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Omega 3 and CLA naturally enhanced levels of animal products: Effects of grass and linseed supplementation on the fatty acid composition of lamb meat and sheep milk

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SUMMARY – Changes in agricultural practices and consumption habits are accountable for large modifications in the west-European human diet and partly responsible for a higher prevalence of particular diseases. Reducing the saturated fatty acids (SFA) content of animal products and increasing the poly-unsaturated fatty acids (PUFA), n-3 and conjugated linoleic acid (CLA) yields can effectively help people to meet the new nutritional guidelines. Our experiments showed that linseed supplementation to lambs and ewes make it possible to naturally reach these goals by making the milk and meat fatty acid composition healthier. We investigated the effects of factors such as amount, period, inclusion time and treatment of the linseed supply on animal performances and their product composition. This technique did not modify zootechnical criteria, or the usual commercial qualities of the products. Therefore, it is possible for the agriculture sector to easily develop nutritional products that are naturally enhanced and that meet the needs and expectations of consumers. This represents a real opportunity for farmers and a potential significant improvement in our health.

Keywords: Conjugated linoleic acids, linseed, milk, meat, omega 3, poly-unsaturated fatty acids, sheep.

RESUME – *"Niveaux en omega 3 et CLA améliorés de façon naturelle pour les produits animaux : Effets de la supplémentation en graminées et graine de lin sur la composition en acides gras de la viande d'agneaux et du lait de brebis". En Occident, l'évolution des pratiques agricoles et des habitudes alimentaires sont notamment responsables de la fréquence plus élevée de certaines maladies. Ainsi, pour suivre les nouvelles recommandations nutritionnelles, il peut être d'intérêt public de réduire le contenu en graisses saturées des productions animales et d'accroître leurs teneurs en acides gras polyinsaturés, surtout ceux de type omega 3 et acides linoléiques conjugués. Nos essais ont montré que l'apport en graine de lin dans la ration des agneaux et des brebis a permis d'atteindre naturellement ces buts et d'améliorer la qualité diététique de la viande et du lait produits. Les effets de différents facteurs tels la quantité de graine de lin, la période de complémentation et le traitement de la graine sur les performances animales et la composition en acides gras de leurs productions sont analysés. Cette technique d'alimentation n'a pas eu d'impact négatif sur les critères zootechniques ni sur les qualités requises par le marché pour ces produits. Le secteur agricole peut donc facilement développer certaines productions nutritionnelles naturellement améliorées qui répondent aux besoins et aux attentes des consommateurs. Elles sont une nouvelle voie et une réelle opportunité pour les producteurs, et une contribution à la prévention dans le domaine de notre santé.*

Mots-clés : *Acides linoléiques conjugués, lin, lait, viande, omega 3, acides gras poly-insaturés, ovins.*

Introduction

Changes in agricultural practices and consumption habits are accountable for large modifications in the west-European human diet. For instance, we eat too many saturated fatty acids (SFA) and not enough poly-unsaturated fatty acids (PUFA); one also observes a deficiency in omega 3 fatty acids (n-3) and an increase of the n-6/n-3 PUFA ratio. All of these factors are partly responsible for a higher

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prevalence of cardiovascular and inflammatory diseases, immune dysfunctions and particular cancers (Calder, 2004). It has also been shown that the conjugated linoleic acid (CLA) isomers have a beneficial anti-carcinogenic effects (Parodi, 1997 in Dhiman *et al*., 1999).

Increasing the n-3 (and CLA) content of the animal products can be naturally obtained by managing their feeding regimes. When young forages, which are the most important and cheapest source of n-3 fatty acids for ruminants (Dewhurst *et al.*, 2003), are not available, linseed is the richest, most common and convenient food for farmers to provide it.

The aim of this work was to inform sheep farmers of the omega 3 products possibilities, limitations and some feeding practises. Therefore we carried out six experiments dealing with linseed supply (with meat lambs and their mothers, with dairy ewes). We analysed the effects of factors such as the amount, period and inclusion time of extruded linseed on animal performances and on the meat and milk fatty acids composition. However, industrial treatment of the linseed induces additional costs for the users and the consumer might feel the product as less natural. Therefore, we also investigated the effects of the treatment of linseed.

Material and methods

Experiment 1: Meat lambs, sheepfold system – Extruded linseed supply

Forty-eight lambs (Ile de France-cross with an initial average weight of 10 kg) – and their mothers – were allocated to six groups. In four groups, only the lambs were fed linseed – at different levels (0%, 3%, 10% and 15%) – and the ewes received no linseed. In two groups the suckling ewes were supplemented with 228 g linseed/day and the lambs fed a 0% or 15% diet. Lambs were offered a concentrated diet *ad libitum*. Lambs diets and those of the ewes had respectively a similar protein level. Growth performances, concentrate intake and carcass characteristics were recorded. Lambs were slaughtered at the same commercially optimal fat score (average live weight of 37 kg). *M. longissimus dorsi* of the 12^{th} and 13^{th} ribs was sampled for analyses. At weaning, a sample of bulk milk – result of the milking of several animals – was collected in the two ewes groups (linseed supplemented or not).

Experiment 2: Meat lambs, pasture system – Extruded linseed supply

Thirty-six lambs (Ile de France-cross) were initially stratified into two groups according to their mother's diet: with or without an extruded linseed supplementation during the two last weeks of the gestation (150 g/day) and the three first weeks of the suckling period (300 g/day). After this period, all the animals were out to pasture, without any supplementation, for approximately three months. Then, the lambs were weaned and allocated to three fattening diets: on pasture with only grass or housed and *ad libitum* concentrate diet offered with 0% or 12.5% extruded linseed supply. Performances measures, slaughtering (average live weight of 41 kg) and meat sampling models were identical to the first experiment.

Experiment 3: Dairy ewes, sheepfold period – Extruded linseed supply

This experiment was divided into two periods of three weeks and conducted on eighty ewes (Belgian milk sheep and Lacaune) stratified into two comparable groups. The two tested diets (without or with 110 g/day extruded linseed supply) had the same energy and protein level. Each period included 16 days of adaptation to the diet followed by 5 days of milk tank recording and sampling. After the first period, diets were exchanged between the two groups.

Experiment 4: Dairy ewes, pasture period – Extruded linseed supply

The trial was conducted during four weeks on 114 ewes (Belgian milk sheep and Lacaune) divided into two feeding groups: without or with 111 g/day extruded linseed supply (isoenergetic and isonitrogenous diets). Milk recording and sampling were performed on the last day of the period on five comparable ewes of each group.

Experiment 5: Linseed treatment – Sheepfold meat lambs

Twenty-four lambs (Suffolk with an initial average live weight of 17 kg) – and the suckling ewes – were allocated to three groups according to the treatment of the linseed supply: whole, crushed or extruded. Lambs were offered the same concentrated diet *ad libitum* containing 3.5% linseed. Growth performances, concentrate intake and carcass characteristics were recorded. Lambs were slaughtered at the same commercially optimal fat score (average live weight of 37 kg). Meat analyses were performed on the *m. extensor carpi ulnaris* removed from the right front leg.

Experiment 6: Linseed treatment – Dairy ewes, sheepfold period

This experiment was conducted (3×3 Latin square design) with three groups of eight ewes (Belgian milk sheep) each, three diets (whole, crushed or extruded linseed) and three periods of 15 days. Ewes were offered 126 g/day linseed supply. Milk production recording and sampling were performed on the last day of each period.

Meat, milk and statistical analyses

HP gas chromatography was used for determining samples profile and composition. All the data were subjected to ANOVA with the GLM procedure – Tukey test ($p = 0.05$) including the fixed effects and their interactions.

Results and discussion

All our results (Tables 1 to 4) are in agreement with those of Wood *et al*. (1999), Geay *et al*. (2002), Maene *et al*. (2002), Wachira *et al*. (2002), Cooper *et al*. (2004) and Raes *et al*. (2004) and confirm that supplying animals with grass or linseed enhances the n-3 and CLA content and reduces the n-6/n-3 ratio of their products. The SFA proportion can also decrease and the PUFA can rise. We also observed that the animal performances were unmodified with a linseed supplementation.

Experiment 1

With sheepfold lambs (Table 1), we cannot assert that the lower growth performances in the 10% and 15% groups (i.e. a diet with 5.8% and 8.1% of fat) are the result of the too much linseed supplementation because these lambs were suffering from echtyma. The SFA, mono-unsaturated fatty acids (MUFA) and PUFA yields were unmodified. The C18:3 levels and the n-6/n-3 ratio depended on the linseed amounts but very significant differences can already been seen with the 3% linseed lamb diet. The CLA percentage only rose in the 15% group.

With the suckling ewe's supplementation, modified milk composition (Table 2) influenced (in accordance with Bas *et al*., 2001) meat fatty acids level: SFA -6%, PUFA +19%, C18:3 +29%, CLA +28%. The n-6/n-3 ratio is however the same.

Experiment 2

With pasture lambs, the ewe's supplementation had no effects on lamb's meat fatty acids composition (data not shown). With a less energetic diet, the "grass only" lambs (Table 3) had, as expected, lower growth performances (and a dressing yield too: 42% vs 47% for the two concentrate fattened lambs groups). Pasture and linseed supplementation significantly increase the proportions of PUFA, C18:3, CLA and 18:1t and decrease the n-6/n-3 ratio. The highest proportion of SFA observed with the grass diet was especially due to the C18:0 (Rondia *et al*., 2003). Our results also show that linseed supplementation is necessary in the housed fattening period (two months) to preserve the high n-3 and CLA meat level of pasture lambs.

Table 1. Effects of different amounts of extruded linseed supply in sheepfold lambs fattening diet on animal performances and meat fatty acids composition (*m. longissimus dorsi*)

Lambs diet	Linseed supply				p value
	0%	3%	10%	15%	
Daily weight gain (g)	341	343	278	287	0.032
% Total fatty acids					
SFA	48.18	48.30	48.73	47.63	0.809
MUFA	42.37	41.58	40.81	41.76	0.533
PUFA	9.52	10.05	10.74	10.62	0.712
C18:3 n-3	1.13[a]	2.12[b]	2.35[bc]	2.83[c]	0.000
CLA	0.73[a]	0.83[ab]	0.80[ab]	1.06[b]	0.054
C18:1t	5.21	5.72	4.40	7.10	0.340
n-6/n-3†	6.37[a]	3.22[b]	2.91[bc]	2.27[c]	0.000

†n-6/n-3: C18:2 n-6/C18:3 n-3.
a,b,c: values in the same row with different superscripts differ significantly.

Table 2. Effects of extruded linseed supply in suckling ewe diet on milk composition and on sheepfold lambs performances and meat fatty acids composition (*m. longissimus dorsi*)

Suckling ewe diet	Milk		Lambs		
	Linseed supply		Linseed supply		p value
	0 g/day	228 g/day	0 g/day	228 g/day	
Daily weight gain (g)	–	–	316	306	0.664
Total fatty acids (%)					
SFA	57.01	51.97	48.31	45.53	0.001
MUFA	36.86	39.31	41.75	42.58	0.299
PUFA	6.12	8.71	9.98	11.88	0.010
C18:3 n-3	0.98	2.55	1.93	2.49	0.019
CLA	1.80	2.22	0.93	1.19	0.014
C18:1t	3.10	4.86	5.98	7.53	0.070
n-6/n-3†	3.15	0.94	4.36	3.85	0.132

†n-6/n-3: C18:2 n-6/C18:3 n-3.

Experiment 3 and 4

Extruded linseed supplementation to dairy ewes (sheepfold and pasture periods) does not induce statistical changes in milk production and fat content (Table 4). These observations are in contradiction with the results of other studies showing the "milk fat depression" effect of a high PUFA cows supply (Focant *et al*., 1998; Griinari *et al*., 1998; Chouinard *et al*., 1999).

In the sheepfold period, linseed supply increased the amounts of MUFA (+32%), PUFA (+86%), C18:3 (+147%) and CLA-C18:2 9c11t (+90%). The SFA proportion and the n-6/n-3 ratio were reduced by 12% and by 39% respectively. Out to pasture, only the SFA, MUFA and C18:1t contents were modified (respectively –4%, +10% and +37%) with the linseed. The grass diet was beneficial for CLA (in accordance with Chilliard *et al*., 2001) and C18:1t but did not make the linseed supply very efficient for the C18:3. This suggests an increased biohydrogenation process in the rumen that involves a higher percentage of precursors of the stearic acid.

Table 3. Effects of different lambs fattening diet on animal performances and meat fatty acids composition (*m. longissimus dorsi*)

Lambs diet	Grass only	Concentrate-Extruded linseed supply		p value
		0%	12.5%	
Daily weight gain (g)	182[a]	221[b]	220[b]	0.040
% Total fatty acids				
SFA	49.26[a]	47.14[b]	45.54[b]	0.000
MUFA	40.81[a]	43.32[b]	42.94[b]	0.005
PUFA	9.93[a]	9.54[b]	11.53[a]	0.026
C18:3 n-3	2.66[a]	1.31[b]	2.84[a]	0.000
CLA	1.25[a]	0.82[b]	0.94[ab]	0.021
C18:1t	3.60[ab]	2.71[a]	5.63[b]	0.008
n-6/n-3†	2.28[a]	5.75[b]	2.75[a]	0.000

†n-6/n-3: C18:2 n-6/C18:3 n-3.
a,b: values in the same row with different superscripts differ significantly.

Table 4. Effect of extruded linseed supply in dairy ewes diet during the sheepfold and pasture periods on milk production and fatty acids composition

Diet		Sheepfold			Pasture		
		Linseed supply		p value	Linseed supply		p value
		0 g/day	110 g/day		0 g/day	111 g/day	
Production	kg/day	2.05	2.00	0.166	1.71	1.60	0.706
	Fat cont. (%)	6.46	6.42	0.822	5.89	5.69	0.536
% Total fatty acids							
SFA		78.88	70.46	0.000	70.18	67.05	0.035
MUFA		17.89	23.56	0.000	24.00	26.34	0.035
PUFA		3.22	5.98	0.000	5.82	6.61	0.051
C18:3 n-3		0.61	1.51	0.000	0.76	0.87	0.108
C18:2 9c,11t		0.50	0.95	0.000	2.05	2.34	0.139
C18:1t		1.40	3.23	0.000	4.53	6.19	0.029
n-6/n-3†		2.96	1.81	0.000	1.99	1.82	0.098

†n-6/n-3: C18:2 n-6/C18:3 n-3.

Experiment 5

The results in Table 5 show that the two linseed treatments did not improve growth performances and did not modify any fatty acid percentages. The carcasses characteristics and the concentrate consumption were also unmodified. So, sheepfold lambs were able to digest and metabolize the whole linseeds. In accordance with Raes (2003) and Raes *et al*. (2004), extrusion did not involve a higher biohydrogenation of the diet.

Table 5. Effects of the treatment of the linseed supply in sheepfold lambs diet on animal performances and meat fatty acids composition (*m. extensor carpi ulnaris*)

Diet	Linseed supply (3.5%)			p value
	Whole	Crushed	Extruded	
Daily weight gain (g)	377	343	361	0.538
% Total fatty acids				
SFA	32.16	29.47	30.66	0.781
MUFA	36.23	32.16	32.55	0.628
PUFA	23.60	28.31	27.59	0.449
C18:3 n-3	1.90	2.29	2.38	0.227
C20:5 n-3	1.03	1.42	1.30	0.479
C22:6 n-3	0.59	0.80	0.64	0.406
n-3 total	5.80	6.65	5.92	0.389
C18:2 9c,11t	0.79	0.78	0.93	0.544
C18:1t	2.08	2.00	2.68	0.485
n-6/n-3†	6.60	6.34	6.53	0.957

††n-6/n-3: C18:2 n-6/C18:3 n-3.

Experiment 6

Linseed treatment did neither modify the winter milk production nor the fat content (Table 6). The SFA, C18:3 amounts and the n-6/n-3 ratio were also the same. However, extrusion processes reduced the MUFA and improve the PUFA percentage. The CLA-C18:2 9c11t and C18:1t levels were also increased. These results are in agreement with the *in vitro* observations of Chow *et al.* (2002) and means that, in this experiment, a higher percentage of linolenic acid is hydrogenated in the rumen consequently to extrusion.

Conclusions

Linseed supplementation to ewes and lambs is a natural feeding practise that is able to modify the fatty acids composition of their products (meat and milk) in a healthy way. Very small amounts (3 to 5% of the diet) can actually reduce the SFA content and the n-6/n-3 ratio, and improve the PUFA, n-3 and CLA yields, effectively helping people to meet the new nutritional guidelines. This technique does not interfere with the sheep's performances, or the usual commercial qualities of the products. Whole, crushed or different extruded forms of linseed that are already available on the market can be used and their high energetic level does not necessarily induce additional costs and this can be very convenient for the farmers.

Therefore, it is possible for the farmers to easily develop nutritional products that are naturally enhanced (e.g. "omega 3") and that meet the needs and expectations of consumers. This represents a real opportunity for agriculture. It is a good way for this sector to promote itself by answering the new social and health problems of our society. The success of such an approach however depends on complying with a number of criteria and involves the management of specific critical points.

Table 6. Effects of the treatment of the linseed supply (126 g/day) in dairy ewe diet (sheepfold period) on milk production and fatty acids composition

Diet		Linseed treatment			p value
		Whole	Crushed	Extruded	
Production	kg/day	1.42	1.46	1.49	0.623
	Fat cont. (%)	6.98	6.78	7.00	0.566
% Total fatty acids					
SFA		66.92	66.96	67.54	0.411
MUFA		27.91[a]	27.59[a]	26.00[b]	0.000
PUFA		5.17[a]	5.45[a]	6.46[b]	0.000
C18:3 n-3		1.75	1.78	1.87	0.206
C18:2 9c,11t		0.56[a]	0.61[a]	0.87[b]	0.000
C18:1t		1.71[a]	1.87[a]	2.88[b]	0.000
n-6/n-3†		1.19	1.20	1.26	0.512

†n-6/n-3: C18:2 n-6/C18:3 n-3.
a,b: values in the same row with different superscripts differ significantly.

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References

Bas, P., Sauvant, D. and Morand-Fehr, P. (2001). Influence du type de matière grasse incorporée dans la ration sur la composition en acides gras des dépôts adipeux et des muscles chez les agneaux. *Renc. Rech. Rum.*, 8: 116.

Calder, P.C. (2004). Omega-3 fatty acids: The good oil? In: *Danone Chair, Academic year 2003-2004, Université Libre de Bruxelles.* Oral communications.

Chilliard, Y., Ferlay, A. and Doreau, M. (2001). Contrôle de la qualité nutritionnelle des matières grasses du lait par l'alimentation des vaches laitières : Acides gras *trans*, polyinsaturés, acide linoléique conjugué*. INRA Prod. Anim.*, 15: 37-52.

Chouinard, P.Y., Corneau, L., Saebo, A. and Bauman, D.E. (1999). Milk yield and composition during abomasal infusion of conjugated linoleic acids in dairy cows. *J. Dairy Sci.*, 82: 2737-2745.

Chow, T.T., Fievez, V., Raes, K., Demeyer, D. and de Smet, S. (2002). Lipolysis and biohydrogenation of linoleic and linolenic acid in vitro: Comparison of linseed products and grass. *Med. Facul. Landbouww. Univ. Gent*, 67(4): 305-308.

Cooper, S.L., Sinclair, L.A., Wilkinson, R.G., Hallett, K.G., Enser, M. and Wood, J.D. (2004). Manipulation of the n-3 polyunsaturated fatty acid content of muscle and adipose tissue in lambs. *J. Anim. Sci.*, 82: 1461-1470.

Dewhurst, R.J., Scollan, N.D., Lee, M.R., Ougham, H.J. and Humphreys, M.O. (2003). Forage breeding and management to increase the beneficial fatty acid content of ruminant products. *Proc. Nutr. Soc.*, 62: 329-336.

Dhiman, T.R., Anannd, G.R., Satter, L.D. and Pariza, M.W. (1999). Conjugated linoleic acid content of milk from cows fed different diets. *J. Dairy Sci.*, 82: 2146-2156.

Focant, M., Mignolet, E., Marique, M., Clabots, F., Breyne, T., Dalemans, D. and Larondelle, Y. (1998). The effect of vitamin E supplementation of cows diets containing rapeseed and linseed on the prevention of milk fat oxidation. *J. Dairy Sci.*, 81: 1095-1101.

Geay, Y., Bauchart, D., Hocquette, J-F. and Culioli, J. (2002). Valeur diététique et qualités

sensorielles des viandes des ruminants. Incidence de l'alimentation des animaux. *INRA Prod. Anim.*, 15: 37-52.
Griinari, J.M., Dwyer, D.A., Mc Guire, M.A., Bauman, D.E., Palmquist, D.L. and Nurmela, K.V. (1998). Trans-octadecenoic acids and milk fat depression in lactating dairy cows. *J. Dairy Sci.*, 81(5): 1251-1261.
Maene, D., Dehareng, F., Huneau, A., Davin, C. and Deswysen, A.G. (2002). Influence du régime alimentaire sur le profil en acides linoléiques conjugués de la viande d'agneau. *Renc. Rech. Rum.*, 9: 322.
Parodi, P.W. (1997).Cow's milk fat component as potential anti-carcinogenic agents. *J. Nutr.,* 127: 1055-1060. Quoted in: Dhiman, T.R. Anand, G.R., Satter, L.D. and Pariza, M.W. (1999). Conjugated linoleic acid content of milk from cows fed different diets. *J. Dairy Sci.*, 82: 2146-2156.
Raes, K. (2003). *Optimisation of the fatty acid composition of beef and eggs: Influence of feed and animals factors*. PhD. Thesis. Universiteit Gent, faculteit Landbouwkundige en toegepaste Biologische Wetenschappen , Gent, Belgium, 237 pp.
Raes, K., Haak, L., Balcaen, A., Claeys, E., Demeyer, D. and de Smet S. (2004). 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.
Rondia, P., Delmotte, C., Dehareng, F., Maene, D., Toussaint, J.F. and Bartiaux-Thill, N. (2003). Incidence d'un apport en graines de lin chez la brebis et l'agneau sur les performances et le profil en acides gras de la viande d'agneaux élevés en bergerie ou au pâturage. *Renc. Rech. Rum.*, 10: 227-230.
Wachira, A.M., Sinclair, L.A., Wilkinson, R.G., Enser, M., Wood, J.D. and Fisher, A.V. (2002). Effects of dietary fat source and breed on the carcass composition, n-3 polyunsaturated fatty acid an conjugated linoleic acid content of sheep meat and adipose tissue. *Br. J. Nutr.*, 88: 697-709.
Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Richardson, R.I. and Sheard, P.R. (1999). Manipulating meat quality and composition. *Proc. Nutr. Soc.*, 58: 363-370.