17.82
Cistus ladanifer	5.00	5.00	5.00	10.00	10.00	10.00	20.00	20.00	20.00
Dehydrated lucerne	45.00	45.00	45.00	40.00	40.00	40.00	30.00	30.00	30.00
Oil[a]	0.00	4.00	8.00	0.00	4.00	8.00	0.00	4.00	8.00
Sodium bicarbonate	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Calcium carbonate	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Minerals and vitamins	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Chemical composition									
Dry matter (g/kg)	910	915	918	910	916	917	910	912	916
Crude protein	165	157	164	162	156	159	165	162	155
NDF[b]	368	374	364	361	344	354	334	320	316
Starch	255	249	258	263	241	198	258	222	180
Ether extract	23	63	105	30	70	112	38	78	116
Total phenols	5.9	5.8	7.6	10.5	10.0	12.6	20.0	21.5	22.2
CT[c]	2.5	2.9	2.6	6.5	6.9	7.4	16.3	14.5	16.1

[a] Soybean oil and linseed oil (1:2 vol/vol).
[b] Neutral detergent fibre.
[c] Condensed tannins.