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Influence of the type of lipids of the diets on fatty acid composition of adipose tissue and muscle in sheep

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SUMMARY – The fatty acid contents and profiles of adipose tissues and muscles influence the characteristics of meat quality. The variations of the fatty acid composition of these deposits have been studied by meta-analysis of published data, in relation with types of lipids contained in the diets. With diets rich in non fat-supplemented concentrate, the percentages of $C_{18:0}$ and $C_{18:3}$ were lower and the percentages of $C_{18:1}$ and $C_{18:2}$ were higher in the adipose tissues and in the muscles than with forage-based diets. The supplementation of diets with vegetable fat produced adipose tissues and muscles with a higher level of monounsaturated and polyunsaturated fatty acids compared to animal fat. Each fat source induced a specific answer in lipid tissues which depended on the lipid composition of the diet.

Key words: Lamb, fatty acids, adipose tissues, muscles, meta-analysis, dietary fats.

RESUME – *"Influence du type de lipides de la ration sur la composition en acides gras des dépôts adipeux et des muscles des agneaux". La teneur et le profil des acides gras des dépôts adipeux et des muscles influencent la qualité de la viande. Les variations de composition des lipides de ces dépôts ont été étudiées chez les agneaux par méta-analyse des données publiées, en relation avec le type de lipides de la ration. Avec des rations riches en concentrés non supplémentés en lipides, les dépôts adipeux et les muscles sont plus pauvres en* $C_{18:0}$ *et en* $C_{18:3}$ *mais plus riches en* $C_{18:1}$ *et en* $C_{18:2}$ *qu'avec des rations à base de fourrage. L'incorporation de matières grasses d'origine végétale dans les rations induisent des teneurs plus élevées en acides gras monoinsaturés et polyinsaturés dans les dépôts adipeux et les muscles. Chaque matière grasse incorporée dans la ration des agneaux induit une réponse différente selon sa composition en lipides.*

Mots-clés : *Agneaux, acides gras, tissus adipeux, muscles, méta-analyse, ration.*

Introduction

The nutritional factors have limited effects on fatty acid composition of adipose tissues and muscles of ruminants compared to monogastric animals due to the hydrogenation of the dietary lipids in the rumen (Wood and Enser, 1997; Nürnberg *et al*., 1998). The ruminant meat consumption is often reduced because of a negative image resulting of a high level of saturated and of *trans* fatty acids and a very low level of polyunsaturated fatty acids (PUFA). Some differences in the fatty acid composition and sensorial characteristics were found between lambs reared on grass or with concentrate based diets (Kemp *et al*., 1980; Larick and Turner, 1990; Bas and Morand-Fehr, 2000). The energy sources and nitrogen sources of the concentrate have specific characteristics on fatty acid composition of adipose tissues (Bas and Morand-Fehr, 2000). The fattening diets for ruminants were sometimes enriched with animal or vegetable fats for increasing the energy density of the diet and thus, to increase the growth rate and the fattening status. The objective of this work was to investigate the impact of feeding different sources of fats on the changes of fatty acid composition of adipose tissues and muscles of lambs and to analyse the specific effects of the main fat sources used in animal diets.

Material and methods

This work was made by meta-analysis of a database elaborated from available results of the bibliography about this topic. In this data base one observation represented one group of lambs in an experiment. This data base, which contained 1204 observations, summed up the results of 135 publications coming from 24 countries. The fatty acid percentages of adipose tissues or of muscles were the explained variables in this data base. They were analysed with coded variables linked to research work and with coded variables linked to animals and to diets. The types of diets, unsupplemented with fat, were divided in: roughage alone (pasture or hay without any supplementation), roughage + concentrate, concentrate alone (diet containing less than 25% of roughage and without distribution of hay or straw in the trough), complete diet (mixed diet containing more than 25% of chopped or ground roughage), ewe milk. The influence of fat supplementation in the diet was studied in subcutaneous adipose tissues and in internal adipose tissues (perirenal, omental, and mesenteric), on one hand and in intramuscular fat, on the other hand. The general term of "animal fat" put together tallow, lard and undefined animal fat but were distinguished from fish oil. Data were performed with the GLM procedure of SAS (1987) for studying causes of variations of fatty acids percentages, with carrying special care of the heterogeneity between most criteria concerned by the treatment effect tested. In this approach the lipid sources were distinguished by comparison to a mean control diet resulting of all the control groups of lambs fed non fat-supplemented diets, in the studies with fat-supplemented diets.

Results and discussion

The Tables 1 and 2 summarised the results of the effects of types of non fat-supplemented diets, on fatty acid percentages in adipose tissues and in muscles.

The adipose tissues and the muscles of lambs fed ewe milk had lower PUFA and $C_{18:0}$ percentages than those fed diets roughage or concentrate based diets, but they had the highest percentages of $C_{14:0}$ and of $C_{16:0}$. The high percentages of $C_{14:0}$ and of $C_{16:0}$ of ewes' milk fed lambs reflected the ewe milk composition but their relatively high PUFA percentages in muscles could be the consequence of low triacylglycerol: phospholipid ratio in the young unweaned animals. With roughage alone, the adipose tissues and the muscles had higher percentages of $C_{18:0}$ and in $C_{18:3}$, but lower percentages of $C_{18:1}$ and $C_{18:2}$, than with the other types of solid diets. Yet, between these diets, the magnitude of the differences in $C_{18:0}$ and $C_{18:1}$ percentages was more important in subcutaneous and internal adipose tissues than in muscles. With diets based on concentrate alone, the adipose tissues and the muscles had lower saturated fatty acid percentages ($C_{14:0}$, $C_{16:0}$ and particularly $C_{18:0}$) and higher $C_{18:2}$ and $C_{18:1}$ percentages. The complete diet and the roughage + concentrate diet had intermediary effects on fatty acid percentages between roughage alone and concentrate alone diet.

Table 1. Effect of type of diet on the fatty acid composition of adipose tissues (n = number of observations for each fatty acid; R = roughage; C = concentrate; R + C = roughage + concentrate; SE = standard error)†

Diets	n	Fatty acids						
		$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Roughage	30-64	4.4^a	21.0^a	2.5^a	26.0^a	36.0^a	3.4^a	2.8^a
SE		0.23	0.40	0.20	0.68	0.64	0.30	0.16
R + C	71-139	3.7^b	21.9^a	3.1^b	19.7^b	38.9^b	4.0^a	0.5^b
SE		0.15	0.26	0.14	0.47	0.45	0.21	0.10
Complete diet	119-165	3.8^b	23.4^b	3.0^b	22.2^c	37.6^c	5.7^b	2.1^c
SE		0.11	0.26	0.14	0.43	0.41	0.18	0.08
Concentrate	137-213	2.8^c	20.5^a	3.6^c	19.6^b	41.9^d	5.4^b	0.8^d
SE		0.14	0.21	0.10	0.36	0.34	0.15	0.07
Ewe milk	24-28	7.9^d	23.6^b	3.4^{bc}	14.6^d	39.5^{bc}	3.6^a	1.0^d
SE		0.32	0.61	0.35	1.09	1.03	0.47	0.18

†Concentrates and complete diets were non fat-supplemented.
[a,b,c,d]For each fatty acid, means in a column with different superscripts were significantly different (P < 0.05).

Table 2. Effect of type of diet on the fatty acid composition of muscles (n = number of observations for each fatty acid; R = roughage; C = concentrate; R + C = roughage + concentrate; SE = standard error)[†]

Diets	n	Fatty acids						
		$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Roughage	15-17	3.1^{a}	21.9^{ab}	3.4^{a}	17.5^{a}	39.1^{a}	5.9^{ab}	1.9^{a}
SE		0.38	2.79	0.37	1.21	1.20	0.54	0.19
R + C	29-33	3.8^{b}	23.5^{c}	3.1^{ab}	14.6^{b}	42.8^{b}	6.9^{ac}	0.5^{b}
SE		0.27	1.60	0.26	0.85	0.84	0.39	0.14
Complete diet	36-40	2.3^{c}	23.8^{c}	2.1^{b}	17.2^{a}	40.4^{ab}	5.6^{b}	1.4^{c}
SE		0.24	2.43	0.21	0.77	0.76	0.35	0.13
Concentrate	46	2.8^{a}	20.7^{a}	4.3^{c}	13.2^{c}	41.1^{ab}	7.2^{c}	0.5^{b}
SE		0.21	3.38	0.19	0.72	0.71	0.33	0.11
Ewe milk	4	7.7^{d}	23.8^{bc}	2.3^{b}	12.4^{bc}	43.2^{ab}	5.0^{ab}	1.7^{ac}
SE		0.73	1.40	0.65	2.43	2.40	1.10	0.39

[†]Concentrates and complete diets were non fat-supplemented.
[a,b,c,d]For each fatty acid, means in a column with different superscripts were significantly different ($P < 0.05$).

On the whole, with "animal fat" or with fish oil, the percentage of total saturated fatty acids were higher in the 3 analysed adipose tissues than with control (non fat-supplemented) diets or than with vegetable fat-supplemented diets, mainly on account of an increase in $C_{16:0}$ percentage (Table 3).

Table 3. Effect of type of supplemented fat in the diet on the fatty acid composition of adipose tissues and muscles (n = number of observations for each fatty acid; SE = standard error adjusted for the effects of the location of adipose tissues)

Diets	n	Fatty acids						
		$C_{14:0}$	$C_{16:0}$	$C_{16:1}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$
Control	62-75	3.0^{a}	23.1^{a}	2.1^{a}	20.4^{ab}	39.5^{a}	4.5^{ac}	1.1^{a}
SE		0.11	0.27	0.11	0.54	0.46	0.25	0.10
Animal fat	18-20	3.2^{a}	24.5^{b}	2.9^{b}	21.2^{b}	38.2^{a}	3.3^{b}	0.5^{b}
SE		0.19	0.52	0.19	1.04	0.90	0.48	0.19
Fish oil	7-9	3.1^{a}	23.9^{ab}	1.2^{c}	22.2^{b}	34.6^{b}	4.3^{abc}	1.1^{a}
SE		0.31	0.76	0.54	1.54	1.34	0.71	0.27
Rapeseed	44	2.8^{a}	20.8^{c}	1.4^{c}	19.9^{ab}	39.0^{a}	3.9^{ab}	0.7^{b}
SE		0.13	0.35	0.12	0.70	0.61	0.32	0.12
Maize oil	26-32	3.2^{a}	21.6^{c}	2.3^{a}	18.4^{ac}	42.5^{c}	7.0^{d}	1.1^{a}
SE		0.17	0.43	0.18	0.84	0.73	0.39	0.16
Sunflower	13	2.7^{a}	21.7^{c}	2.3^{a}	16.9^{c}	43.1^{c}	5.8^{cd}	0.5^{b}
SE		0.23	0.65	0.21	1.31	1.13	0.60	0.22
Protected fat[†]	7-11	1.9^{b}	16.3^{d}	2.1^{a}	21.3^{ab}	35.6^{b}	20.9^{e}	1.9^{c}
SE		0.30	0.82	0.29	1.40	1.21	0.65	0.30

[†]The protected fat, formaldehyde treated, were composed of vegetable fat (sunflower, soya and rapeseed).
[a,b,c,d,e]For each fatty acid, means in a column with different superscripts were significantly different ($P < 0.05$).

This difference was the more important with vegetable protected fat. With animal fat-supplemented diets there was a higher monounsaturated fatty acid percentage ($C_{16:1}$ and $C_{18:1}$) but a lower percentage in $C_{18:3}$ in adipose tissues than with fish oil-supplemented diets. The PUFA percentage in adipose tissues was generally increased with vegetable fat, except with rapeseed. Maize produced an strong increase in the percentages of $C_{18:2}$ and a moderate increase of $C_{18:3}$. Sunflower induced only an increase in $C_{18:2}$ percentage. With vegetable protected fat supplementation, both $C_{18:2}$ and $C_{18:3}$ percentages were greatly increased. With most fat supplementation, the $C_{18:2}$ percentage was higher in muscles than in adipose tissues, except with maize oil and with protected fat for which the values of $C_{18:2}$ were the highest. By contrast with these fat suplementations, the $C_{18:3}$ percentages appeared quite similar in adipose tissues and in muscles. With sunflower supplementation, the total saturated fatty acid percentage appeared lower than with maize or with rapeseed supplementation.

Conclusion

This meta-analysis permitted to show the magnitude and the variation trends in fatty acid percentage achieved in adipose deposits and in muscles of lambs due to different fat supplementation. The fatty acid profile of lamb tissues could reflect the fatty acid composition of the diet when rumen was by-passed, as in the milk feeding period or when rumen hydrolysis and hydrogenation were reduced with protected fat. Although the ruminal action could be effective on the hydrogenation of the unsaturated fatty acids the supply of PUFA in the concentrate or in the complete diet produced a moderate but evident increase in the monoenoic, dienoic and trienoic fatty acid percentages in relation with the supply of these unsaturated fatty acids in the fat supplementation. With non-fat supplementation, the roughage based diets (pasture or hay) were liable to increase the trienoic fatty acid percentage in adipose tissue and in muscles.

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