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Abstract. Extruded linseed supplement is widely used to improve the nutritional quality of ruminant products by increasing the percentage of the polyunsaturated (PUFA), the omega 3 and the conjugated linoleic (CLA) fatty acids. In order to decrease costs and environmental impacts of treatment and of transport, it would be interesting to privilege the native linseed and/or local sources in unsaturated fatty acids such as rapeseed cake. This work studied the effects of a linseed (whole and extruded forms) and of a rapeseed cake supplement on fatty acid composition of goat milk and cheeses. The diet did not affect the milk yield or the milk fat and protein content. The cheese-making outputs were also similar. The milk fatty acid composition showed that the bio-hydrogenation was less complete with the extruded linseed and increased the PUFA, omega 3 and CLA contents. However, whole seed could be digested and similar modifications induced. The rapeseed cake induced significantly less saturated fatty acids and a high CLA content. It also seemed to maintain conditions in the rumen that limit hydrogenation. Lastly, cheese-making and refining did not alter the fatty acid composition.

Keywords. Conjugated linoleic acids – Linseed – Goat – Milk – Omega 3 – Polyunsaturated fatty acids – Rapeseed cake.

La supplémentation par des oléagineux (lin entier ou extrudé et tourteau de colza) pour améliorer la qualité nutritionnelle du lait et du fromage de chèvre

Résumé. *La complémentation avec des graines de lin extrudées est couramment utilisée pour améliorer la qualité nutritionnelle des produits issus des ruminants. Cela permet d'accroître la proportion en acides gras poly-insaturés (PUFA), en oméga 3 et en acides linoléiques conjugués (CLA). Cependant, compte tenu du coût et de l'impact sur l'environnement du traitement et du transport, il serait intéressant de privilégier l'usage de graine de lin entière et/ou de sources indigènes en insaturés telles que le tourteau de colza produit à la ferme. Ce travail a permis d'étudier les effets d'une complémentation en graine de lin (formes entière et extrudée) et en tourteau de colza sur la production laitière et le profil en acides gras du lait et du fromage de chèvre. Le régime n'a eu aucun impact sur la quantité de lait produit et les teneurs en matières grasses et en protéines. Les rendements fromagers ont également été semblables. Le profil en acides gras montre que l'hydrogénation dans le rumen fut moins complète avec l'extrusion et que les proportions des PUFA, des oméga 3 et des CLA ont augmenté. Cependant, la graine entière a pu être digérée par les animaux et a conféré des modifications similaires. Le colza a diminué significativement la teneur en acides gras saturés et a augmenté celle des CLA. Ce tourteau semble également avoir créé des conditions dans le rumen qui ont limité la bio-hydrogénation. Enfin, la fabrication fromagère et l'affinage n'ont pas altéré le profil en acides gras.*

Mots-clés. *Acides linoléiques conjugués – Graine de lin – Chèvre – Lait – Oméga 3 – Acides gras poly-insaturés – Tourteau de colza.*

I – Introduction

In west-European countries, the over-consumption of fat – and especially in the form of saturated fatty acids (SFA) – is a cause of the emergence of certain serious illnesses (obesity, cardiovascular problems, diabetes, cancers). However, even if fat consumption is too high, the population suffers,

by reason of certain dietary imbalances, from a general deficiency in poly-unsaturated fats (PUFA) some of which are essential. The ratio of omega 6/omega 3 (n-6/n-3) fatty acids in the diet is often too high. Due to their potential richness in fat and especially due to their fatty acids (FA) composition, livestock products are often blamed. Thus, in order to better cope with new nutritional recommendations and also to respond to consumer demand, it is of utmost interest to modify the fat composition of meat and milk, and this ideally, by natural methods. For example, it would be healthy to reduce the proportion of SFA and increase PUFA, to enhance the omega 3 level and conjugated linoleic acids (CLA) whose positive impact on human health is widely acknowledged today.

Animal diet can contribute to this. In the absence of, or in addition to, growing green forage (rich in PUFA), linseed – 50% of whose FA is omega 3 – is usually used to achieve these goals. In our own area, this seed is mainly imported (from Canada) and extruded forms are the most consistently used for animal feeding. Transport and treatment obviously have price implications for these industrial products, which also generate considerable environmental costs.

Beside linseed, our region has its own indigenous oleaginous source: rapeseed, which comprises some 60% of mono-unsaturated FA (MUFA) and a significant content (10%) of omega 3. Today, with the emergence of bio-fuels, mechanically produced rape expeller, cold-pressed locally on farms, is making its appearance on the market. It contains some 20% oil and thus represents an indigenous source of omega 3, less costly than linseed in environmental terms and over which we can ensure control.

Milk and by-products are of great nutritional interest. They can have an important impact on our food balance and represent an important source of essential fatty acids. To improve their fat composition would be of great nutritional value. It is a new society challenge and a duty for our agriculture in particular to continue to improve the quality of its products (residues, composition, etc.) and moreover, their modes of production, so as to integrate environmental considerations.

The purpose of this study was to compare the impact of the following different oleaginous supplements in the diet of goats, either extruded linseed, or whole linseed, or farm produced rapeseed cake, on dairy production and on milk and cheese composition.

II – Materials and methods

The test was carried out over three 14 day periods with 129 goats allocated into three groups (Latin square experimental device 3 × 3). The animals were of the Saanen breed and had extended lactations of long duration. The goats were fed hay *ad libitum*. Before the start of the trial, the three groups received a basic concentrated mixture (2.1 kg/d/goat) composed of alfalfa, linseed expeller, barley, spelt, wheat and dehydrated sugarbeet. During the trial, all the animals continued to receive this basic ration in which the linseed expeller was replaced by coconut expeller. With the "extruded linseed" (EL) diet, each goat received 200 g more per day of a commercial concentrate composed of extruded linseed and of malt sprouts in a ratio 1/1 (that is to say 4% of linseed in the total concentrate). The animals on the "whole linseed" (WL) diet received 100 g of whole linseed (that is also 4% of the concentrate) and 100 g of malt sprouts. The "Rape" (RC) group received 200 g of farm rapeseed cake. All the concentrates were distributed in two daily meals after each milking. The Table 1 shows the daily contribution of the concentrated diets.

Evening (at 17.30) and morning (at 09.00) milk yield recording and sampling were performed four times: the day before the beginning of the experiment and the last day of each of the 3 periods. Lactic fresh and refined (3 weeks at 4°C) cheeses were manufactured with the morning milk. The composition of milk and that of cheeses was analyzed. The cheese-making outputs were compared.

The Röse-Gottlieb reference method was used for the fat (ISO 1211 FIL-IDF 1D:1996 for milk and ISO 1735 FIL-IDF 5:2004 for cheese) and the Kjeldahl reference method (ISO 8968-1 FIL-IDF 20-1

and 2) for the protein contents determination. Urea analysis was carried out following the enzymatic reference method using difference in pH (ISO 14637 FIL-IDF 195). Somatic cell count was made according to the standard FIL-IDF 148a with a Fossomatic 5000 (Foss – Denmark).

Table 1. Daily contribution of the different concentrated diets

	Diets†		
	Before the trial	**RC**	**WL**	**EL**
Dry matter (kg)	1.81	2.05	2.05
Cellulose (g)	295	338	339
Fat (g)	46	89	84
Starch (g)	292	268	281
UFL††	1.85	2.12	2.11
PDIN†††	202	227	217
PDIE†††	212	237	232
PDIA†††	111	123	118
C18:1 c-9 (g)	4.8	23.9	8.4
C18:2 c (g)	9.4	15.1	12.2
C18:3 c (g)	10.7	6.0	19.5

†RC: rapeseed cake; WL: whole linseed; EL: extruded linseed.
††UFL: energy feed unit (1700 kcal).
†††PDIN, PDIE, PDIA: digestible proteins in the intestine (INRA units).

For the fatty acids determination, the fat was extracted from milk and cheese samples according to ISO 14156 FIL-IDF 172:2001. The fatty acids methyl esters (FAME's) were prepared according to the standard method ISO 15884 FIL-IDF 182:2002. For the determination of the FAME's the standard ISO 15885 FIL-IDF 184:2002 was used. The gas chromatograph (model Agilent 6890, Agilent Technologies, Inc., Palo Alto, CA, USA) with a CPSil-88 capillary column (Varian, Inc., Palo Alto, CA, USA – length of 100 m and an internal diameter of 0.25 mm). The conditions for the chromatographic analyses were: carrier gas, helium; average velocity, 19 cm/s; cold on-column injector; flame ionization detector at 255°C; and a temperature program from 60°C (5 min) to 165°C (at 14°C/min), then 165 to 225°C (at 2°C/min). The volume injected was 0.5 µl. The response factors used for measuring the fatty acids concentrations were the same as those described by Collomb and Bühler (2000). All the data were subjected to ANOVA with the GLM procedure ($p = 0.05$) including the fixed effects and their interactions.

III – Results and discussion

1. General observations

For every group, the extruded linseed based concentrate was immediately and completely consumed. On the other hand, RC and EL concentrates required a few days of adaptation before being well eaten by the goats. No health problem linked to the consumption of native linseed was observed. The visual examination of faeces seemed to indicate that the whole linseed was digested. Despite a higher concentrate intake during the trial, consumption of hay remained similar to that before the experiment, identical for the three groups and the different periods (1 kg raw matter/goat/day).

2. Dairy production

The diet did not show any significant impact on milk yield, on fat and protein content, on the urea level and on the number of somatic cells (Table 2). These observations seem to confirm that the whole linseed could be well digested by the animals. With the RC diet, the milk yield and the urea rate testify however to one upward trend which could be charged to the diet which was slightly richer in proteins (Table 1). In general, the high number of cells did not result in the goats suffering from mastitis. Lactations of long duration are a possible cause of this. The statistical analysis did not show any evolution in milk yield, nor in the fat, the urea contents, the cells over the three periods. On the other hand, the protein content was higher at the third period (3.51% over the periods 1 and 2 *vs* 3.70% at the time of the period 3, P = 0.007). Whatever the diet, the amount of milk needed to produce fresh cheese was similar and about 24% for the raw matter (either 4.2 kg of milk per kg of cheese) and 56% for the dry matter.

Table 2. Effect of diet and time of milking on milk yield, fat, protein and urea level, and somatic cells

		Diet				Milking		
	Before the trial†	**RC**	**WL**	**EL**	**P**	**Evening**	**Morning**	**P**
Yield (kg/milking/goat)	1.10	1.11	1.08	1.09	0.945	0.81	1.38	0.000
Fat (%)	3.72	3.98	3.95	3.91	0.903	4.33	3.56	0.000
Protein (%)	3.35	3.56	3.58	3.59	0.928	3.57	3.59	0.780
Urea (mg/l)	–	231	205	213	0.623	205	228	0.363
Cells (×1000)	–	2180	2132	2363	0.895	2480	1970	0.249

†Average of the 3 groups.

Compared to the period "Before the trial", the fat-supplemented diets did not induce an increase of the milk yield as observed with mid- or late-lactation goats (Chilliard *et al.*, 2003) and by Bernard *et al.* (2005). This can be explained in particular by the structure of the groups composed of animals in different lactation stages. On the other hand, the data confirm that a fat supplement does not decrease the milk fat content, conversely to what was observed in dairy cows (Focant *et al.*, 1998). This is in concordance with Chilliard *et al.* (2003), Rondia *et al.* (2002, 2004) and Bernard *et al.* (2005) did not observe a milk fat depression any more with dairy ewes.

Relative to the time of milking, the Table 2 data confirm the usual observations: higher milk yield and lower fat content at the morning milking compared to the evening one and stability of the protein content. We did not observe any difference for the urea content and the number of cells. No interaction was observed between the diet and the time of milking for any of the parameters under consideration.

3. Milk fatty acids composition

Because of its composition, the RC resulted in a significant reduction of the saturated FA content in favour of the mono-unsaturated FA of which it is rich (Table 3). The EL diet resulted in significantly higher contents of PUFA and n-3, in a lower level of stearic acid and in a much lower n-3/n-6 ratio. The oleic acid proportions were equal for the three diets, as is ration intake. The RC diet resulted in higher levels of C18: 1 t and of CLA (C18:2 c-9, t-11) as observed by Andrade *et al.* (2004).

A similar analysis of the data concerning only the diets with linseed demonstrated that extrusion seems to result in conditions in the rumen which limit the bio-hydrogenation of the PUFA and allow the passage of larger quantities of intermediate FA. This confirms the results of Rondia *et al*. (2005)

with dairy ewes and general observations of Chilliard *et al.* (2003) that bio-hydrogenation is more efficient when the added oil is included in the seeds. The same observations about extruded linseed were made with beef meat production (Normand *et al.*, 2005). However these differences were not confirmed with lamb meat (Delmotte *et al.*, 2005). As supposed by Pottier *et al*. (2004), the lower rate of hydrogenation observed with extruded linseed could be explained by the heat treatment which increases the effectiveness of the starch of commercial food (EL) compared to the natural mixture of its components (WL). One could thus suppose that the whole linseed makes the ration more fibrous and supports bio-hydrogenation (Rondia *et al.*, 2004; Dang Van, 2006b). These assumptions must however be taken with caution because nothing enables us to claim that the assimilation of whole seed is similar to the extruded form in every way.

Table 3. Effect diet and time of milking on milk fatty acids composition

% total fatty acids	Diet					Milking		
	Before the trial†	RC	WL	EL	P	Evening	Morning	P
SFA††	76.5	72.9[a]	76.3[b]	76.7[b]	0.002	74.9	75.7	0.416
MUFA††	19.2	23.6[a]	20.1[b]	19.0[b]	0.000	21.3	20.4	0.349
PUFA††	4.22	3.5[a]	3.7[a]	4.3[b]	0.000	3.8	3.9	0.418
C16:0	31.3	27.1	29.3	28.4	0.071	28.2	28.3	0.858
C18:0	5.9	7.1[a]	6.4[ab]	5.7[b]	0.001	6.5	6.3	0.373
C18:1 t-10 and t-11	1.08	1.77[a]	0.80[b]	1.15[ab]	0.000	1.30	1.18	0.402
C18:1 c-9	15.6	18.9[a]	16.5[b]	15.3[b]	0.001	17.3	16.6	0.410
C18:2 c	2.01	1.70	1.72	1.70	0.057	1.71	1.70	0.914
C18:3 c	0.94	0.49[a]	0.81[b]	1.04[c]	0.000	0.76	0.80	0.059
C18:2 c-9, t-11	0.68	0.81[a]	0.48[b]	0.73[a]	0.000	0.65	0.69	0.418
Ratio n-6/n-3††	2.15	3.55[a]	2.13[b]	1.65[b]	0.000	2.56	2.33	0.195

†Average of the 3 groups.
††SFA: saturated fatty acids; MUFA: mono-unsaturated fatty acids; PUFA: poly-unsaturated fatty acids; Ratio n-6/n-3: C18:2 c/C18:3 c.
[a,b,c]Values with the same letter do not differ significantly.

However, even though its PUFA content was lower, the "Before the trial" diet provided a milk whose FA composition was very comparable with that of EL diet. This seems to confirm the impact of the treatment of seed to limit the phenomena of bio-hydrogenation. All these observations have to take into account the large amount of dehydrated sugarbeet in all diets (1 kg raw matter/day/goat) that influences the hydrogenation process (Dang Van *et al.*, 2006a,b). The FA composition of the evening and the morning milks were identical (Table 3). No interaction was observed between the diet and the time of milking for all the parameters under consideration.

4. Cheeses fatty acids composition

Table 4 shows FA composition of the cheeses. Analysis of these data confirms the observations made with evening and morning milks. The analysis of fresh and refined cheeses shows that their FA composition remained stable and identical to that of the milk whatever the diet (Table 5). This confirms the observations of Rondia *et al.* (2002) and Ferlay *et al.* (2005). No taste or manufacturing defect related to the modification of the composition and the higher PUFA content could be detected.

Table 4. Effect of diet on fatty acids composition of fresh and of refined cheeses

% total fatty acids	Fresh cheese				Refined cheese			
	RC	WL	EL	P	RC	WL	EL	P
SFA	74.1	76.0	74.6	0.299	74.1	77.6	75.9	0.139
MUFA	22.5	20.3	20.6	0.111	22.4[a]	18.2[b]	18.8[b]	0.037
PUFA	3.4[a]	3.7[ab]	4.8[b]	0.019	3.5	4.2	5.2	0.135
C16:0	26.8	29.4	28.2	0.396	28.2	29.7	29.0	0.824
C18:0	7.0	6.5	6.3	0.402	7.5	6.4	6.5	0.172
C18:1 t-10 and t-11	1.78[a]	0.89[b]	1.43[ab]	0.045	2.05[a]	0.80[b]	1.46[ab]	0.015
C18:1 c-9	17.8	16.6	16.3	0.168	16.8	14.4	14.4	0.148
C18:2 c	1.58[a]	1.72[ab]	1.83[b]	0.007	1.44	2.09	1.76	0.351
C18:3 c	0.45[a]	0.80[b]	1.10[c]	0.001	0.48[a]	0.84[b]	1.12[b]	0.007
C18:2 c-9, t-11	0.71[ab]	0.44[a]	0.77[b]	0.031	0.83	0.56	1.01	0.199
Ratio n-6/n-3	3.47[a]	2.17[b]	1.67[b]	0.000	3.00[a]	2.47[ab]	1.60[b]	0.026

[a,b]Values with the same letter do not differ significantly

Table 5. Effect of cheese-making and refining on fatty acids composition

% total fatty acids	Milk	Cheese		P
		Fresh	Refined	
SFA	75.7	74.9	75.9	0.552
MUFA	20.4	21.1	19.8	0.421
PUFA	3.9	4.0	4.3	0.503
C16:0	28.9	28.1	29.0	0.698
C18:0	6.3	6.6	6.8	0.273
C18:1 t-10 and t-11	1.18	1.37	1.44	0.566
C18:1 c-9	16.6	16.9	15.2	0.077
C18:2 c	1.71	1.71	1.76	0.921
C18:3 c	0.80	0.79	0.81	0.982
C18:2 c-9, t-11	0.69	0.64	0.80	0.335
Ratio n-6/n-3	2.33	2.43	2.35	0.959

IV – Conclusions

Inclusion of an oleaginous supplement to goats in the form of linseed or of rapeseed cake resulted in an improvement of the dietetic quality of the goat's milk without affecting the milk yield and the fat and protein contents. Focusing on omega 3, the linseed is more appropriate and seems more effective when the seed underwent a treatment (expeller or extruded). In order to reduce the saturated FA proportion, rapeseed cake is more effective. Linseed expeller, extruded linseed and rape cake made equal claim to produce milk richer in CLA. So, the use of linseed expeller makes it possible to obtain similar modifications to those observed with extruded seed and this at lower cost. The nutritional qualities acquired in milk were preserved in fresh and refined cheeses. The modifications did not involve any taste or manufacturing defect. This trial thus confirmed the various

technical possibilities available for the breeders to take into account the new nutritional guidelines by also taking into account the requirements of profitability and environmental needs.

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