Intramuscular fatty acid profile of feedlot lambs fed concentrates with alternative ingredients

Pilar Gómez-Cortés^A, Olalla O. Galisteo^A, Carmen Avilés Ramírez^B, Francisco Peña Blanco^B, Miguel Angel de la Fuente^A, Nieves Núñez Sánchez^B, Andrés L. Martínez Marín^{B,C}

^A Instituto de Investigación en Ciencias de la Alimentación (CSIC-UAM), Nicolás Cabrera, 9. Universidad Autónoma de Madrid, 28049 Madrid, Spain

^B Departamento de Producción Animal, Universidad de Córdoba, Ctra. Madrid-Cádiz km 396, 14071 Córdoba, Spain

^C To whom correspondence should be addressed. Phone/fax: + 34 957 218746. E-mail: palmartm@uco.es

Short Title: Concentrates and meat fatty acid profile of lambs

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Fatty acid (FA) profile plays an important role in meat quality, as it is related to differences in organoleptic attributes, and meat nutritional value. The aim of this study was to evaluate the effect of feeding concentrates that included alternative ingredients on the intramuscular FA profile of feedlot lambs. The concentrate rich in fibrous by-products might improve the FA profile of meat fat from a nutritional point of view.

Abstract. The effect of concentrates based on unconventional ingredients on the intramuscular fatty acid (FA) profile of lambs was evaluated. A total of 105 lambs were assigned to one of three treatments: Control (concentrate based on cereals and soybean meal as commercial concentrates), Camelina (CAM, where 50% of crude protein from soybean meal was replaced by camelina meal), and Fibrous (FIB, concentrate based on several fibrous by-products, camelina meal and other unconventional ingredients). After 42 days in feedlot, the lambs were sacrificed, and the FA profile of intramuscular fat was determined by gas chromatography. Total meat lipids (1.25 g/100 g of meat) were not modified by the treatments. The CAM treatment showed minor effects on the intramuscular fat composition. In contrast, the FIB treatment showed the highest contents of *trans*-11 18:1 (vaccenic acid), *cis*-9 *trans*-11 18:2 (rumenic acid) and α -linolenic acid. Thus, the non-traditional concentrate assayed in the present study might improve the meat quality of light lambs from a nutritional point of view.

Key words: lambs; feedlot ration; meat composition; fatty acids

Introduction

The fatty acid (FA) profile plays an important role in meat quality, as it is related to differences in organoleptic attributes and to the nutritional value of meat for human consumption. Ruminant fat is not considered particularly healthy, mostly due to its high levels of saturated FA (SFA), low content of omega-3 polyunsaturated FA (PUFA) and the variable presence of *trans*-FA. However, ruminants' meat is also a natural source of *cis*-9, *trans*-11 18:2 (rumenic acid, RA), a conjugated linoleic acid (CLA) isomer with well established anticarcinogenic potential that could also reduce the incidence of atherosclerosis (Lock *et al.*, 2009). Extensive research has been carried out to alter the FA profile in ruminant products and feeding regime has showed an essential role in this regard (Shingfield *et al.* 2013; Bessa *et al.*, 2015).

In Mediterranean countries, sheep meat production is mostly derived from light animals, which are less than three months old and up to 30 kg of body weight, reared under intensive conditions and fed with rations based on cereals and soybean to achieve high growth rates (Sañudo *et al.*, 1998). During the last few years, increases in feeding costs have drawn the attention to fibrous by-products (Tufarelli *et al.*, 2011; Blanco *et al.*, 2014) and alternative protein sources (Lanza *et al.*, 2011; Scerra *et al.*, 2011) as potential ingredients of lamb rations. Moreover, it would be advisable to use feedstuffs that do not compete with swine and poultry feeds and take advantage of the ruminant capacity to digest fiber (McNeill, 2013). However, to our knowledge, information regarding the replacement of cereals with a combination of fibrous by-products on lamb meat quality is still scant.

Some studies have reported the effects of replacing soybean meal with legume seeds on the intramuscular FA profile of lambs (Lanza *et al.*, 2011; Scerra *et al.*, 2011). The effects of replacing conventional protein sources by camelina cake or camelina seeds on the intramuscular FA profile of lambs were reported by Noci *et al.* (2011) and Cieslak *et al.* (2013), but no studies have dealt with the effects of solvent-extracted camelina meal. Solvent-extracted camelina meal has a lower fat content than camelina cake (3.0 vs. 13.6%).

In the current research, light fattening lambs were fed a traditional concentrate where soybean meal was partially replaced by camelina meal, and an alternative concentrate where cereals and soybean meal were fully replaced by a combination of several non-traditional feeds, most of them fibrous by-products. Our objective was to investigate the influence of the concentrate type on the intramuscular FA composition.

Material and methods

A detailed description of study materials and procedures can be found in a previous paper (Avilés *et al.* 2018). Briefly, a total of 105 uncastrated male lambs from Manchega breed with 13.9 ± 1.74 kg of initial body weight (BW) and 35 ± 7 d old were randomly allocated to 15 straw-bedded pens. Pens were randomly allocated to one of three treatments (five replicates per treatment), which differed on the concentrate supplied: Control (CON, concentrate based on cereals and soybean meal as commercial concentrates), Camelina (CAM, where 50% of crude protein from soybean meal was replaced by camelina meal), and Fibrous (FIB, concentrate based on several fibrous by-products, camelina meal and other unconventional ingredients) (Table 1). Barley straw was offered as roughage in all the treatments. On day 42 of the trial, two lambs per pen

(i.e. ten lambs from each experimental treatment) with the final BW closest to the average pen BW were tagged to track their carcasses. Then, all animals were sent to a commercial abattoir for their sacrifice. A sample from *Longissimus thoracis* muscle was obtained for intramuscular FA analysis after 6 d of ageing at 4 °C.

[Insert Table 1 near here]

Intramuscular fat (IMF) was extracted using the Bligh and Dyer method (1959) and expressed as meat percentage. FA were derivatized to methyl esters (FAME) by base-catalyzed methanolysis (ISO, 2002) and analyzed by gas chromatography (GC) using an Agilent model 6890 N Network System (Palo Alto, CA, USA) equipped with an autoinjector, a flame ionization detector (FID), and fitted with a CP-Sil 88 fused silica capillary column (100 m x 0.25 mm i.d., Varian, Middelburg, The Netherlands). Injector and detector temperature was 250 °C. Helium was the carrier gas and samples were injected with a split ratio of 1:100. Initial oven temperature was 45 °C. After 4 min, it was raised at 13 °C min⁻¹ to 165 °C and held for 35 min. Then, oven temperature was increased to 215 °C at 4 °C/min and maintained for 30 min. A complementary GC analysis of all meat samples was carried out to determine minor FA not well resolved with the CPSil-88 capillary column. Another Agilent gas chromatograph, model 7820A GC System, equipped with auto-injector and FID, was fitted with a SLB-IL111 capillary column (100 m x 0.25 mm i.d., Supelco). Injector and detector temperature was 250 °C. Helium was the carrier gas and samples were injected with a split ratio of 1:100. Initial oven temperature was isothermal at 168 °C for 45 min. Then, it was raised at 5 °C/min to 210 °C, and held for 35 min. Identification and quantification of FAME was accomplished as described by De la Fuente *et al.* (2015).

Concentrate composition was determined according to AOAC (2000) and Van Soest *et al.* (1991) procedures, whereas its FA profile was examined following Sukhija and Palmquist (1988) method.

Data were analyzed with the MIXED procedure of SAS 3.5 University Edition (SAS Institute Inc., Cary, NC). In the statistical model, the treatment (CON, CAM, FIB) was the fixed effect and the pen nested within treatment was the random effect. Pen was the experimental unit (two lambs per pen). Significant differences were declared at $P < 0.05$. When the model was significant, differences between least squares means were assessed using the Tukey's test.

Results and discussion

Final BW (25.8 ± 1.12 kg) and average daily gain (290 ± 23.8 g/d) did not differ between treatments ($P > 0.05$). However, feed conversion ratio was 23% higher in the FIB treatment ($P < 0.05$), because of the higher daily intake. The FIB concentrate was the cheapest per kg of product. However, as a result of the poorer feed conversion, the FIB treatment was not the cheapest per kg of BW gain (0.590, 0.611 and 0.640 €/kg BW gain in the CAM, FIB and CON treatments, respectively) (Avilés *et al.*, 2018).

The type of concentrate did not modify ($P > 0.05$) the IMF content (Table 2). Average IMF level was $1.25 \pm 0.22\%$, which is within the common range of Spanish light lambs (Tejeda *et al.*, 2008; Panea *et al.*, 2011), but lower than the values reported in other countries where lambs are sacrificed at older ages and heavier weights (Díaz *et al.*, 2005).

The CON concentrate included ingredients commonly used in the rations of feedlot light lambs (Santos-Silva *et al.*, 2002; Bodas *et al.* 2007; Blanco *et al.*, 2014). The CAM concentrate only differed from the CON concentrate in the presence of camelina meal, while the FIB concentrate was very different in terms of ingredients and nutritive profile. The FIB concentrate contained a much higher NDF content and a more unsaturated FA profile (Table 1). Accordingly, any intramuscular FA profile differences between the CON and CAM treatments should be related to the camelina meal included in the latter. On the other hand, if observed, differences between the FIB and CON treatments should be attributed not only to the presence of camelina by-products and other unusual ingredients in the FIB concentrate, but also to its high NDF to starch ratio, the unsaturation degree of its fat, and its greater consumption. In this regard, replacing cereals by NDF rich feedstuffs in the diet has proven to modify ruminal fermentation parameters in lambs (Fimbres *et al.* 2002; Bodas *et al.*, 2007), whereas the interaction between starch intake and dietary FA has shown a significant effect on the intramuscular FA profile (Oliveira *et al.* 2017).

Meat contents of medium-chain SFA (10:0; 12:0, 14:0 and 16:0) were not affected ($P>0.05$) by the type of concentrate (Table 2). It is worth mentioning that the CON and CAM treatments supplied ~ 1.4 times more preformed 16:0 than the FIB treatment (Table 1). This would suggest that the large differences in the rumen total volatile FA production and their molar proportions that should occur between treatments, due to the expected lower fermentation rate of the main carbohydrates in the FIB treatment, had no effects on lipogenesis (Bodas *et al.*, 2007; Fimbres *et al.*, 2002). However, less 16:0 was desaturated to *cis*-9 16:1 in the FIB treatment ($P<0.05$) compared with the other treatments (Table 2). Neither Lanza *et al.* (2011) nor Cieslak *et al.* (2013) observed

changes on 12:0, 14:0, 16:0 and *cis*-9 16:1 concentrations in the IMF of lambs fed diets where camelina cake partially replaced rapeseed and soybean meal.

Due to their microbial origin, odd and branched chain FA changes in ruminant fat could reflect dietary effects on the rumen environment (Fievez *et al.*, 2012). The FIB treatment presented the lowest levels ($P<0.05$) of 15:0 and 17:0, which could be explained by the low starch content of the concentrate, as those FA are synthesized from propionate by ruminal bacteria (Fievez *et al.*, 2012). Oliveira *et al.* (2017) reported that rations with high starch contents resulted in larger proportions of 15:0 and 17:0 in lamb IMF than mid-starch diets. In addition, both FA did not differ ($P>0.05$) between the CAM and CON treatments. This result was in agreement with Scerra *et al.* (2011), who did not find differences in the IMF contents of 15:0 and 17:0 in lambs fed diets where peas and faba beans replaced soybean meal. According to the composition of the diets in Scerra *et al.* (2011), the amount of starch consumed by their animals had to be quite similar to the amount of starch consumed in the CAM and CON treatments of the present work. The effect of the type of concentrate on branched-chain FA was not so clear. Compared with the CON treatment, both the CAM and FIB treatments decreased ($P<0.05$) 14:0 *iso* and increased ($P<0.05$) 17:0 *anteiso* contents, whereas the FIB treatment also increased ($P<0.05$) 15:0 *iso* and 16:0 *iso* levels.

[Insert Table 2 near here]

Stearic (18:0) and oleic (*cis*-9 18:1) acids were the most abundant in IMF and summed more than one third of total FA (Table 2). The FIB treatment showed the lowest contents ($P<0.05$) of both FA. It could be attributed to a lower elongase activity in those

animals, but no significant differences were found between treatments (Table 2). The
 observed results might be related to the contents of unsaturated FA with 18-C atoms in
 the IMF. The FIB treatment showed higher levels ($P<0.05$) of *trans*-11 18:1 (vaccenic
 acid, VA) and RA compared with the other treatments (Table 1). Therefore, a more
 incomplete rumen biohydrogenation (RBH) of the dietary PUFA in the FIB treatment
 could be suspected, thus decreasing the amount of 18:0 that could reach the muscle and
 then be converted into *cis*-9 18:1 via Δ -9 desaturase (Oliveira *et al.*, 2017). These
 results were unexpected since a lower availability of starch in the rumen has been
 related to a more complete RBH (Kucuk *et al.*, 2001). A possible explanation would be
 linked to the presence of polyphenols and tannins in the FIB concentrate, supplied by
 camelina by-products and other ingredients such as grape seed meal and bitter vetch
 (Shi *et al.* 2003; Sadeghi *et al.*, 2009; Terpin *et al.*, 2012). Phenolic compounds have
 shown alterations in rumen bacterial populations that are involved in the last step of
 RBH, i.e. the conversion of VA to 18:0 (Vasta *et al.*, 2010; Rana *et al.*, 2011). As a
 result, an increased availability of VA in animal tissues would promote higher levels of
 RA due to Δ -9 desaturation of the former (Griinari and Bauman, 1999). Palmquist *et al.*
 (2004) calculated that, on average, 28% of VA was desaturated to RA in the muscle of
 lambs fed different diets and that 87% of RA in muscle derived from VA desaturation.
 Applying the regression model of Palmquist *et al.* (2004) to the data obtained in the
 present work, it was calculated that 17% of available VA was converted into RA and
 that 90% of measured RA was produced endogenously from VA desaturation.

The higher levels of total *trans* 18:1 in the CAM and FIB treatments compared with the
 CON treatment is in agreement with the findings of Noci *et al.* (2011) and Cieslak *et al.*
 (2013) in lambs fed camelina by-products. *Trans*-10 18:1 levels exceeded those of VA

in all the treatments (Table 1) and would suggest that the dietary conditions predisposed a shift in RBH pathways (Bessa *et al.*, 2005). Moreover, both *trans*-10 18:1 and VA RBH pathways could operate simultaneously when lambs were fed the FIB concentrate despite its high NDF to starch ratio. An explanation would be that the forage provided was of poor quality and available carbohydrates in the FIB concentrate might still be rapidly fermented, both supporting *trans*-10 producing bacteria. Costa *et al.* (2017) have reported that a high NDF to starch ratio does not prevent the *trans*-10 RBH shift in lambs, but favors VA accumulation in meat lipids. A ratio of *trans*-10 18:1 to VA higher than 1 would deem the meat less desirable from the human health point of view (Bessa *et al.*, 2015). It is noteworthy that this ratio decreased by four-times ($P<0.05$) in the FIB treatment (Figure 1) and was very close to the recommended threshold value (Bessa *et al.*, 2015).

The contents of RA in the CON and CAM treatments were very low (Table 2), in line with the levels reported by Oliveira *et al.* (2017). In contrast, the FIB concentrate generated higher RA contents in IMF than those previously reported (Oliveira *et al.*, 2017), despite the fact that our concentrate did not include supplementary oil. Although the amount of RA needed to generate a real benefit in humans is not clearly defined, RA increases in IMF should be considered positive from a nutritional standpoint (Bessa *et al.*, 2015).

[Insert Figure 1 near here]

Regarding other minor CLA isomers, the FIB treatment also increased ($P<0.05$) *trans*-7,*cis*-9 18:2 (Table 2). *Trans*-7,*cis*-9 18:2, similarly to RA, is endogenously synthesized

by Δ -9 desaturation from *trans*-7 18:1 generated by RBH (Corl *et al.*, 2002). As can be seen in Table 2, the chromatographic peak comprising *trans*-7 18:1, its precursor, also increased significantly in the FIB treatment. Under normal rumen function, *trans*-7,*cis*-9 18:2 is the second most abundant CLA isomer in ruminant derived products (Martins *et al.*, 2007). However, *trans*-10,*cis*-12 18:2 showed higher levels than *trans*-7,*cis*-9 18:2 in the CON and CAM treatments (Table 2). *Trans*-10,*cis*-12 18:2 is formed solely from the alternative RBH pathway of linoleic acid that produces *trans*-10 18:1 (Jenkins *et al.* 2008). This result suggests that the *trans*-10 18:1 shifted RBH route would have been less promoted in lambs fed the FIB concentrate.

In relation to other PUFA detected in IMF, the most abundant were linoleic (*cis*-9, *cis*-12 18:2) and arachidonic (20:4 n-6) acids and no other PUFA exceeded 0.5 % of total FAME (Table 2). The highest levels of linoleic and α -linolenic acids were observed ($P<0.05$) in the FIB treatment, in agreement with the FA profile of the FIB concentrate (Table 1) and its higher intake (Avilés *et al.*, 2018). However, no differences ($P>0.05$) were observed in the IMF contents of their derivatives, arachidonic and eicosapentaenoic acids. Apart from linoleic acid, relevant amounts of other non-conjugated 18:2 isomers were quantified in all treatments: *cis*-9,*trans*-13, *cis*-9,*trans*-12 and *trans*-11,*cis*-15. All of them recently reported by Vahmani *et al.* (2016) in beef fat.

Conclusions

Partial replacement of soybean meal by camelina meal in the concentrate of light fattening lambs had minor effects on their intramuscular FA profile. On the contrary, feeding a concentrate without cereals or soybean meal and rich in unconventional ingredients, including camelina meal and husks as well as several fibrous by-products,

increased the contents of VA, RA and α -linolenic acid in the IMF, which might be considered favorable from the point of view of human health.

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Conflict of interest

The authors declare no conflicts of interest.

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418

Table 1. Ingredients, chemical composition and fatty acid (FA) profile of the experimental concentrates

	CON	CAM	FIB
Ingredients (g/kg feed as-fed)			
Cereals (barley, maize, wheat)	70.0	70.0	-
Soybean meal	20.0	10.1	-
Camelina meal	-	12.0	6.0
Other	4.2 ¹	2.1 ¹	89.8 ²
Calcium carbonate	2.7	2.7	3.1
Calcium salts of palm oil	2.0	2.0	-
Salt	0.6	0.6	0.6
Mineral-vitamin premix ³	0.5	0.5	0.5
Chemical composition (g/kg feed as-fed)			
Dry matter	89.2	89.1	88.7
Ash	5.6	6.3	8.1
Crude protein	15.7	15.6	15.8
Crude fat	4.3	4.1	3.9
Neutral detergent fiber	13.4	15.5	30.8
Starch	43.3	39.2	20.0
FA profile (g/100 g FA)			
12:0	0.57	0.79	0.76
14:0	1.54	2.03	1.96
16:0	35.39	33.17	25.07
18:0	7.87	8.91	9.93
<i>cis</i> -9 18:1	25.09	26.33	23.66
18:2 n-6	26.84	24.78	33.45
18:3 n-6	0.27	0.58	0.50
18:3 n-3	2.11	2.87	3.90

¹Wheat bran.

²Soybean hulls (14.0%), wheat bran (12.0%), corn gluten feed (10.7%), bitter vetch (10.0%), hominy feed (10%), corn dried distiller grains with solubles (10%), dehydrated barley sprouts (6%), NaOH-treated wheat straw (5%), grape seed meal extracted (5%), camelina husks (4.8%), rice bran (2.3%), cane molasses (2%).

³Troumix ovino (Trouw Nutrition, Madrid, Spain), composition per kg: vitamin A, 1500000 UI; vitamin D3, 150000 UI; vitamin E, 2700 UI; choline chloride, 20000 mg; manganese, 6000 mg; zinc, 12000 mg; iodine, 200 mg; cobalt, 99 mg; selenium, 45 mg; iron, 7000 mg.

Table 2. Total fat content (g/100 g of meat) and intramuscular fatty acid (FA) composition (g/100 g of total FA methyl esters) of *Longissimus thoracis* muscle from lambs fed a concentrate based on cereals and soybean meal (CON), the same concentrate with camelina meal replacing 50% of crude protein from soybean meal (CAM), and a concentrate based on fibrous by-products, including camelina meal and camelina husks (FIB).

	CON	CAM	FIB	S.E.	P
Number of lambs	10	10	10		
Total fat content	1.26	1.27	1.23	0.049	0.89
Saturated FA					
10:0	0.09	0.11	0.11	0.005	0.37
12:0	0.10	0.12	0.13	0.008	0.33
14:0	1.54	1.80	1.77	0.080	0.36
15:0	0.34 ^a	0.32 ^a	0.24 ^b	0.015	<0.05
16:0 (palmitic)	16.48	17.50	16.18	0.293	0.16
17:0	1.45 ^a	1.34 ^a	0.84 ^b	0.083	<0.001
18:0 (stearic)	11.03 ^a	10.5 ^{ab}	10.18 ^b	0.143	<0.05
19:0	0.18 ^a	0.19 ^a	0.12 ^b	0.011	<0.01
20:0	0.09 ^b	0.09 ^b	0.11 ^a	0.003	<0.01
22:0	0.11	0.10	0.10	0.004	0.95
23:0	0.12	0.13	0.14	0.007	0.56
14:0 <i>iso</i>	0.34 ^a	0.24 ^b	0.23 ^b	0.016	<0.01
15:0 <i>iso</i>	0.05 ^b	0.05 ^b	0.08 ^a	0.004	<0.01
15:0 <i>anteiso</i>	0.10	0.09	0.10	0.003	0.50
16:0 <i>iso</i>	0.08 ^b	0.08 ^b	0.11 ^a	0.004	<0.01
17:0 <i>iso</i>	0.14	0.13	0.14	0.007	0.72
17:0 <i>anteiso</i>	0.27 ^b	0.45 ^a	0.44 ^a	0.026	<0.001
18:0 <i>iso</i>	0.10	0.09	0.09	0.004	0.77
Monounsaturated FA					
<i>cis</i> -7 16:1	0.17 ^a	0.16 ^{ab}	0.13 ^b	0.006	0.03
<i>cis</i> -9 16:1	1.10 ^a	0.96 ^a	0.67 ^b	0.055	<0.001
<i>cis</i> -9 17:1	0.89 ^a	0.68 ^b	0.34 ^c	0.066	<0.001
<i>cis</i> -9 18:1 (oleic)	25.4 ^{ab}	27.46 ^a	23.6 ^b	0.578	<0.05
<i>cis</i> -11 18:1	2.06 ^a	2.14 ^a	1.57 ^b	0.076	<0.001
<i>cis</i> -12 18:1	0.32 ^b	0.29 ^b	0.42 ^a	0.020	<0.01

<i>cis</i> -13 18:1	0.15	0.15	0.13	0.006	0.16
<i>cis</i> -11 20:1	0.15 ^c	0.23 ^b	0.30 ^a	0.017	<0.001
<i>cis</i> -15 24:1	1.03	1.17	1.43	0.087	0.16
<i>trans</i> -9 16:1	0.06 ^b	0.09 ^b	0.22 ^a	0.021	<0.001
<i>trans</i> -13 16:1	0.11	0.12	0.11	0.004	0.47
<i>trans</i> (6+7+8) 18:1	0.18 ^b	0.15 ^b	0.28 ^a	0.019	<0.01
<i>trans</i> -9 18:1	0.18 ^b	0.17 ^b	0.31 ^a	0.019	<0.001
<i>trans</i> -10 18:1	3.33	4.77	4.54	0.283	0.07
<i>trans</i> -11 18:1 (vaccenic)	0.67 ^b	1.26 ^b	3.59 ^a	0.363	<0.001
<i>trans</i> -12 18:1	0.29 ^b	0.30 ^b	0.43 ^a	0.023	<0.05
18:2 non-conjugated					
<i>cis</i> -9, <i>trans</i> -13	0.17 ^b	0.14 ^b	0.22 ^a	0.010	<0.001
<i>cis</i> -9, <i>trans</i> -12	0.10	0.09	0.11	0.004	0.14
<i>trans</i> -11, <i>cis</i> -15 18:2	0.04 ^c	0.22 ^b	0.27 ^a	0.028	<0.001
<i>cis</i> -9, <i>cis</i> -12 18:2 (linoleic)	10.48 ^{ab}	8.99 ^b	11.12 ^a	0.342	<0.05
18:2 conjugated					
<i>trans</i> -7, <i>cis</i> -9 18:2	0.06 ^b	0.06 ^{ab}	0.09 ^a	0.006	<0.05
<i>cis</i> -9, <i>trans</i> -11 18:2 (rumenic)	0.18 ^b	0.28 ^b	0.79 ^a	0.076	<0.001
<i>trans</i> -10, <i>cis</i> -12 18:2	0.10 ^a	0.10 ^a	0.08 ^b	0.003	<0.05
<i>trans</i> -11, <i>cis</i> -13 18:2	0.04	0.04	0.03	0.002	0.39
<i>trans</i> -11, <i>trans</i> -13 18:2	0.03	0.02	0.02	0.002	0.36
Other 18:2 conjugated	0.07	0.07	0.06	0.002	0.98
Other polyunsaturated FA					
18:3 n-6	0.14 ^a	0.08 ^b	0.08 ^b	0.008	<0.001
18:3 n-3 (α -linolenic)	0.26 ^b	0.25 ^b	0.34 ^a	0.013	<0.01
20:2 n-6	0.08 ^b	0.10 ^b	0.13 ^a	0.006	<0.01
<i>cis</i> -9, <i>trans</i> -11, <i>cis</i> -15 18:3	0.33	0.30	0.28	0.013	0.21
20:3 n-6	0.24	0.24	0.25	0.008	0.97
20:4 n-6	3.65	3.29	3.27	0.128	0.43
20:5 n-3	0.16	0.15	0.13	0.008	0.32
22:4 n-6 (eicosapentanoic)	0.50 ^a	0.38 ^b	0.44 ^{ab}	0.018	<0.01
22:5 n-6	0.16	0.14	0.11	0.009	0.06
22:5 n-3(docosapentanoic)	0.40	0.38	0.39	0.015	0.89

22:6 n-3 (docosahexanoic)	0.10 ^b	0.14 ^a	0.11 ^{ab}	0.007	<0.05
Total saturated FA	32.60 ^{ab}	33.34 ^a	31.12 ^b	0.391	<0.05
Total <i>cis</i> monounsaturated FA	31.27 ^a	33.24 ^a	28.59 ^b	0.613	<0.001
Total <i>trans</i> monounsaturated FA	4.65 ^c	6.70 ^b	9.18 ^a	0.543	<0.001
Total polyunsaturated FA	17.27 ^{ab}	15.44 ^b	18.29 ^a	0.493	<0.05
Total <i>trans</i> 18:1	4.47 ^c	6.49 ^b	8.86 ^a	0.392	<0.001
Total CLA ^A	0.46 ^b	0.57 ^b	1.07 ^a	0.076	<0.001
16:0 desaturase index ^B	6.62 ^a	5.41 ^b	4.06 ^c	0.301	<0.001
Elongase index ^C	67.47	67.30	66.76	0.304	0.45

^{a-c} Means in the same row with no superscript letters after them or with a common superscript letter following them are not significantly different ($P < 0.05$)

^ACLA: conjugated linoleic acid.

^B cis -9 16:1 / (16:0 + cis -9 16:1).

^C(18:0 + cis -9 18:1) / (16:0 + cis -9 16:1 + 18:0 + cis -9 18:1).

S.E.: standard error of the mean.

Figure 1. Ratios *trans*-10 18:1/*trans*-11 18:1 (Vaccenic acid) in *Longissimus thoracis* muscle from lambs fed a concentrate based on cereals and soybean meal (CON), the same concentrate with camelina meal replacing 50% of crude protein from soybean meal (CAM), and a concentrate based on fibrous by-products, including camelina meal and camelina husks (FIB). Different letters indicate significant differences between treatments ($P < 0.05$).