Effect of including whole linseed and vitamin E in the diet of young bulls slaughtered at two fat covers on the sensory quality of beef packaged in two different packaging systems

Pere Albertí,[a*] María M Campo,[b] María J Beriain,[c] Guillermo Ripoll[a] and Carlos Sañudo[b]

Abstract

BACKGROUND: Forty-six Pirenaica young bulls, slaughtered at two levels of fatness (3 and 4 mm), were used to evaluate the effect of the inclusion of 50 g kg^{-1} linseed alone or with 200 IU vitamin E kg^{-1} in the concentrate and of the meat packaging system (vacuum or modified atmosphere packaging (MAP)) on the beef sensory quality.

RESULTS: The inclusion of linseed or supplementation with vitamin E in the concentrate induced no significant differences in the main meat sensory scores and overall appraisal except under MAP, where small differences due to concentrate ingredients were found in juiciness and metallic flavor intensity. Extending the display time up to 4 or 8 days in high-oxygen MAP had detrimental effects on sensory attributes. Meat from animals with 4 mm fat cover depth were rated more tender and juicy, less fibrous and with a higher intensity of beef flavor and rancid odor than meat from 3 mm fat cover bulls when both samples were vacuum packaged.

CONCLUSION: The inclusion of 50 g kg^{-1} linseed in the concentrate fed to bulls had no detrimental effect on the beef sensory quality. The vacuum-packaged meat of bulls slaughtered at 4 mm fat cover was rated higher on sensory analysis than that at 3 mm fat cover.

Keywords: linseed; fatty acid profile; muscle color; beef

INTRODUCTION

The consumer at the moment of purchase judges the quality of meat based on intrinsic and extrinsic cues. For many consumers, color, price, visible fat and joint appearance are the most impor- tant factors when purchasing beef, while tenderness, flavor and juiciness are important factors linked to eating satisfaction.[1] Many consumers prefer lean beef, because meat is scored by the quantity and quality of fat present, as fat has been linked to cardiovascular diseases.[2,3] However, consumer valuation of nutritional and health claims varies across countries, and different marketing strategies are possible.[4] Therefore many consumers prefer lean beef as evi- dence of healthiness and also support the development of tech- nologies that can improve the health attributes of meat products and guarantee eating quality.[5]

Prime beef cuts can be aged in vacuum packaging before being cut into steaks and sold by the butcher or placed on trays for self-service displays. Vacuum-packaged beef has a purple or brown appearance, making it visually unappealing to most con- sumers. Therefore, seeking the best appearance for beef, modified atmosphere packaging (MAP) has been imposed on over-wrapped trays. However, aging in MAP raises some issues, as oxygen pro- motes oxidation of lipids and pigments[6] and has negative influ- ences on shear force,[7] thawing losses and sensory quality.[8]

Feedstuffs rich in polyunsaturated fatty acids are being used to improve the fatty acid profile of beef.[9] The increase in polyunsat- urated fatty acids in intramuscular fat can increase lipid oxidation during retail display[10] or can reduce some palatability attributes.[11] However, the eating quality of the cattle that receive linseed does not always differ from the control.[10] Regarding the fatty acids of the fattening diet, it should be considered that oleic acid is gener- ally related to desirable flavors, while polyunsaturated fatty acids have been associated with unpleasant or abnormal flavors.[12]

Whole linseed partially escapes ruminal biohydrogenation and increases the content of 18:3n-3 in beef, decreasing the n-6/n-3

* Correspondence to: P Albertí, Unidad de Tecnología en Producción Ani- mal, CITA de Aragón, Avda Montañana 930, E-50059 Zaragoza, Spain.
E-mail: palberti@aragon.es

a Centro de Investigación y Tecnología Agroalimentaria (CITA), Gobierno de Aragón, Avda Montañana 930, E-50059, Zaragoza, Spain

b Facultad de Veterinaria, Universidad de Zaragoza, C/ Miguel Servet 177,
E-50013, Zaragoza, Spain

c E.T.S. Ingenieros Agrónomos, Universidad Pública de Navarra, Campus de Arrosadia, E-31006, Pamplona, Spain

ratio.[13–17] However, these studies evaluated the performances and carcass traits but did not assess the sensory quality of the meat. Feeding bulls with concentrates that contain ingredients that increase unsaturated fatty acids in the meat increases the need for dietary vitamin E supplementation to prevent flavor deterioration due to lipid oxidation.[18]

Therefore the objective of this study was to compare the effects of including whole linseed and vitamin E in the concentrate in young bulls slaughtered at two fat covers on the sensory quality of the beef packaged in two different packaging systems.

EXPERIMENTAL

Animals and diets

The experiment was carried out with 46 Pirenaica young bulls (270.7 ± 28.4 kg carcass weight) reared in six lots. Half of the animals were fed until they reached 3 mm of dorsal fat cover depth, and the other half until they reached 4 mm. Two lots were fed with each of the following diets: a control concentrate (n = 7), concentrate with 50 g kg^{-1} linseed (n = 8) and concentrate with 50 g kg^{-1} linseed plus 200 IU vitamin E kg^{-1} (n = 8). For detailed information, see Albertí *et al.*[19]

At 24 h after slaughter, from the left *longissimus thoracis* muscle, two 2-cm-thick steaks (T5–T6) were removed, vacuum packed and frozen at −20 °C for proximate and vitamin E content analysis. Samples were analyzed for dry matter and ash according to official AOAC methods.[20] Another sample was ground and lyophilized, the nitrogen content was assessed using a protein analyzer (NA2100, Ce Instruments, ThermoQuest Italia, Rodano, Italy) and the intra- muscular fat content was quantified using an Ankom XT10 extrac- tor (MACEDON, NY, USA). Both components were expressed as g kg^{-1} fresh meat.

To determine the α-tocopherol content of the muscle, 1 g of *longissimus thoracis* muscle was treated with a saponification solution, and the non-saponifiable matter was recovered by petroleum ether extraction[21] and analyzed using an Agilent 1100 high-performance liquid chromatograph (Agilent Technologies España SL, Las Rozas, Spain) equipped with a quaternary pump, an Atlantis dC18, 4.6 mm × 200 mm, 3 µm capillary column (Waters Cromatografía, SA, Cerdanyola del Vallès, Spain) and a fluores- cence detector (λ_{ex} = 295 nm, λ_{em} = 340 nm). The mobile phase was an acetonitrile/water mixture (95:5 v/v) with 1 mL L^{-1} triflu- oroacetic acid. The flow rate was 0.025 mL s^{-1}, the temperature of the column oven was 35 °C and the run time was 8 min. No internal standard was used.

Additionally, two 2-cm-thick steaks (T11 – T12) were removed, vacuum packaged and kept at 4 °C in darkness. One was aged for 2 days and the other for 14 days, and then both were frozen at −20 °C for lipid oxidation analysis, which was measured with the thiobarbituric acid-reactive substances (TBARS) method of Ripoll *et al.*[22]

From the *longissimus lumborum* muscle (L1–L6), two 2-cm-thick steaks were vacuum packaged individually and kept at 4 °C. One was aged for 2 days and the other for 14 days, and then both were frozen at −20 °C for sensory analysis. Located next to the previous sample, a 6 cm section was cut, vacuum packed and aged for 7 days at 4 °C. Afterwards, three 2-cm-thick steaks were cut. One was directly vacuum packed and frozen at −20 °C. The other two were packed in a modified atmosphere consisting of polyethylene trays with an 80% O_2/20% CO_2 gas mixture (Praxair, Zaragoza, Spain) sealed with a polyethylene/polyamide laminate film (30 µm, water vapor transmission rate < 7 g m^{-2} day^{-1} at 23 °C and 85% relative humidity (RH), O_2 transmission rate < 15 cm^3 m^{-2} day^{-1} at 23 °C and 0% RH, CO_2 transmission rate < 75 cm^3 m^{-2} day^{-1} at 23 °C and 0% RH; Linpac Packaging SL, Linpac plastic pontivy S.A., Noyal-Pontivy, France). The trays were placed into a vertical retail display at 3 ± 1 °C and fluorescently lit with 1400 lx intensity for 12 h a day for a duration of either 4 or 8 days. After this display time, samples were vacuum packaged and frozen at −20 °C for sensory analysis.

Sensory evaluation

Beef samples were thawed for 24 h at 4 °C. Steaks were cooked on a double-hotplate grill (Sammic P8D2, Sammic S.L., Azcoitia Guipuzkoa, Spain) at 200 °C until their internal temperature reached 70 °C. Sample temperature was monitored with a ther- mocouple probe (Jenway 2000, Bibby Scientific Ltd., Essex, UK) inserted horizontally at the steak midpoint.

Each steak was cut into nine pieces of approximately 2 cm per side and then wrapped individually in aluminum foil and coded. Samples were kept warm in a heater at 60 °C until they were tasted by panelists. Evaluations were based on quantitative descriptors in a balanced incomplete block design. Panelists received samples in individual cabins under controlled environmental conditions and red light (ISO 8589:1988). The trained panel included nine persons who were previously checked for coherence for each attribute (ISO 8586–1:1993). They evaluated 11 attributes: beef, lactic and rancid odor intensities; tenderness; fibrousness; juiciness; beef, metallic, lactic and rancid flavor intensities; and overall appraisal. The attribute liver flavor intensity was included on the display time panel. Panelists assessed samples using a 10 cm unstructured line scale from 0 = no odor detected, tough, dry or low flavor to 10 = very intense odor, very tender, very juicy or very high flavor. To avoid the possible effects of the order of presentation and carryover effects, samples were randomly presented to the panelists in each session.

The three sensory panels performed were as follows.

Effect of aging time, concentrate type and fat cover

In the first sensory analysis, to assess the effect of two aging times of meat kept under vacuum conditions from bulls fed three diets and slaughtered at two levels of fat cover thickness, panelists performed ten sessions, receiving three plates with four samples in each session for a total 120 samples.

Effect of display time and concentrate type on meat of 3 mm fat cover In the second sensory analysis, to assess the effect of three display times of meat in MAP from bulls fed three diets and slaughtered at 3 mm fat cover, panelists performed six sessions, receiving three plates with four samples in each session for a total of 72 samples.

Effect of display time and concentrate type on meat of 4 mm fat cover The third sensory analysis was similar to those previously described but performed with meat from 4 mm fat cover animals.

Statistical analysis

A two-way analysis of variance was performed using the SAS v9.1 GLM procedure (SAS Institute Inc., Cary, NC, USA) to determine the effect of three concentrate compositions and two fat cover depths on meat analysis characteristics. The MIXED procedure was applied to calculate the least square means of the lipid oxidation during storage, with concentrate, fat cover depth and time as the fixed effects and animal as the random effect in the model. Significant

differences between treatments were assessed using Tukey's test, with significance being determined at $P < 0.05$.

The GLM procedure was used for sensory evaluations, including the mean per animal for each attribute. For the first sensory analysis (meat vacuum aged at different times), the 3 × 2 × 2 model included concentrate type, fat cover depth and time as the fixed effects and their interactions. For the second and third sensory analyses (meat packaged in MAP at different display times), the 3×3 model included concentrate type and time as the fixed effects and their interaction. The session effect was assessed, but it was not significant and therefore was not included in the final model. Differences between treatments were compared by treatment by applying the Tukey test.

Furthermore, with the results of the first sensory analysis and with the combination of the second and third sensory analyses, a generalized Procrustes analysis (GPA) was used to summarize the results graphically in biplots using the program XLStat 2009 (Addinsoft, Paris, France) in order to minimize differences among panelists.

RESULTS AND DISCUSSION

Effect of diet on meat quality

The fat cover at slaughter had more effect ($P < 0.05$) on the *longis- simus thoracis* proximal composition (except protein) than the composition of the diet ($P > 0.05$) (Table 1). The meat of carcasses with 4 mm subcutaneous fat thickness had higher intramuscular fat content and dry matter (14.0 and 251.3 g kg^{-1} respectively) than the meat from carcasses with 3 mm fat thickness (9.6 and 243.5 g kg^{-1} respectively). Although the animals were fed concen- trate, the loin muscle had a relatively low intramuscular fat content, which corresponds to a young entire bull of a late maturing breed. These low fat contents agree with Spanish consumer preferences for lean beef as an intrinsic quality cue related to health quality.[23]

Vitamin E-enriched concentrate produced meat with a signifi- cantly higher vitamin content ($P < 0.05$): 1.52 *vs* 0.81 mg kg^{-1} in the control group (Table 1). Moreover, the meat of bulls fed longer to reach thicker fat cover had significantly more vitamin con- tent (1.32 mg kg^{-1}) than the meat of bulls with less subcutaneous fat cover (0.97 mg kg^{-1}). The increase in vitamin E content could increase the lipid stability and therefore the shelf life and sensory quality of the beef. However, these vitamin E values were lower than those obtained in meat from grass-fed animals, which usually reach over 3 mg kg^{-1}.[24,25] The vitamin E level in meat would have likely increased if bulls had been slaughtered older and heavier.

Lipid oxidation of vacuum-packaged meat samples was more influenced by the fat cover and aging time than by the concentrate composition (Table 2). Improvement of the fat cover resulted in a significant increase in malondialdehyde (MDA) from 0.28 to 0.54 mg kg^{-1}. Additionally, the lipid oxidation increased from 0.36 to 0.46 mg MDA kg^{-1} when the aging time was extended from 2 to 14 days. However, the effect of including linseed or enrichment with vitamin E on the concentrate did not modify the levels of MDA, which were 0.4 mg kg^{-1} on average. These low oxidation rates were due to the beef being kept vacuum packed and refrigerated in a dark environment, which are the best conditions to control the lipid oxidation process.[26]

Sensory analysis of beef affected by aging time, concentrate type and fat cover

The results are summarized in Table 3. The composition of the concentrate fed to bulls did not influence any of the sensory attributes, but the fat cover at slaughter and the aging time did significantly modify some attributes.

The beef aged 14 days was rated as more tender and less fibrous ($P < 0.0001$), with greater beef intensity and rancid flavor than the meat aged 2 days. However, the overall appraisal was not related to these other sensory attributes. Monsón *et al.*[27] found that aging had a very important effect on tenderness, odor and flavor char- acteristics, but overall appraisal was not always consistent with these traits, depending on the breed effect. The juiciness remained unchanged as reported by Jeremiah and Gibson.[28] The improve- ment of tenderness by aging was not substantial enough to modify the overall appraisal.

The greatest intensity of odor and flavor of these meats was attributed to beef, followed by metallic, acid and lactic odors and flavors, with rancid having the lowest notes. It is known that unsaturated fatty acid content in beef makes it more prone to oxididation,[29] giving off-flavors. However, neither rancid odor nor flavor increased in the meat from animals fed diets containing linseed or with vitamin E supplementation, most likely because vacuum conditions did not favor oxidation.

The composition of the concentrate did not affect the sensory attribute values as judged by the panel. Tenderness, juiciness and flavor are the most important attributes in the variation between meat sensory assessments.[30] The absence of significant differences in these attributes corresponded with a similar overall appraisal note. These results are in agreement with those reported by Maddock *et al.*,[11] who found no effects on the intensity of flavor or tenderness from 14 day vacuum-aged beef of yearling heifers that had consumed 80 g kg^{-1} linseed in their diet, although steaks from the control group were rated juicier than those that included linseed.

Supplementation with vitamin E in the feed did not increase the note of positive odors or flavors, nor did it decrease off-flavors. Therefore it seems that if polyunsaturated fatty acid percentage is not increased,[19] there is no need for vitamin E supplemen- tation, because it increases costs without obtaining a positive effect on beef sensory traits, at least in vacuum-packaged meat. Juárez *et al.*[31] also found no effect among treatments for sensory attributes in steaks of steers fed diets with or without 100 g kg^{-1} flaxseed and 600 IU day^{-1} of vitamin E supplementation.

The subcutaneous fat thickness of the carcass had a significant effect on sensory meat attributes, especially tenderness, fibrous- ness, juiciness, rancid odor and beef flavor. Bulls slaughtered at 4 mm fat cover had meat rated as more tender and juicy, less fibrous and with slightly higher rancid odor and beef flavor inten- sities than the meat of bulls slaughtered at 3 mm. Fiems *et al.*[32] also found a moderate correlation between fat and tenderness. In some experiments, lipid content has not been necessarily related to differences in flavor,[33] but in other cases the increase in intra- muscular fat improved meat flavor[34] in cows. Despite the signifi- cant differences found in some of the main sensory attributes, the overall appraisal did not significantly differ between the two levels of fattening. It could be that the positive differences in tenderness, juiciness and beef flavor or the negative differences in rancid odor were not large enough to promote changes in overall appraisal. The results of Hunt *et al.*,[35] however, state that when tenderness is acceptable, flavor and juiciness play a major role in determin- ing overall acceptability. Globally, fat cover effects on meat sensory attributes were less important than aging.

The analysis of the results of the sensory assessment by panelists obtained with GPA is shown in Fig. 1. The first two main axes explained 66.4% of the total variance. The first axis accounted for

Table 1. Meat composition (fresh matter) of *longissimus thoracis* muscle from young Pirenaica bulls fed three concentrate diets and slaughtered at two dorsal fat cover depths

	Concentrate (CN)			Fat cover (F)		Pooled	*P* value		
Parameter	C	L	L + E	3 mm	4 mm	SE	CN	F	CN × F
Dry matter (g kg^{-1})	244.6	250.4	246.8	243.5*b*	251.3*a*	0.31	0.180	0.004	0.327
Protein (g kg^{-1})	222.7	223.1	219.5	219.5	223.9	0.37	0.559	0.175	0.355
Intramuscular fat (g kg^{-1})	8.6	13.0	13.4	9.6*b*	14.0*a*	0.25	0.118	0.020	0.646
Vitamin E (mg kg^{-1})	0.81*b*	1.06*ab*	1.52*a*	0.97*b*	1.32*a*	0.207	0.005	0.050	0.787

Values with different letters in the same row are significantly different at $P < 0.05$. C, control concentrate group; L, linseed-supplemented concentrate group; L + E, (linseed + 20 g kg^{-1} vitamin E)-supplemented concentrate group.

Table 2. Effect of diet, fat cover and aging on oxidation (TBARS index) of vacuum-packaged meat from young Pirenaica bulls

	Concentrate (CN)			Fat cover (F)		Aging (A)			*P* value						
Parameter	C	L	L + E	3 mm	4 mm	2 days	14 days	Pooled SE	CN	F	A	CN × F	CN × A	F × A	CN × F × A
TBARS[a]	0.40	0.43	0.40	0.28b	0.54a	0.36b	0.46a	0.05	0.943	0.001	0.042	0.407	0.341	0.056	0.774

Means with different letters are significantly different ($P < 0.05$). C, control concentrate group; L, linseed-supplemented concentrate group; L + E, (linseed + 20 g kg^{-1} vitamin E)-supplemented concentrate group.
[a] Thiobarbituric acid-reactive substances in mg malondialdehyde kg^{-1}.

51.1% of the variation, and the main attributes were related to tenderness (−0.99), fibrousness (0.97), beef flavor intensity (−0.83), overall appraisal (−0.82) and acid (−0.63) and rancid (−0.60) flavor intensities. The second axis accounted for 13.3% of the variation, and the main attributes were beef odor intensity (−0.59) and juiciness (0.53). On the right side, outlined by fibrousness, the six lots of meat aged for 2 days and the lot supplemented with linseed and vitamin E aged for 14 days are grouped. Located on the opposite side are the rest of the lots of 14 day aged meat, characterized by the rest of the attributes except juiciness and metallic flavor, which are placed between the two ellipses. Beef aged 14 days remains close in tenderness, beef flavor intensity and overall appraisal attributes and far in fibrousness. Most of the animals slaughtered with 4 mm fat cover are placed on the top and on the left of the figure; therefore they were assessed as more juicy, tender, with more beef flavor intensity and with higher overall appraisal. Animals fed control concentrate were placed in the negative zone of the second axis, linked to a higher beef odor intensity and less juicy attributes. The beef aged 14 days from bulls fed linseed and vitamin E slaughtered with 3 mm fat cover was located in the same area as the 2 day aged meat, probably owing to its low intramuscular fat content (9.9 g kg^{-1}) in comparison with the same diet of animals fed to 4 mm fat cover (16.9 g kg^{-1}). The effects of aging were more important on meat sensory attributes than the fat cover of the bulls.

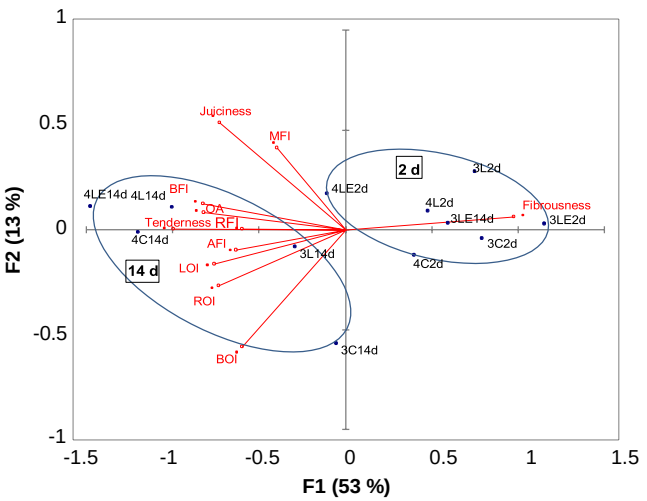

Figure 1. Plot of panel sensory attributes of vacuum-packed meat aged for 2 or 14 days of bulls fed three concentrates and slaughtered at two levels of fatness. AFI, acid flavor intensity; BFI, beef flavor intensity: BOI, beef odor intensity; LOI, lactic odor intensity; LiFI, liver flavor intensity; MFI, metallic flavor intensity; OA, overall appraisal; RFI, rancid flavor intensity; ROI, rancid odor intensity. C, control; L, linseed; LE, linseed + vitamin E; 2d, 2 days aging; 14d, 14 days aging; 3, 3 mm fat cover; 4; 4 mm fat cover.

Effect of display time and diet on sensory quality of MAP packaged beef

The results for 3 and 4 mm fat cover are summarized in Tables 4 and 5 respectively. Linseed inclusion in concentrate produced meat that was rated slightly more juicy by panelists but similar for all other attributes, including overall appraisal. In MAP rich in oxy- gen, some differences in odor or flavor are expected between the meats owing to the feeding diet. In our study, linseed inclusion in concentrate did not alter the total saturated, monounsaturated or polyunsaturated fatty acid percentages.[19] However, the relative proportion of some polyunsaturated fatty acids was modified, significantly increasing the *n*-3 fatty acids. Therefore, as the percent- age of polyunsaturated fatty acids did not increase, there was no substrate for higher lipid oxidation.

Extending the display time to 4 or 8 days for meat packaged in MAP yielded significant differences among attributes, reducing beef odor and flavor intensity and increasing rancid odor and fla- vor intensity as well as acid flavor intensity. Although tenderness, juiciness and fibrousness were rated similarly, the overall appraisal decreased significantly with longer display times owing to the neg- ative effect of the increase in rancidity.

Table 3. Means of sensory evaluation by trained panel of vacuum-packaged beef of young Pirenaica bulls

	Concentrate (CN)			Fat cover (F)		Aging (A)			*P* value						
Attribute	C	L	L + E	3 mm	4 mm	2 days	14 days	SEM	CN	F	A	CN × F	CN × A	F × A	CN × F × A
Beef odor intensity	4.80	4.76	4.70	4.73	4.77	4.70	4.81	0.137	0.474	0.448	0.087	0.402	0.232	0.479	0.871
Lactic odor intensity	1.57	1.48	1.42	1.45	1.53	1.44	1.55	0.151	0.251	0.283	0.135	0.302	0.203	0.520	0.935
Rancid odor intensity	1.09	1.03	1.07	1.00*b*	1.15*a*	1.02	1.11	0.107	0.620	0.001	0.078	0.748	0.229	0.842	0.997
Tenderness	4.60	4.67	4.59	4.31*b*	4.93*a*	4.22*b*	5.01*a*	0.299	0.889	< 0.0001	< 0.0001	0.078	0.768	0.108	0.956
Fibrousness	5.87	5.81	5.78	5.95*a*	5.69*b*	6.06*a*	5.59*b*	0.214	0.736	0.014	< 0.0001	0.419	0.735	0.649	0.751
Juiciness	4.03	4.12	4.15	4.00*b*	4.21*a*	4.07	4.13	0.186	0.525	0.013	0.499	0.405	0.964	0.152	0.566
Beef flavor intensity	5.40	5.36	5.41	5.31*b*	5.46*a*	5.29*b*	5.48*a*	0.129	0.834	0.016	0.003	0.032	0.688	0.653	0.462
Metallic flavor intensity	3.14	3.14	3.27	3.17	3.20	3.16	3.21	0.148	0.219	0.716	0.418	0.326	0.660	0.296	0.215
Acid flavor intensity	2.90	2.87	2.90	2.82	2.95	2.82	2.96	0.158	0.961	0.092	0.072	0.973	0.405	0.346	0.113
Rancid flavor intensity	1.22	1.27	1.33	1.23	1.31	1.20*b*	1.35*a*	0.117	0.278	0.177	0.011	0.761	0.049	0.855	0.581
Overall appraisal	4.23	4.18	4.14	4.11	4.27	4.11	4.26	0.188	0.730	0.082	0.108	0.050	0.506	0.426	0.742

Means with different letters in the same row are significantly different ($P < 0.05$). C, control concentrate group; L, linseed-supplemented concentrate group; L + E, (linseed + 20 g kg^{-1} vitamin E)-supplemented concentrate group.

Table 4. Means of sensory evaluation by trained panel of beef at different display times in MAP of young Pirenaica bulls slaughtered at 3 mm subcutaneous fat cover

	Concentrate (CN)			Display time (T)				*P* value		
Attribute	C	L	L + E	0 days	4 days	8 days	SEM	CN	T	CN × T
Beef odor intensity	4.02	4.07	4.02	4.67*a*	3.95*b*	3.50*c*	0.201	0.882	< 0.0001	0.099
Lactic odor intensity	1.08	1.32	1.19	1.25	1.17	1.17	0.133	0.077	0.062	0.616
Rancid odor intensity	1.43	1.58	1.40	1.09*b*	1.54*a*	1.78*a*	0.156	0.242	< 0.0001	0.300
Tenderness	4.33	4.42	4.28	4.36	4.37	4.30	0.268	0.841	0.981	0.566
Fibrousness	5.81	5.71	5.85	5.83	5.71	5.84	0.228	0.800	0.872	0.624
Juiciness	3.52*b*	3.75*ab*	3.90*a*	3.87	3.77	3.53	0.181	0.043	0.053	0.616
Beef flavor intensity	4.11	4.18	4.27	4.74*a*	4.10*b*	3.71*c*	0.187	0.466	< 0.0001	0.240
Liver flavor intensity	1.57	1.65	1.59	1.50	1.62	1.69	0.101	0.689	0.062	0.411
Metallic flavor intensity	2.83	2.80	2.79	2.77	2.80	2.85	0.097	0.964	0.698	0.477
Acid flavor intensity	2.70	2.63	2.68	2.52*b*	2.59*b*	2.91*a*	0.154	0.845	0.006	0.519
Rancid flavor intensity	2.18	2.27	2.04	1.15*c*	2.18*b*	3.17*a*	0.180	0.174	< 0.0001	0.272
Overall appraisal	3.82	3.80	3.80	4.35*a*	3.85*b*	3.22*c*	0.187	0.984	< 0.0001	0.548

Means with different letters in the same row are significantly different ($P < 0.05$). C, control concentrate group; L, linseed-supplemented concentrate group; L + E, (linseed + 20 g kg^{-1} vitamin E)-supplemented concentrate group.

The vitamin E and linseed supplements improved the juiciness in relation to the control group. No significant differences were found between the other sensory attributes, including overall appraisal. The indication of no significant effect of linseed or vitamin E on the beef sensory characteristics in our study agrees with the results of one study,[31] but other studies, including a diet containing 100 g kg^{-1} ground flaxseed, have described detrimental effects due to more pronounced off-flavors, even if flavor intensity did not differ.[36]

The results obtained with GPA in meat packaged in MAP and dis- played for 8 days from bulls slaughtered at 3 and 4 mm fat depth are presented in Fig. 2. The first axis accounted for 57.1% of the variation, and the main attributes were related to rancid flavor intensity (−0.99), overall appraisal (0.97), beef odor (0.93) and fla- vor (0.91) intensities, rancid odor intensity (−0.84) and acid (−0.77) and liver (−0.63) flavor intensities. The second axis accounted for 16.5% of the variation, and the main attribute was metallic flavor intensity (0.66). The tenderness and fibrousness vectors appeared next, which indicates that 7 days of aging was enough to reach adequate tenderness, and no additional improvement in tex- ture was achieved during display time. Therefore tenderness and fibrousness attributes explained a residual part of the variability of the sensory evaluation. This confirms the lack of statistical signifi- cance of tenderness on the previous statistical analysis.

In Fig. 2, from the right side to the left side, the meat is grouped by time on display. The highest increase in overall appraisal, beef odor and flavor intensities corresponds to meat that was not on display. In the opposite zone are the six lots of meat displayed for 8 days, which were characterized by high rancid flavor and odor intensity. On the top part of the graph, the meat of bulls with 3 mm depth fat cover is linked to metallic flavor intensity, while at the bottom there is the meat of animals with 4 mm fat cover, which was characterized by acid and liver flavor intensities. It should be noted that the two distribution areas for the 3 and 4 mm fat cover animals may correspond also to the two sensory assessments performed, because both are confounding factors for the GPA.

The most valued meat was that of bulls slaughtered at 3 or 4 mm fat cover, previously aged for 7 days in vacuum and then

Table 5. Means of sensory evaluation by trained panel of beef at different display times in MAP of young Pirenaica bulls slaughtered at 4 mm subcutaneous fat cover

	Concentrate (CN)			Display time (T)				*P* value		
Attribute	C	L	L + E	0 days	4 days	8 days	SEM	CN	T	CN × T
Beef odor intensity	4.16	4.38	4.44	4.63*a*	4.38*b*	3.87*c*	0.189	0.237	< 0.0001	0.379
Lactic odor intensity	1.27	1.30	1.48	1.49	1.37	1.20	0.183	0.617	0.173	0.669
Rancid odor intensity	1.69	1.44	1.50	1.31*b*	1.58*ab*	1.71*a*	0.171	0.139	0.012	0.996
Tenderness	4.21	4.19	4.34	4.15	4.29	4.30	0.333	0.870	0.905	0.663
Fibrousness	5.68	5.68	5.59	5.72	5.66	5.57	0.255	0.732	0.914	0.630
Juiciness	3.55	3.60	3.84	3.82	3.63	3.57	0.246	0.439	0.307	0.222
Beef flavor intensity	4.93	5.0	5.11	5.31*a*	5.05*a*	4.68*b*	0.234	0.246	< 0.0001	0.367
Liver flavor intensity	1.64	1.72	1.74	1.69	1.72	1.69	0.145	0.635	0.786	0.674
Metallic flavor intensity	2.66*a*	2.35*b*	2.51*ab*	2.54	2.43	2.55	0.136	0.029	0.538	0.729
Acid flavor intensity	2.93	2.73	2.91	2.71*b*	2.72*b*	3.13*a*	0.158	0.131	0.008	0.113
Rancid flavor intensity	2.59	2.25	2.41	1.16*c*	2.38*b*	3.64*a*	0.256	0.345	< 0.0001	0.471
Overall appraisal	3.56	3.60	3.75	4.26*a*	3.75*b*	2.95*c*	0.228	0.458	< 0.0001	0.509

Means with different letters in the same row are significantly different ($P < 0.05$). C, control concentrate group; L, linseed-supplemented concentrate group; L + E, (linseed + 20 g kg^{-1} vitamin E)-supplemented concentrate group.

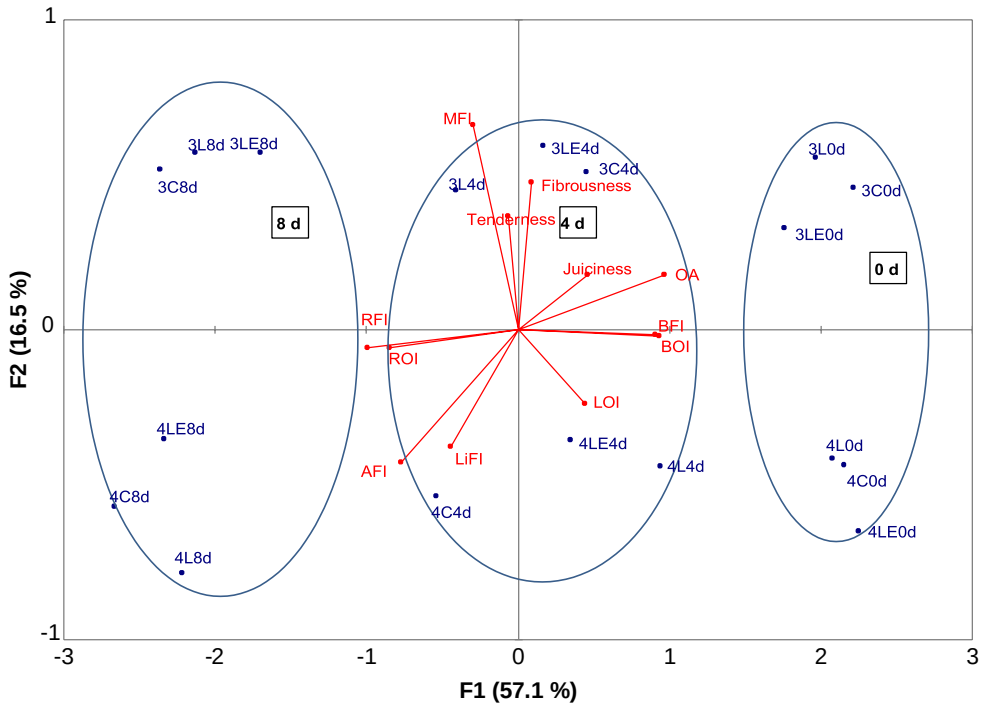

Figure 2. Plot of panel sensory attributes of beef aged 7 days, MAP packed and displayed for 0, 4 or 8 days of bulls fed three concentrates and slaughtered at two levels of fatness. 0d, no display; 4d, 4 days display; 8d, 8 days display. See Fig. 1 for explanation of other abbreviations used.

packed in MAP at the initial time of display. In contrast to the MAP, the anaerobic environment of the vacuum-packed meat limited the rancidity.[8] Thus rancid flavor increased slightly and rancid odor did not change significantly. When samples did not differ in tenderness, the larger sensory difference between lots was flavor, odor or juiciness,[35,37] which all play a major role in determining the overall acceptability. Nevertheless, consumers usually do not detect oxidation flavors until oxidation products have reached a level of at least 2 mg MDA kg^{-1} tissue.[38–40]

The results of this study suggest that the effect of linseed or vitamin E enrichment of feed for young bulls was less important on the meat sensory assessment than the effect of the fat cover of the carcasses and was much less important than aging time or packaging procedures. The vacuum-packaged meat of bulls slaughtered at 4 mm fat cover was rated higher on sensory analysis than that at 3 mm fat cover. The meat of young Pirenaica bulls mightbe aged in vacuum for less than 7 days and then sold directly to retail customers for cutting and display in MAP for a short time in order to ensure tenderness and few negative flavors.

CONCLUSIONS

The inclusion of 50 g kg^{-1} linseed or supplementation with 200 IU vitamin E kg^{-1} in the concentrate fed to bulls had no

significant effect on the main beef sensory attribute scores. Aging time in a vacuum package and display time of aged beef had significant effects on sensory rating. Fat cover of the carcass improved the sensory ratings of tenderness and juiciness, espe- cially in vacuum-packaged meat. Meat aged for 14 days in vacuum was rated less fibrous and tenderer, with more beef flavor intensity but also a more intense rancid flavor, than meat aged for only 2 days. In vacuum-aged beef later packaged in MAP, an increase in display time significantly increased the intensity of negative notes such as rancid odor and flavor and decreased positive notes such as beef odor, lowering the overall appraisal.

ACKNOWLEDGEMENT

This research was supported by INIA of Spain, project RTA 2005 – 00183.

REFERENCES

1 Robbins K, Jensen J, Ryan KJ, Homco-Ryan C, McKeith FK and Brewer MS, Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Sci* **65**:721–729 (2003).
2 EFSA, Scientific report of EFSA. Outcome of the public consultation on the Draft Opinion of the Scientific Panel on Dietetic Products, Nutri- tion, and Allergies (NDA) on Dietary Reference Values for fats, includ- ing saturated fatty acids, polyunsaturated fatty acids, monounsatu- rated fatty acids, *trans* fatty acids, and cholesterol. *EFSA J* **8**(5):1507 (2010).
3 McNeill SH, Harris KB, Field TG and Van Elswyk ME, The evolution of lean beef: identifying lean beef in today's U.S. marketplace. *Meat Sci* **90**:1–8 (2012).
4 Van Wezemael L, Caputo V, Nayga Jr RM, Chryssochoidis G and Verbeke W, European consumer preferences for beef with nutrition and health claims: a multi-country investigation using discrete choice experiments. *Food Pol* **44**:167–176 (2014).
5 Verbeke W, Van Wezemael L, de Barcellos MD, Kügler JO, Hocquette J-F, Ueland Ø, *et al.*, European beef consumers' interest in a beef eating-quality guarantee: insights from a qualitative study in four EU countries. *Appetite* **54**:289–296 (2010).
6 Jakobsen M and Bertelsen G, Colour stability and lipid oxidation of fresh beef. Development of a response surface model for predicting the effects of temperature, storage time, and modified atmosphere composition. *Meat Sci* **54**:49–57 (2000).
7 Seyfert M, Hunt MC, Mancini RA, Hachmeister KA, Kropf DH, Unruh JA, *et al.*, Beef quadriceps hot boning and modified-atmosphere packaging influence properties of injection-enhanced beef round muscles. *J Anim Sci* **83**:686–693 (2005).
8 Lagerstedt Å, Lundström K and Lindahl G, Influence of vacuum or high-oxygen modified atmosphere packaging on quality of beef *M. longissimus dorsi* steaks after different ageing times. *Meat Sci* **87**:101 – 106 (2011).
9 Wood JD, Richardson RI, Nute GR, Fisher AV, Campo MM, Kasapidou E, *et al.*, Effects of fatty acids on meat quality: a review. *Meat Sci* **66**:21–32 (2003).
10 Vatansever L, Kurt E, Enser M, Nute GR, Scollan ND, Wood JD, *et al.*, Shelf life and eating quality of beef from cattle of different breeds given diets differing in *n*-3 polyunsaturated fatty acid composition. *Anim Sci* **71**:471–482 (2000).
11 Maddock TD, Bauer ML, Koch KB, Anderson VL, Maddock RJ, Barcelo-Coblijn G, *et al.*, Effect of processing flax in beef feedlot diets on performance, carcass characteristics, and trained sensory panel ratings. *J Anim Sci* **84**:1544–1551 (2006).
12 Duckett SK, Wagner DG, Yates LD, Dolezal HG and May SG, Effects of time on feed on beef nutrient composition. *J Anim Sci* **71**:2079–2088 (1993).
13 Corazzin M, Bovolenta S, Sepulcri A and Piasentier E, Effect of whole lin- seed addition on meat production and quality of Italian Simmental and Holstein young bulls. *Meat Sci* **90**:99–105 (2012).
14 Juárez M, Dugan MER, Aalhus JL, Aldai N, Basarab JA, Baron VS, *et al.*, Effects of vitamin E and flaxseed on rumen-derived fatty acid intermediates in beef intramuscular fat. *Meat Sci* **88**:434–440 (2011).
15 Mach N, Devant M, Diaz I, Font-Furnols M, Oliver MA, Garcia JA, *et al.*, Increasing the amount of *n*-3 fatty acid in meat from young Holstein bulls through nutrition. *J Anim Sci* **84**:3039–3048 (2006).
16 Raes K, Haak L, Balcaen A, Claeys E, Demeyer D and De Smet S, Effect of linseed feeding at similar linoleic acid levels on the fatty acid composition of double-muscled Belgian Blue young bulls. *Meat Sci* **66**:307–315 (2004).
17 Scollan N, Hocquette JF, Nuernberg K, Dannenberger D, Richard- son I and Moloney A, Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. *Meat Sci* **74**:17 – 33 (2006).
18 Wood JD and Enser DM, Factors influencing fatty acids in meat and the role of antioxidants in improving meat quality. *Br J Nutr* **78**:S49–S60 (1997).
19 Albertí P, Beriain MJ, Ripoll G, Sarriés V, Panea B, Mendizabal JA, *et al.*, Effect of including linseed in a concentrate fed to young bulls on intramuscular fatty acids and beef color. *Meat Sci* **96**:1258–1265 (2014).
20 AOAC, *Official Methods of Analysis* (17th rev. edn). Association of Official Analytical Chemists, Washington, DC (2000).
21 Liu Q, Scheller KK and Schaefer DM, A simplified procedure for vita- min E determination in beef muscle. *J Anim Sci* **74**:2406–2410 (1996).
22 Ripoll G, Joy M and Muñoz F, Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat. *Meat Sci* **87**:88–93 (2011).
23 Realini CE, Kallas Z, Pérez-Juan M, Gómez I, Olleta JL, Beriain MJ, *et al.*, Relative importance of cues underlying Spanish consumers' beef choice and segmentation, and consumer liking of beef enriched with *n*-3 and CLA fatty acids. *Food Qual Prefer* **33**:74–85 (2014).
24 Realini CE, Duckett SK, Brito GW, Dalla Rizza M and De Mattos D, Effect of pasture vs. concentrate feeding with or without antioxidants on carcass characteristics, fatty acid composition, and quality of Uruguayan beef. *Meat Sci* **66**:567–577 (2004).
25 Yang A, Lanari MC, Brewster M and Tume RK, Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. *Meat Sci* **60**:41–50 (2002).
26 Franco D, González L, Bispo E, Latorre A, Moreno T, Sineiro J, *et al.*, Effects of calf diet, antioxidants, packaging type and storage time on beef steak storage. *Meat Sci* **90**:871–880 (2012).
27 Monsón F, Sañudo C and Sierra I, Influence of breed and ageing time on the sensory meat quality and consumer acceptability in intensively reared beef. *Meat Sci* **71**:471–479 (2005).
28 Jeremiah LE and Gibson LL, The effects of postmortem product han- dling and aging time on beef palatability. *Food Res Int* **36**:929–941 (2003).
29 Warren HE, Scollan ND, Nute GR, Hughes SI, Wood JD and Richardson RI, Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. *II: Meat stability and flavour. Meat Sci* **78**:270–278 (2008).
30 Rødbotten M, Kubberød E, Lea P and Ueland Ø, A sensory map of the meat universe. Sensory profile of meat from 15 species. *Meat Sci* **68**:137–144 (2004).
31 Juárez M, Dugan MER, Aldai N, Basarab JA, Baron VS, McAllister TA, *et al.*, Beef quality attributes as affected by increasing the intramuscular levels of vitamin E and omega-3 fatty acids. *Meat Sci* **90**:764–769 (2012).
32 Fiems LO, De Campeneere S, Van de Voorde G, Vanacker JM and Boucque CV, Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. *Meat Sci* **56**:41–47 (2000).
33 Melton SL, Effects of feeds on flavor of red meat: a review. *J Anim Sci* **68**:4421 – 4435 (1990).
34 Vestergaard M, Madsen NT, Bligaard HB, Bredahl L, Rasmussen PT and Andersen HR, Consequences of two or four months of fin- ishing feeding of culled dry dairy cows on carcass characteristics and technological and sensory meat quality. *Meat Sci* **76**:635–643 (2007).
35 Hunt MR, Garmyn AJ, O'Quinn TG, Corbin CH, Legako JF, Rathmann RJ, *et al.*, Consumer assessment of beef palatability from four beef muscles from USDA Choice and Select graded carcasses. *Meat Sci* **98**:1–8 (2014).
36 LaBrune HJ, Reinhardt CD, Dikeman ME and Drouillard JS, Effects of grain processing and dietary lipid source on performance, carcass

characteristics, plasma fatty acids, and sensory properties of steaks from finishing cattle. *J Anim Sci* **86**:167–172 (2008).

37 Sitz BM, Calkins CR, Feuz DM, Umberger WJ and Eskridge KM, Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. *J Anim Sci* **83**:2863–2868 (2005).

38 Campo MM, Nute GR, Hughes SI, Enser M, Wood JD and Richardson RI, Flavour perception of oxidation in beef. *Meat Sci* **72**:303–311 (2006).

39 Greene BE and Cumuze TH, Relationship between TBA numbers and inexperienced panelists' assessments of oxidized flavor in cooked beef. *J Food Sci* **47**:52–54 (1982).

40 Zakrys PI, Hogan SA, O'Sullivan MG, Allen P and Kerry JP, Effects of oxygen concentration on the sensory evaluation and quality indicators of beef muscle packed under modified atmosphere. *Meat Sci* **79**:648–655 (2008).