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Fatty acids and sensory characteristics of Spanish dry-cured loin enriched in acid α-linolenic and α-tocopherol

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Abstract

The effects of using α-linolenic and α-tocopherol acid-enriched pork on the fatty acids and sensory characteristics of Spanish dry-cured loins were investigated. For the study, five batches of Spanish dry-cured loins were manufactured using pork loin enriched in polyunsaturated $n-3$ fatty acids and α-tocopherol. Tissues were obtained from pigs fed on diets with the same ingredients, except for the oil source which corresponded to: [sunflower (C), linseed (L) and linseed and olive (1/1, w/w) (LO)] and two different amounts of α-tocopheryl acetate [20 (C, L and LO) or 200 (LOE and LE) mg/kg diet]. Dry-cured loins with polyunsaturated fatty acid $n6/n3$ ratios below 4 were obtained from linseed and linseed/olive oil-enriched batches. Dry-cured loin manufactured with pork from animals fed on diets enriched only with linseed oil presented the worst sensory characteristics and higher TBAR values than did dry-cured loins from animals fed on diets enriched with linseed and olive oil and linseed oil plus tocopheryl acetate.

Keywords: Dry-cured loin; Fatty acid; PUFA $n-6/n-3$ ratio; α-Tocopherol

1. Introduction

Previous papers have reported the enrichment of pork and pig adipose tissue with $n-3$ polyunsaturated fatty acid (PUFA) by incorporating linseed oil and/or olive oil in the pig diet (D'Arrigo et al., 2002; Hoz et al., 2003). By this approach, pork meat and lard were obtained with reduced PUFA $n-6/n-3$ ratios, reaching values close to 2. Also, pork lipid peroxidation was controlled by the inclusion of tocopheryl acetate in the pig diet (D'Arrigo et al., 2002; Hoz et al., 2003). Using both raw materials (meat and lard), the possibility of manufacturing "salchichon" (dry fermented sausage) with a low PUFA $n-6/n-3$ ratio and with appropriate sensory characteristics has been reported (Hoz, D'Arrigo, Cambero, & Ordóñez, 2004). It is, therefore, possible to enrich this product in PUFA $n-3$ without changing its chemical and sensory properties.

The interest in enriching the PUFA $n-3$ content of meat products arises from the beneficial effects assigned to these fatty acids on human health (Alexander, 1998; Rose & Connolly, 1999; Simopoulos, 1997). Many chronic conditions (cardiovascular disease, diabetes, cancer, obesity, autoimmune diseases, rheumatoid arthritis, asthma, and depression) have been associated with increased production of thromboxane A_2, leukotriene B_4, IL-1B, IL-6, TNF and C-reactive protein (Simopoulos, 2004). These factors increase as a result of increased omega-6 fatty acid intake and decrease as a result of increased omega-3 fatty acid intake, either α-linolenic acid or EPA or DHA. High PUFA $n-6/n-3$ ratios in the human diet have been strongly correlated with chronic diseases (Simopoulos, 2004). Consequently, nutritional authorities have recommended the consumption of foods enriched in $n-3$ PUFA, establishing a $n-6/n-3$ PUFA ratio of less than 4 (British Nutrition Foundation, 1992) to improve the health status in humans.

In general, enrichment of the meat product in $n-3$ PUFAs implies a greater susceptibility of the lipids to

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oxidation because the greater the number of double bonds, the faster are the oxidation reactions (Gurr, Harwood, & Frayn, 2002). Rapid oxidation may give rise to excessive rancidity, which can lead to the product being rejected by the consumer. In the present work, α-tocopherol was used to reduce the susceptibility to oxidation.

This work was designed to study the chemical and sensory characteristics of a Spanish dry-cured loin manufactured with pork enriched in PUFA $n-3$ and α-tocopherol. Spanish dry-cured loin is a highly appreciated meat product, manufactured with the whole pork loin, mixed with different seasonings and stuffed in a natural or synthetic case.

2. Materials and methods

2.1. Experimental design

The material used in this trial was obtained from the same pigs as those used in a previous experiment for manufacturing dry fermented sausages (Hoz et al., 2004). Fifty Large White and Great York crossed female pigs were fed with five different diets. The pigs were divided into five groups with 10 pigs in each group. All diets were formulated with the same ingredients, except for the fat source (30 g/kg in all cases) and α-tocopherol (Hoz et al., 2004). Dietary fat sources were sunflower oil (rich in C18:2$n-6$) for the control diet (C), linseed oil (L, rich in C18:3$n-3$) and a 1:1 (w/w) mixture of linseed oil and olive oil (LO, rich in C18:1$n-9$). Within each dietary fat treatment containing L, a control group was fed a basal level (20 mg α-tocopheryl acetate/kg diet) of vitamin E (Hoffman La Roche, Switzerland), and the others received a supplemented level (200 mg α-tocopheryl acetate/kg diet) of vitamin E (batches LOE and LE).

Animals were stunned, slaughtered and exsanguinated at a local slaughterhouse at 100.1 kg ± 7.09 live weight. Pork loins were obtained after 24 h of refrigeration at 4 °C.

2.2. Preparation of the experimental dry-cured loin

To prepare a large amount of dry-cured loin, the whole left loins (*Longissimus dorsi*) of ten animals fed the same diet were used. For each of the five diets (C, L, LE, LO and LOE), ten dry-cured loins were manufactured. All the dry-cured loins were manufactured on the same day using the same technology, ingredients and formulation. Raw material was whole pork loin (*Longissimus dorsi*) of about 3.0 kg after removing the surface fat and connective tissue. Additives and other ingredients (g/kg of raw material) were water (25), NaCl (25), glucose (5), curing salts composed of $NaNO_3$ (2) and $NaNO_2$ (1), ascorbic acid (1.0), sweet paprika (15), hot paprika (5), powdered garlic (2), oregano (1). All the additives and other ingredients were mixed. This mixture was then evenly distributed on the loin surface and the ten loins from every batch were covered with the mixture of additives and ingredients and then left at 4 °C for 48 h. Afterwards, each loin was packed into synthetic casing (90 mm in diameter). The resulting fifty pieces were ripened together in an Ibercex ripening cabinet, model G-28 (ASL, San Fernando de Henares, Spain). The meat products were kept at 23 °C and 94% relative humidity (RH) for 48 h. Then, the temperature and RH were slowly reduced to 8 °C and 84%, respectively, within 72 h. These ripening conditions were used until the end of the ripening process (a total of 25 days). At that time, the a_w was below 0.92 and the final product was vacuum-packed and maintained at room temperature.

Samples were taken at the end of the ripening process (0 months) and after 1 and 4 months of vacuum storage. Samples were vacuum packed, frozen at −18 °C and stored until analysis.

2.3. Chemical analysis

Protein (by Kjeldhal nitrogen), moisture (oven air-drying method) and ash (muffle furnace) were analyzed following the AOAC (1995) procedure. Water activity (a_w) was determined using a Decagon CX1 hygrometer (Decagon Devices Inc., Pullman, WA) at 25 °C.

The concentration of α-tocopherol was quantified as described by Rey, Lopez-Bote, Soares, and Isabel (1997). Analyses were carried out by reverse phase HPLC (HP 1050, Hewlett-Packard, Waldbronn, Germany) equipped for separation with a C18 column (RP-18, Hewlett-Packard). The mobile phase was methanol:water (97:3 v/v) at a flow rate of 2 ml/min, and the ultraviolet detector was fixed at 292 nm.

Lipids from adipose tissue samples were obtained using the method of Bligh and Dyer described by Hanson and Olley (1963). Fatty acid methyl esters were prepared, using the method of Murrieta, Hess, and Rule (2003). For this, transmethylation was performed using 1 ml of 1.09 M methanol and HCl and a 1 ml methanol addition to each lipid sample, followed by heating at 80 °C for 30 min and vortex-mixing every 5 min. Upon cooling, 1 ml H_2O and 2 ml hexane were added to each tube. Tubes were capped and vortex-mixed for about 15 s and then centrifuged for 3 min at 3000 rpm. The hexane layer was transferred to GLC vials containing anhydrous Na_2SO_4. The methyl esters were extracted with 3 ml of petroleum ether. Then, 1 μl was analyzed using a Perkin–Elmer 8420 gas chromatograph (Perkin–Elmer, Beaconsfield, UK) equipped with a flame ionization detector and a capillary column HP-Innowax (30 m × 0.32 mm, i.d. and 0.25 μm). Helium, at 2.0 ml/min, was used as the carrier gas and a split/splitless injector was used with a split ratio of 10/1. The temperature programme was as follows: injector and detector temperatures 250°C, the initial column temperature was 200 °C, which was maintained for 2 min, 200–245 °C at 3.5 °C min^{-1} and then maintained for 7 min. Fatty acid methyl esters were identified by comparison with previously run standards. Analyses were done in duplicate.

Lipid oxidation was determined using the 2-thiobarbituric acid method (TBARs) described by Salih, Smith, and Dawson (1987). A quantity of 5 g of sample was homogenized in 15 ml of 0.38 M $HClO_4$ for 3 min in an ice bath. To avoid further oxidation, 0.5 ml of a 0.19 M BHT ethanolic solution was added. The homogenate was centrifuged (3000*g*, 5 min, 5 °C) and filtered through filter paper (Whatman No. 54). An aliquot of 0.7 ml was mixed with 0.7 ml of a 0.02 M TBA solution and heated at 100 °C for 30 min. After cooling, the mixture was centrifuged at 3000*g* for 15 min at 5 °C. Finally, the absorbance was measured at 532 nm. Results were expressed as mg malondialdehyde/kg sample.

Colour measurements were performed using a tristimulus colorimeter (Minolta Chroma Meter CR300, Minolta Corporation, NJ). The L^*-, a^*- and b^*-values were measured four times on the surface of the dry-cured loin at three different analysis times [0 (freshly cut dry-cured loin hours), 4 and 24 h after cutting]. After the first colour measurement, samples were kept at room temperature without protection.

2.4. Sensory analysis

To determine the possible sensory differences between the dry-cured loin batches, a triangle and an acceptance test were performed. At the end of the ripening period, dry-cured loin samples were evaluated by a panel of fifteen tasters, selected from among the members of the Departmento de Nutrición, Bromatología y Tecnología de los Alimentos, who had been previously trained in the sensory assessment of meat products. The evaluation was performed between meals, after breakfast and before the midday meal. To reduce fatigue, panel members participated in three sessions per day (two of the triangular test and one of the acceptance tests) with a minimum of 1 h between sessions.

From each dry-cured loin, the outer part (1 cm) was discarded and the remainder was cut into pieces of $0.3 \times 4 \times 4$ cm. These samples were left for 20 min to reach room temperature. The evaluations were performed in individual booths, built according to the criteria of the International Standards Organization (ISO, 1981a) DP 6658. The tasters were given unsalted crackers and room temperature water to clean the palate between samples. White fluorescent light was used during tests.

The triangle test (ISO, 1981b) was performed by the forced-choice option, in which the tasters must choose the sample that, in their opinion, is different. The combinations of samples used in the triangular test were: C vs. L, C vs. LE, C vs. LO, C vs. LOE, L vs. LE, L vs. LO, L vs. LOE, LE vs. LO, LE vs. LOE and LO vs. LOE. To complement the triangle test, testers were asked to indicate their reasons for selecting one particular sample of the three used in the analysis.

For the acceptance test, the hedonic rating option was used. One sample was presented at a time and the panellists were asked to rate the following attributes of the sausages on a non-structured 10 cm hedonic scale: colour, odour, flavour and texture. Samples were given scores of 1 (very poor) to 10 (excellent). The overall acceptability was calculated using the expression: overall quality: (Colour × 0.1) + (Odour × 0.15) + (Flavour × 0.5) + (Texture × 0.25).

2.5. Statistical analysis

Data were analyzed using the General Linear Model of SAS (2001). An individual dry-cured loin was the experimental unit for analysis of all data. The comparative analyses between means were conducted using the Duncan multiple range test. Data were presented as the means of each group and the standard deviation (SD) of the mean.

3. Results and discussion

3.1. Compositional and nutritional features

In previous research, it has been shown that the concentration of $n-3$ fatty acids (Cheriam & Sim, 1995) in both pork muscle and adipose tissue can be increased as a result of a clear reduction (<4) in PUFA $n-6/n-3$ ratio (D'Arrigo et al., 2002; Hoz et al., 2003). Using the loin (*Longissimus dorsi*) plus some seasoning, several experimental batches of Spanish dry-cured loin were produced. No effect

Table 1
Chemical composition of Spanish dry-cured loin[A]

	Dietary treatment[A]				
	C	L	LE	LO	LOE
Dry matter (g/100 g product)	46.66 ± 1.66	46.25 ± 2.32	47.99 ± 2.17	46.88 ± 1.33	47.12 ± 2.37
Fat (% DM[B])	5.4 ± 0.39	4.17 ± 2.31	4.62 ± 1.39	5.65 ± 0.85	6.08 ± 1.19
Protein (% DM[B])	36.6 ± 2.19	37.5 ± 1.55	37.2 ± 2.87	36.0 ± 3.19	35.4 ± 1.78
Ash (% DM[B])	4.13 ± 0.22	4.01 ± 0.73	4.71 ± 0.59	4.36 ± 0.15	4.27 ± 0.25

Values of Spanish dry loins are means of data from different vacuum storage times (0, 1 and 4 months).
[a,b,c,d] Means in the same row with different letters are significantly different ($p < 0.05$).
[A] Loin of animals fed with different diets [C, control (sunflower oil, 30 g kg^{-1}); L, linseed oil (30 g kg^{-1}); LE, linseed oil (30 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1}); LO, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}); LOE, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1})].
[B] DM: dry matter, g/100 g dry product.

Table 2
α-Tocopherol content (mg/kg wet matter) and TBARs values (mg malondialdehyde kg^{-1}) of the Spanish dry-cured loin after 0, 1 and 4 months of vacuum storage

Vacuum storage time (month)	Dietary treatments[A]				
	C	L	LE	LO	LOE
α-Tocopherol content					
0	0.91 ± 0.29c	0.71 ± 0.75c	1.78 ± 0.61a	1.11 ± 0.34b	1.95 ± 0.21a
1	0.84 ± 0.24c	0.66 ± 0.33c	1.73 ± 0.71a	0.97 ± 0.21b	1.81 ± 0.66a
4	0.80 ± 0.46c	0.61 ± 0.17c	1.74 ± 0.45a	1.07 ± 0.21b	1.75 ± 0.21a
TBARs values					
0	1.24 ± 0.31b β	2.97 ± 0.51a β	1.22 ± 0.06b β	1.35 ± 0.26b β	0.87 ± 0.07c χ
1	2.72 ± 0.17bc α	4.05 ± 0.29a α	3.05 ± 0.09b α	2.66 ± 0.09c α	2.52 ± 0.39c β
4	2.99 ± 0.39b α	4.18 ± 1.89a α	3.29 ± 0.18b α	3.16 ± 0.87b α	3.38 ± 0.09b α

[a,b,c] Means in the same row and with different letters are significantly different ($p < 0.05$).
[α,β,χ] Means in the same column with different letters are significantly different ($p < 0.05$).
[A] Loin of animals fed with different diets [C, control (sunflower oil, 30 g kg^{-1}); L, linseed oil (30 g kg^{-1}); LE, linseed oil (30 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1}); LO, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}); LOE, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1})].

of dietary treatment was observed on dry matter, fat, protein, or ash concentration in any sample (Table 1). The α-tocopherol content (Table 2) in the dry-cured loins manufactured with *Longissimus dorsi* muscle enriched in α-tocopherol (LE and LOE) was significantly greater ($p < 0.05$) than in those made with muscle from pigs fed on a diet of basal α-tocopherol content (C, L and LO) maintaining the differences in α-tocopherol level observed in pork muscle (Hoz et al., 2003). No reduction in α-tocopherol was observed during vacuum storage of dry-cured loin (0, 1 and 4 months) (Table 2). The TBARs values of dry-cured loins (Table 2) manufactured with meat from animals fed on diets enriched in linseed oil (batch L) were always significant ($p < 0.05$) and higher than those of

Table 3
Fatty acid composition (means ± standard error of the total fatty acid percentage) of the Spanish dry-cured loin

Dietary treatment[A]						
Fatty acid	C	L	LE	LO	LOE	$p<$
C12:0	0.04 ± 0.004	0.04 ± 0.004	0.04 ± 0.004	0.04 ± 0.004	0.05 ± 0.004	n.s.
C14:0	0.94 ± 0.03a	0.83 ± 0.04b	0.83 ± 0.03b	0.95 ± 0.03a	0.93 ± 0.03ab	0.05
C16:0	21.27 ± 0.17	20.37 ± 0.18	20.4 ± 0.17	21.2 ± 0.17	21.1 ± 0.18	n.s.
C16:1*n*7	0.37 ± 0.02a	0.30 ± 0.02b	0.27 ± 0.02c	0.30 ± 0.02b	0.36 ± 0.02a	0.01
C18:0	12.6 ± 0.17a	12.4 ± 0.18a	11.5 ± 0.16b	12.5 ± 0.16a	12.4 ± 0.16a	0.005
C18:1*n*9	43.3 ± 0.55b	42.7 ± 0.59b	42.3 ± 0.55b	43.2 ± 0.55b	44.5 ± 0.55a	0.05
C18:2*n*6	16.7 ± 0.31a	13.1 ± 0.33b	13.63 ± 0.31b	12.2 ± 0.31c	11.8 ± 0.31c	0.005
C18:3*n*6	0.06 ± 0.006	0.06 ± 0.14	0.05 ± 0.007	0.05 ± 0.01	0..05 ± 0.004	n.s.
C18:3*n*3	0.83 ± 0.07d	6.25 ± 0.88a	6.40 ± 0.19a	5.07 ± 0.77b	4.25 ± 0.69c	0.005
CLA	0.08 ± 0.007	0.07 ± 0.005	0.08 ± 0.007	0.07 ± 0.007	0.09 ± 0.02a	n.s.
C20:0	0.25 ± 0.03a	0.23 ± 0.02ab	0.25 ± 0.03a	0.21 ± 0.03b	0.25 ± 0.03a	0.05
C20:1*n*9	0.95 ± 0.08ab	0.94 ± 0.03ab	0.91 ± 0.05b	0.86 ± 0.06b	1.03 ± 0.16a	0.01
C20:4*n*6	0.35 ± 0.02a	0.23 ± 0.02c	0.22 ± 0.01c	0.23 ± 0.01c	0.28 ± 0.07b	0.005
C20:5*n*3	0.21 ± 0.03c	0.96 ± 0.12a	0.96 ± 0.04a	0.81 ± 0.07b	0.69 ± 0.09b	0.005
C22:4*n*6	0.13 ± 0.01a	0.07 ± 0.01b	0.05 ± 0.007b	0.06 ± 0.01b	0.08 ± 0.01b	0.005
C22:5*n*3	0.19 ± 0.04d	0.35 ± 0.04a	0.24 ± 0.05c	0.30 ± 0.04b	0.32 ± 0.04ab	0.005
C22:6*n*3	0.12 ± 0.007	0.12 ± 0.01	0.12 ± 0.007	0.10 ± 0.007	0.12 ± 0.007	n.s.
Total SFA	35.1 ± 0.28a	33.3 ± 0.30b	33.1 ± 0.28b	35.1 ± 0.28a	34.7 ± 0.28a	0.01
Total MUFA	46.1 ± 0.51b	46.0 ± 0.54b	45.0 ± 0.51b	46.0 ± 0.53b	47.5 ± 0.51a	0.05
Total PUFA	19.6 ± 0.48b	21.6 ± 0.52a	22.5 ± 0.48a	19.5 ± 0.49b	18.3 ± 0.48b	0.01
*n*6	17.2 ± 0.33a	13.5 ± 0.35b	14.0 ± 0.65b	12.5 ± 0.58b	12.2 ± 0.47b	0.01
*n*3	1.43 ± 0.08b	7.75 ± 0.91a	7.80 ± 0.52a	6.35 ± 0.84a	5.46 ± 0.51a	0.005
*n*6/*n*3	13.4 ± 0.34a	1.87 ± 0.37b	2.00 ± 0.34b	2.24 ± 0.33b	2.54 ± 0.55b	0.005

Values of Spanish dry loins are means of data from different vacuum storage times (0, 1 and 4 months).
n.s., no significative.
CLA, conjugated linoleic acid.
[a,b,c,d] Means in the same row with different letters are significantly different ($p < 0.05$).
[A] Loin of animals fed with different diets [C, control (sunflower oil, 30 g kg^{-1}); L, linseed oil (30 g kg^{-1}); LE, linseed oil (30 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1}); LO, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}); LOE, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1})].

the remaining batches (C, LE, LO and LOE). This fact indicates a higher lipid oxidation caused by the enrichment in PUFA (Table 3) and the lower α-tocopherol concentration (Table 2).

Differences in the fatty acid (FA) composition of pork muscle (Hoz et al., 2003) and also in the dry-cured loins (present paper) were observed, reflecting the diet consumed by pigs (Hoz et al., 2003; Hoz et al., 2004). Significant differences ($p < 0.05$) were found in C14:0, C16:1$n-7$, C-18:0, C18:1$n9$, C18:2$n-6$, C18:3$n-3$, C20:0, C20:1$n-9$, C20:4$n-6$, C20:5$n-3$, C22:4$n-6$ and C22:5$n-3$ (Table 3). In the FA of the $n-3$ family, the main effect was detected on C18:3$n-3$. Dry-cured loins L, LE, LO and LOE, were richer in these FAs (C18:3$n-3$,C20:5$n-3$, and C22:5$n-3$) than was the control. C18:2$n-6$ was the dominant one of the $n-6$ family, showing a significantly ($p < 0.005$) higher content in the control batch products, followed by those of batches L and LE and, finally, LO and LOE. Similar results had been previously reported in back fat and muscle (D'Arrigo et al., 2002; Hoz et al., 2003). The total $n-6$, $n-3$ FA contents and the PUFA $n-6/n-3$ ratio varied considerably depending on the dry-cured loin batches. Significant differences ($p < 0.05$) were found among the control and the remaining batches (L, LE, LO and LOE) which presented $n-6/n-3$ ratios close to 13 and 2, respectively. Experimental dry-cured loins (L, LE, LO and LOE) had a $n-6/n-3$ ratio below 4 according to published nutritional recommendations (British Nutrition Foundation, 1992).

Table 4
Significance level of the results of the triangle test sensorial analysis of Spanish dry-cured loin

	Dietary treatment[A]				
	C	L	LE	LO	LOE
C	×	$p < 0.05$	n.s.	n.s.	n.s.
L	×	×	$p < 0.05$	$p < 0.05$	$p < 0.01$
LE	×	×	×	n.s.	n.s.
LO	×	×	×	×	n.s.
LOE	×	×	×	×	×

n.s., not significant ($p > 0.05$).
[A] Loin of animals fed with different diets [C, control (sunflower oil. 30 g kg^{-1}); L, linseed oil (30 g kg^{-1}); LE, linseed oil (30 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1}); LO, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}); LOE, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1})].

3.2. Colour instrumental evaluation

The L^*-, a^*- and b^*-values of control and experimental dry-cured loins were determined in the product a few minutes (time of air exposure 0) after opening the package (data not shown). No effect of diet was observed ($p > 0.05$). A clear influence of air exposure after cutting (0, 4 and 24 h) was only observed in all batches in the L^* values, which is usual in meat products (Perlo et al., 1995; Hoz et al., 2004). This parameter showed an average value of 45.2 ± 2.10 in freshly cut dry-cured loin and of 36.9 ± 1.98 after 24 h. The a^* values varied from a minimum of 7.64 ± 0.54 in fresh cut loin to a maximum of 7.9 ± 0.58 at 24 h. The b^* parameter changed from 8.7. ± 0.46 of freshly cut to 10.7 ± 1.37 at 4–24 h. These differences after air exposure were probably due, initially, to the loss of surface water (Faustman & Cassens, 1990) and, afterwards to oxidation processes (Zanardi, Novelli, Ghiretti, Dorigoni, & Chizzolini, 1999). These results are in general agreement with those recorded for other meat products, such as salami or salchichon (Hoz et al., 2004; Zanardi et al., 1999).

3.3. Sensory analysis

In the triangular test (Table 4), significant differences ($p < 0.05$) were found when Spanish dry-cured loin from batches L were compared with samples from all the other batches. Significant differences ($p < 0.05$) in these comparisons always corresponded to observations of rancidity for flavour and odour.

The odour and flavour (Table 5) of L dry-cured loin received lower scores ($p < 0.05$) than did the other batches. The overall acceptability was also significantly ($p < 0.05$) lower in the L dry-cured loin batch with values of 4.44 ± 1.39, while the remaining batches presented values of around 7.20. This is because testers detected rancid notes

Table 5
Acceptance test of some sensorial attributes and overall acceptability of the Spanish dry-cured loin

	Dietary treatment[A]				
	C	L	LE	LO	LOE
Colour	7.37 ± 1.36	7.15 ± 1.24	7.29 ± 1.71	7.09 ± 0.99	7.63 ±1.10
Odour	7.56 ± 1.50a	4.65 ± 2.01b	7.75 ± 1.36a	7.13 ± 1.16a	7.47 ± 1.91a
Flavour	6.83 ± 1.29a	3.72 ± 1.88b	6.61 ± 1.54a	6.53 ± 1.67a	6.88 ± 1.13a
Textura	7.36 ± 2.93	7.58 ± 2.88	7.33 ± 2.48	7.28 ± 2.19	7.25 ± 1.85
Overall acceptability[B]	7.14 ± 1.15a	4.44 ± 1.39b	7.25 ± 1.31a	7.05 ± 2.15a	7.37 ± 1.62a

[a,b] Means in the same row with different letter are significantly different ($p < 0.05$).
[A] Loin of animals fed with different diets [C, control (sunflower oil. 30 g kg^{-1}); L, linseed oil (30 g kg^{-1}); LE, linseed oil (30 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1}); LO, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}); LOE, linseed oil (15 g kg^{-1}) + olive oil (15 g kg^{-1}) + α-tocopheryl acetate (200 mg kg^{-1})].
[B] Overall quality: (Colour × 0.1) + (Odour × 0.15) + (Flavour × 0. 5) + (Texture × 0.25).

in odour and flavour, probably due to the higher TBARs values (Table 2). Similar results were found in dry fermented sausages (Hoz et al., 2004) manufactured with raw materials enriched in $n-3$ PUFAs but without α-tocopherol. These sausages revealed an unpleasant and slightly rancid taste.

The results obtained here, showed the possibility of manufacturing Spanish dry-cured loin enriched in α-linolenic acid with a PUFA *n*6/*n*3 ratio below 4. However, to obtain products without negative effects on composition, lipid stability and sensory properties, the product must be enriched with α-tocopherol to avoid the adverse effects of lipid oxidation. This approach could be attempted in dry ham production. This subject merits further investigation, which is currently in progress.

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