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FATTY ACID COMPOSITION OF FAROESE LAMB MEAT

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Ágrip á íslensku:

Tilgangur þessa verkefnis var að skoða áhrif framleiðsluárs, afkvæmahópa, sláturþyngdar og kyns á fitusýrusamsetningu í færeysku lambakjöti.
Fitusýrusamsetning 133 lamba frá tveimur svæðum á Streymoy í Færeyjum var skoðuð yfir þriggja ára tímabil. Lömbin voru afkomendur 38 áa og 6 hrúta sem einnig voru rannsökuð. Af hverjum skrokki voru tekin sýni af hryggvöðva *(M. longissimus dorsi)* og yfirborðsfitu til fitusýrugreiningar.
Í skýrslunni er gerð er grein fyrir niðurstöðum fitusýrugreininganna auk þess sem gerður er samanburður á fitusýrusamsetningu lamba, áa og hrúta. Einnig er munurinn á fitusýrusamsetningu hryggvöðvans og yfirborðsfitu skoðaður.

Lykilorð á íslensku: *fitusýrusamsetning, lambakjöt, skerpikjöt, lömb, ær, hrútar*

Summary in English:

The aim of this project was to study the effects of production year, progeny groups, carcass weight and sex on the fatty acid composition of subcutaneous and intamuscular fat of Faeroese lambs, ewes and rams.
Fatty acid composition of 133 lambs from two areas on the island Streymoy in the Faeroe Islands were studied over a period of three years. The lambs were derived from 38 ewes and 6 rams that were also studied. Samples were taken from the loin muscle *(M. longissimus dorsi)* and subcutaneous fat of each carcass and analysed for fatty acid composition.
In the report, the results of the analysis of the fatty acids is explained and a comparison between the fatty acid composition of lambs, ewes, and rams is done. In addition, a comparison between the fatty acid composition of the muscle and the subcutaneous fat is made.

English keywords: *fatty acid composition, lamb meat, "skerpikjöt", lambs, ewes, rams*

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1. Introduction

1.1 Production systems in Europe

There are over 250 registered sheep breeds in Europe. They are grown for wool, pelts, meat and milk. They have adapted to different kinds of environment. And they have also been bred and crossbred for different purposes.
The greatest producers and consumers of sheep meat in Europe are the UK, Spain, France and Greece. Sheep meat is of less importance in Germany and Italy. The Nordic countries are only small producers of sheep meat. But the consumption per capita gives more information on the importance on sheep meat in the different countries than the quantities produced/consumed. There are great regional differences in the consumption of lamb meat in Europe. There is almost no consumption in countries like Sweden, Italy and Denmark while there is a strong tradition for lamb meat in other European countries like Iceland, Faeroe Islands, Greece, Norway, Spain, France and the UK (Thorkelsson *et al*.,1999).

A production system can be defined as the breed, sex, feeding regime and age at slaughter. There is more diversity in the production systems of sheep than in other meat production systems in Europe, with more local differences in the meat characteristics than in other meats. There are differences in carcass weights and carcass composition. These factors affect meat quality. They have set local tastes and local products. The lamb meat products are appreciated by the regional consumer but not necessarily by consumers in other parts of Europe.

1.2 Faeroese sheep meat

Sheep meat is the traditional meat in the Faeroe Islands. The average consumption is about 30 kg/capita/year. This is about 1400 metric tons of which 650 tons are produced locally and the rest imported from Iceland and New Zealand (Hagstova Føroya).
The local production system and the ancient traditions in slaughtering of the sheep and processing of the meat are unique both for the Nordic countries and Europe. The production system is extensive. The breed is local and belongs to the North European short tailed group of sheep. It is a direct descendant of the sheep brought to the islands by the viking settlers in the ninth and tenth century. It is related to breeds like the Icelandic, Shetland, Spelsau, Finnsheep, Swedish Landrace, all of which was predominate in Scandinavia and the British Isles during the 8th and 9th century. It has not been isolated and imports of sheep from Iceland and Shetland date as far back as the seventeenth century. Many keep sheep, both farmers and people in towns and villages. The sheep are kept outdoors all year long but they have access to shelters and are supplied with hay during the hardest part of the winter. During the summer the sheep and the lambs graze in either closed home fields or in common grazing

areas in the mountains. The slaughter season is in September and October. Most of the lambs are home-slaughtered at the farms or homes in the villages.
Most of the carcasses are used for production of the traditional air-dried lamb meat "skerpikjöt". The meat is dried in specially constructed huts called "hjallur". For over 1000 years, "hjallurinn" has been just about as important as the houses people have lived in. Most of the "hjallur" huts are along rivers or brooks on low banks or at places that experience had proved to be good for drying meat.
The drying of the sheep meat takes place during the winter months, from October to February/March. It starts in September/October when the temperature in most often around 5-10°C and the humidity is rather high. The weather grows colder and sometimes also drier as the process continues into the winter months.
The quality of the final product is very much dependent on weather conditions, especially in the first period when temperature, humidity and wind have a great influence.
Over the centuries observations have been made regarding the processing and quality of "skerpikjöt". It has been noticed that:

1. "Skerpikjöt" made from meat from rams and ram lambs have on the whole softer subcutaneous fat that meat from ewes and ewe lambs. This difference is not as noticeable in the intramuscluar fat.
2. Subcutaneous fat of lambs that have grazed on high mountain areas or mountains facing north or mountains with many seabirds is softer than on other lambs.
3. There is a noticeable difference in the quality of subcutaneous fat of one-year-old rams from the same closed home field grazing only on cultivated grass 4-5 months before slaughter. So there might be a heredity factor as well as a feed factor.

The quality of the fresh meat, that is freshness and conformation of the carcasses, condition and composition of the fat and weather conditions are also critical for processing and quality of the end product. More than a 1000 years of tradition has led to an acquired taste of how a good "skerpikjöt" should taste like and what kind of meat and what conditions are required for producing it. There is both a local and a family influence on this taste. The exact production conditions differ between villages, farmers and even families within the villages. So there are many meanings, views and believes on how to produce "skerpikjöt" and what a good "skerpikjöt" is all about. But experience has taught that the condition of the fat of the sheep matters. There has been a great interest in the so called "glærfiti," that is a soft fat, presumably with a high amount of fatty acids with a low melting point. Dried sheep meat with "glærfiti" is a special product, with a certain texture and flavour.

1.3 Fatty acids and melting point.

The fat in sheep carcasses is divided into subcutaneous, intermuscular and intramuscular fat. The lipids in the subcutaneous and intermuscular fat are mostly made up of triglyserides but with basically phospholipids in intramuscular fat but the amount of triglyserides depends on the amount of marbling in the muscles.
Lamb fat is solid and very saturated. The saturated fatty acids, myristic C14:0, palmitic, C16:0, stearic, C18:0, and the monounsaturated fatty acids palmitoleic, C16:1 and oleic, C18:1 are predominant in the triglycerides and also, but to lesser degree, in the phospholipids where there are also polyunsaturated fatty acids like linoleic, C18:2, linolenic, C18:3 in considerable proportions. Longer chain polyunsaturated fatty acids, like arachidonic, C20:4, docosahexaenoic acid, C22:4 and eicosapentaenoic acid, C22:5 can also be found in small proportions in the phospholipids. Short chain, methyl branched fatty acids C8:1 and C9:1 contribute very much to sheep meat flavour, even when in small amounts, and their intensity increases with age more in rams than wethers and ewes.

The consistency of fat and melting point depend on lipid composition, especially the fatty acid composition and how much there is of saturated and unsaturated fatty acids but branching of the fatty acids can also influence the melting point (See Table 1.1). The melting point of lamb fat can be from 30°C – 40°C depending on the location on the carcass and the type of feed, age at slaughter and breed.

Table 1.1. Melting points of fatty acids.

Fatty acids	Melting point
Saturated fatty acids	
C10:0	30,5
C12:0	44
C14:0	54
C16:0	64
C18:0	69,7
C20:0	77
Monounsaturated fatty acids	
C14:1 n-9	-4,5
C16:1 n-9	40,0
C18:1 n-7	44,4
C18:1 n-9	12,0
Polyunsaturated fatty acids	
C18: 2n-6	-5
C18: 3n-3	-11

An EU-FAIR project on the quality and composition of lamb meat from production systems in six European countries, the United Kingdom, Spain, France, Greece, Iceland and Italy, was

carried out in 1997-1999. Four types of Icelandic lambs were studied in the project, i.e. conventional ram and ewe autumn lambs, young ewe/ram lambs finished on grass in closed hayfields and older rams lambs finished indoors on hay/silage and slaughtered just before Christmas. The qualitative fatty acid composition of subcutaneous fat and of both phosholipids and neutral lipids in the m.longissimus dorsi between 9th and 10th rib of the right side of Icelandic lamb carcasses of ewe and ram lambs of different ages can be seen in Tables 1.2. -1.4 respectively (Enser *et al*., 2000).

Table 1.2. Proportions of fatty acids in subcutaneous fat over 9th-10th rib of Icelandic lambs.

	Autumn lambs			
Fatty acid	Ewe lambs	Ram lambs	Summer lambs	Christmas Ram lambs
14:0	5.91	5.36	8.06	4.77
16:0	24.4	23.9	23.0	23.9
16:1	2.29	2.21	2.44	2.56
17:0	1.46	1.47	1.23	1.72
18:0	21.6	21.7	17.0	20.4
18:1 trans	4.5	4.1	4.65	4.26
18:1 n-9	27.8	30.0	31.5	31.8
18:1 n-7	0.56	0.60	0.67	0.60
18:2 n-6	1.48	1.54	1.28	1.23
18:3 n-3	1.49	1.52	1.28	1.17
Branched chains	2.35	1.86	2.00	2.65
(C18:0/C18: 1)	0.66	0.63	0.46	0.57

There was a higher proportion of oleic acid (C18:1) and less of myristic (C14:0) and palmitic acid (C16:0) in the subcutaneous fat of the autumn ram lambs than the ewe lambs. The summer lambs were slaughtered almost 3 months old. They were a mixture of ram/ewe lambs. They differ from the other lambs in high proportion of C14:0 the subcutaneous fat and lower proportion of C18:0. The autumn ewe lambs were lowest in C18:1 and higher in saturated acids than the other lambs. The Christmas ram lambs were higher in C18:1 and lower in C18:0 than the autumn lambs. The C18:0/C18:1 ratio was lowest in the summer lambs and highest in the autumn ewe lambs indicating the softest and hardest fat. The amount of subcutaneous fat depends on the degree of fatness of the carcass and is usually between 20-35 % of the carcass weight.

The fatty acid pattern in the neutral portion of the muscle differed a little from the pattern in the subcutaneous fat. The summer lambs still had the highest proportion of C14:0. The autumn ram lambs were highest in C18:1. The Christmas ram lambs were highest in C18:0, C18:2 and C18:3. The neutral lipids were softer than the subcutaneous fat as the C18:0/C18:1 ratio shows. They are softest in the summer lambs and hardest in the Christmas ram lambs.

The amount of neutral lipids depends on the degree of marbling in the muscle but it is usually between 0.5-3.5 % of the muscle weight.

The fatty acid composition of the phospholidids that are located in the cell membranes is quite different from the neutral lipids. The proportion of polyunsaturated fatty acids is high but the amount is only around 1% of the muscle weight. The summer lambs had the highest proportion of C16:0, C18:1, C22:6 and the lowest of C18:2, C18:3, C20:4. The autumn lambs were highest in C18:2 and the Christmas ram lambs in C18:3.

Table 1. 3. Proportions of fatty acids in neutral lipids of m.longissimus dorsi at 9th-10 th rib of Icelandic lambs.

Fatty acid	**Ewe lambs**	**Ram lambs**	**Summer lambs**	**Christmas ram lambs**
12:0	0.20	0.18	0.34	0.11
14:0	3.39	3.36	4.54	2.39
16:0	25.3	25.0	23.6	24.6
16:1	2.12	2.23	2.52	1.99
18:0	16.8	15.6	14.5	18.0
18:1 trans	2.75	2.37	2.86	2.27
18:1 n-9	39.9	42.2	40.0	40.0
18:1 n-7	0.76	0.77	0.93	0.79
18:2 n-6	1.51	1.46	1.88	2.08
18:3 n-3	1.43	1.38	1.48	1.55
20:4 n-6	0.02	0.03	0.24	0.25
20:5 n-3	0.03	0.05	0.25	0.19
22:5 n-3	0.13	0.15	0.32	0.25
22:6 n-3	0.01	0.02	0.14	0.06
(C18:0/C18:1)	0.39	0.35	0.33	0.42

Table 1.4. Proportions of fatty acids in phospholipids of m.longissimus dorsi at 9th-10.th th rib of Icelandic lambs.

Fatty acid	**Ewe lambs**	**Ram lambs**	**Summer lambs**	**Christmas ram lambs**
14:0	0.23	0.21	0.55	0.31
16:0	12.2	12.2	13.7	13.3
16:1	1.00	0.94	1.16	1.27
18:0	12.0	11.9	12.0	11.3
18:1 trans	0.66	0.86	1.21	0.74
18:1 n-9	20.5	20.6	24.4	21.8
18:1 n-7	1.79	1.79	1.96	1.77
18:2 n-6	14.7	15.3	11.2	12.9
18:3 n-3	6.22	6.46	5.74	6.65
20:3 n-6	0.68	0.67	0.56	0.64
20:4 n-6	4.91	4.73	3.84	4.79
20:5 n-3	4.88	4.94	4.69	4.68
22:4 n-6	0.17	0.16	0.14	0.13
22:5 n-3	3.98	3.65	3.50	3.54
22:6 n-3	1.67	1.59	2.18	1.37
(C18:0/C18:1)	0.52	0.51	0.44	0.46

1.4 Processing of air-dried meat.

Skerpikjöt

The processing of "skerpikjöt" is described in a *cand brom* report by Beinta í Bø (Annual Report of Heilsufrödiliga Starvstovan 1990). The study was carried out in 1988-1989. The meat was from 40 foreparts which came from and were processed at the farm Kirkjuböur. The lambs had all grazed in the same field.

There were small changes in water activity during the first month of processing but then it dropped gradually from 0.965 to 0.90 in the beginning of January but changed very little after that. The percentage of dry matter changed from being 30% to about 45-50% during six moths of processing. The weight loss at the same time was about 35%.

There was a clear evidence of proteolysis. Total volatile nitrogen (TVN) increased very sharply until the beginning of January when it reached a level of 400 mg/ 100g but changed very little after that. The protein degradation was very fast the first two – three months and then slowed downs. The protein degradation was accompanied by an increase in the pH of the meat from 6.4 to 6.8-7.4. The pH dropped again in February, presumably due to yeast fermentation of carbohydrates in the meat.

Fat degradation was only studied in intamuscular fat by measuring TBA. Thiobarbituric acid (TBA) increased from 0 mmol – 30 mmol malonaldehyde/kg. This means that there had been a continuous fat hydrolysis and fat oxidation.

The total number of bacteria increased very little during the six months, being about 10^8/g inside the meat. The number of yeasts increased but proteolytic and sulfite-reducing bacteria decreased as drying continued. The meat had become so dry in January that bacteria could no longer grow in it and moulds and yeasts took over. They were airborne from the natural surroundings of the "hjallur". The conditions for the microbes changed during processing and fewer types could grow. *Micrococcus* was predominant in the surface layer and *Pseudomonas* inside the meat. But the changes after that were not as expected. Either *Enterobactericeae* or *Micrococcus* changed on being predominant both on the surface and inside the meat.

Air dried ham

Many scientific reports have been written on the chemical changes which take place during the processing of air dried ham in different countries. Desired flavour and texture develop during many months of processing as the consequence of protein and fat degradation, that is proteolysis and lipolysis (Toldrá *et al*., 2000). The formation of the flavour that gives the desired taste and odour is due to a complex combination of chemical reactions, involving enzymes, fat oxidation, Maillard reactions, Strecker degradation and more. Over 260 volatiles have been analysed in dried ham (Toldrá, 1998). But the foundation of the quality is in the raw material and the technology applied during processing. One important factor is the thickness of the subcutaneous fat that affects the quantity of fat in the underlying muscle

tissue (García-Garrido *et al*., 2000). The age at slaughter can affect the colour, amount of fat in the muscle and the activity of proteases. (Sárraga *et al*., 1993). Raised temperature at the end of the process can increase the risk of defects like too soft hams and colour changes (Martin *et al*., 1998).

Proteolysis

The activity of proteases during the processing of raw ham leads to the formation of small peptides and free amino acids (Toldrá and Flores, 1999). The chemical reactions are much more complicated during the processing of dried meat, with many types of proteases involved and with great changes in the microstructure of the meat (See Fig.1.1)

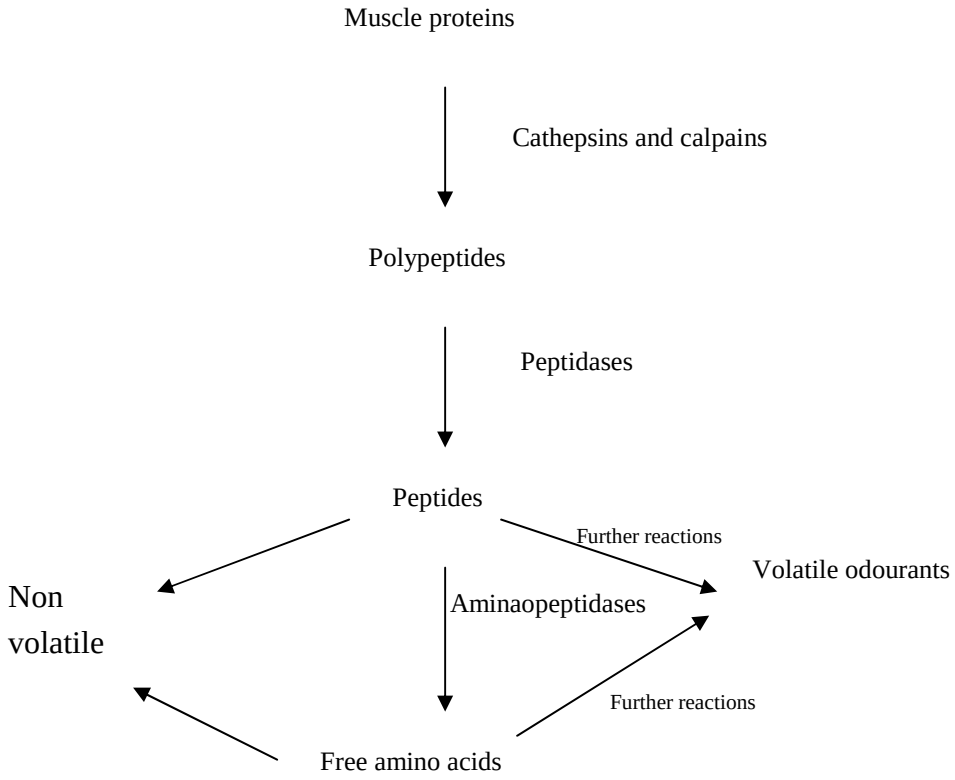

Figure 1.1. Main step in the *post-mortem* degradation of muscle

Lipolysis

The variation in the flavour and odour of air dried ham has been linked to the amount, composition and the degradation of the fat during processing. The fat goes both through autoxidation and enzymatic oxidation during processing (see Fig 1.2). The action of lipases lead to the accumulation of free fatty acids that are autoxidised and form volatile chemicals

with a certain taste and odour that are characteristic for the relevant type of air dried ham (Timón, *et al.*, 2001). The free fatty acids in the final product are also characteristic for every type of air dried ham and depend on the type of feed given to the pigs. The degradation enzymes of the fat depot are both in the adipose and muscle tissue.

Most of the fat degradation takes place during the first five months of processing (Gonzalez and Ockerman, 2000; Toldrá, 1998). It depends partly on temperature which can both reduce and increase enzyme activity. The accumulation of free fatty acids during the first five months is due to the high lipase activity at the beginning of the process. The taste and odour of the fatty acids depend to a great extent on their melting point. They are the precursors of flavour and odour chemicals in the final product that are believed to form when free fatty acids react with protein degradation products like peptides and amino acids.

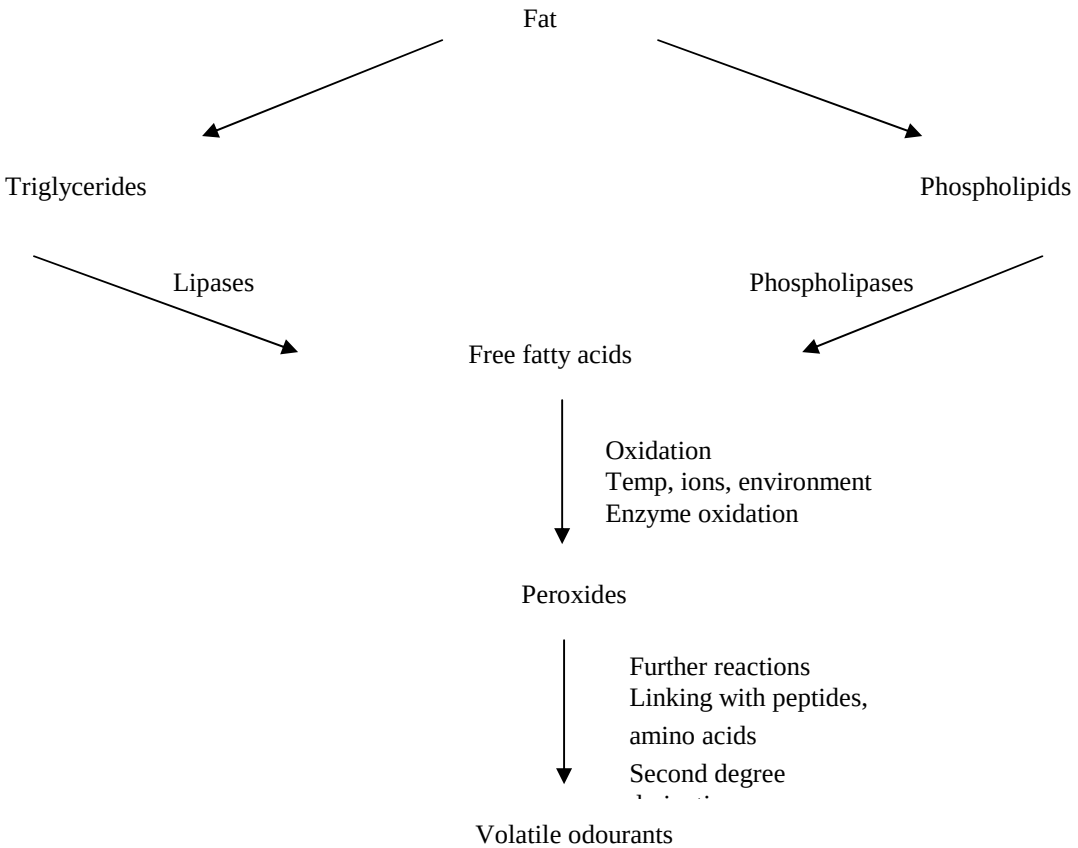

Figure1. 2. Flow diagram of the major steps in the *post mortem* degradation of fat.

The aim of this project was to study the effects of the production year, progeny groups, carcass weight and sex on the fatty acid composition of subcutaneous and intamuscular fat of Faeroese lambs, ewes and rams.

2. Material and methods

2.1 Animals

Fatty acid composition of 133 lambs from two areas (progeny group V and T. i.e. each year the lambs in each group were the progeny of two different rams but not the same rams every year) on the island Streymoy in the Faeroe Islands were studied over a period of three years. In the first year, samples of 40 lambs were taken, 20 from each progeny group(V1,T1), 20 males and 20 females. In the second year, 55 lambs were studied, 23 from progeny group V2 and 32 from progeny group T2, 30 males and 25 females. In the last year, 38 lambs were studied, 18 from progeny group V3 and 20 from progeny group T3, 17 males and 21 females. Each year, two rams (sires) were slaughtered, one from each progeny group. In the last year, samples of two rams (not sires) were taken in addition.

The lambs were from 38 ewes (18 from group V and 20 from T) between 4 and 8 years old that were slaughtered in the last year, except for one from group T that was slaughtered in the second year. Two ewes from group V died during the last year and were therefore not included in the study.

The lambs were born during the months of April and May and were slaughtered when they were about five months old. They stayed with the ewes, unweaned, until they were slaughtered. All the lambs were only fed grass and grazed on upland flora the whole period from May until October.

All the sheep were slaughtered in the same commercial slaughterhouse. After slaughter, hot carcass weight was determined and the carcasses were then chilled at 2°C for 24 hours in a conventional chiller.

From each carcass 150-200 g samples were taken from loin muscle *(M. longissimus dorsi)* and subcutaneous fat, between the 9th - 10th rib, and analysed for fatty acid composition. The samples were vacuum-packed and stored at -20°C until analysis.

2.2 Fatty acid composition

The intramuscular fat was extracted by the method of Bligh & Dyer (1959), using a chloroform/methanol/water mixture (v:v:v/2:2:1.8). The subcutaneous fat was extracted with chloroform. Fatty acids were converted to methyl esters by base-catalysed

transesterification, any free acids in the fat were esterified by subsequent reaction with BF_3/CH_3OH. The methyl esters were analysed by gas chromatography on an Omegawax 320 capillary column; 30 m x 0.32 ID fused silica (Supelco, Bellefonte, PA). Injector and detector temperature were 300°C and 310°C respectively. The column was programmed as follows: 160°C for 2 minutes, then raised to 210°C at 3°C/min, and this temperature was then maintained for 10 minutes.

Fatty acids were quantified, using tricosanoic acid methyl ester (23:0) added prior to saponification as an internal standard. Peaks were identified, using standards when available (Sigma Chemical Co, Ltd). Systematic and trivial names of fatty acids analysed in the project can be seen in Appendix 2 (Table A4).

2.3 Data analysis

Differences in the fatty acid profiles of lambs in subcutaneous fat and intramuscular fat of the progeny groups and sexes, as well as their interactions were analysed by analysis of variance, using the General Linear Model (GLM) procedure of the Number Cruncher Statistical Software (NCSS) 2000. Carcass weight was included as a linear covariate. The age of the lambs did not influence the fatty acid composition and was therefore not included.

One way ANOVA was used for statistical analysis of ewes.

Principal Component Analysis (PCA) was performed to study the main variance in the data set by the Unscrambler 7.5 software package (CAMO A/S). The fatty acid results were standardised to equal variance prior to PCA.

3 Results and discussion

3.1 Carcass weight

Table 3.1 shows the effect of progeny group and sex on the carcass weight for all three years. The average carcass weight was 15.4 kg in 1997, 15.3 kg in 1998 and 15.1 kg in 1999. The difference between the years was not significant. There was no significant difference between the progeny group but the weight difference between males and females was statistically significant ($p < 0.05$) all the years.

TABLE 3.1. Effect of groups (V and T) and sex on carcass weight (kg) of lambs (mean±standard error).

Year	n	Progeny group (G)				Sex (S)				Significance	
		V		T		Females		Males		G	S
1997	40	14.8	±0.6	16.0	±0.6	14.4	±0.6	16.4	±0.6		*
1998	55	15.7	±0.5	15.0	±0.4	14.5	±0.5	16.2	±0.5		*
1999	38	16.6	±0.6	14.6	±0.6	14.2	±0.5	16.0	±0.6		*

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$

3.2 Subcutaneous fat

Lambs

The fatty acid composition of subcutaneous fat in lambs for the years 1997, 1998, and 1999 are shown in Tables 3.2, 3.3, and 3.4, respectively. PCA biplots for the same results can be seen in Appendix 1 (Figures A1, A2 and A3, respectively).

The effect of carcass weight on the composition of many fatty acids was statistically significant although the influence was not the same between years. If all the years are taken into account, the main tendency is that with increased carcass weight the concentrations of the saturated fatty acids C10:0, C12:0, C14:0, and C20:0 decreased and to some extent C15:0, C16:0, C18:0 and C19:0 but the concentration of C17:0 increased. The concentrations of C18:1 increased with carcass weight while C14:1 decreased. This is in agreement with L'Estrange and Hanrahan (1980) who reported a decrease in C18:0 and an increase in C18:1 with increased carcass weight.

Small changes were seen for C16:1 and C20:1. The only polyunsaturated fatty acids identified in subcutaneous fat were C18:2n-6 and C18:3n-3. The concentration of both of these fatty acids decreased with carcass weight, although small changes were detected for C18:2n-6. In general, with increased carcass weight the total proportion of saturated fatty

acids and polyunsaturated fatty acids decreased while the total proportion of monounsaturated fatty acids and unidentified increased.

Three main fatty acids (C16:0, C18:0 and C18:1) represent the major part (on average 78.5%) of the total fatty acid composition in subcutaneous fat. This is akin to that which has been reported by other researchers (Bas *et a*l., 2000; Sañudo *et al*., 1998).
The subcutaneous fat in lambs, ewes and rams did not contain measurable quantities of C20 and C22 polyunsaturated fatty acids. This is probably due to the low proportion of phospholipid in the adipose fraction and the failure of ruminant adipose tissue to incorporate these fatty acids into the triacylglycerols, despite the fact that they are not hydrogenated by the rumen (Ashes *et al*., 1992; Enser *et al*., 1996).

A significant difference between progeny groups was only detected in the first year (1997, Table 3.2). The concentration of C16:0 and C16:1 were higher in progeny group T1 than in progeny group V1, but the concentration of C 17:0 and C 18:0 were higher in progeny group V1 than in progeny group T1.
A difference between breeds (production systems) in fatty acid composition of subcutaneous fat and muscle has often been reported but a difference between progeny groups within breeds has seldom been reported. A Greek study on suckling lambs, slaughtered six week old, showed a difference in melting point and fatty acid composition of tail and perinephric fat between breeds (Zygiyohannis *et al.,* 1985). L'Estrange *el al.* (1980) found a difference between breeds in melting point in subcutaneous rib fat. It was explained by a difference in C18:0 and C18:1. C18:0 decreased and melting point lowered with increased carcass weight. In the EU-FAIR project on the quality and composition of lamb meat from production systems in six European countries, a clear difference was observed between feed types. Lamb types, fed entirely on milk, had high proportions of the short chain fatty acids, C12:0, C14:0 and C16:0 and the lowest proportion of C18:0 in the subcutaneous fat. The forage (grass) fed types had the lowest proportion of C18:2 and the highest proportions of C18:3 and C22:5 and softer fat. The proportion of the polyunsaturated n-3 fatty acids in the forage fed increased with colder climate and was highest in the Icelandic lambs and second highest in the UK lambs (Enser. *et al*., 2000).

In the first year, significant differences between males and females were observed in the proportions of C15:0, C19:0 and C20:0 which were higher in males than in females, and in C18:1 which was higher in females than in males. In the second year (1998, Table 3.3), no significant difference was detected but in the last year (1999, Table 3.4), the only difference detected was in the proportion of C15:0 and C16:1 which were higher in males than in females. The total concentration of saturated fatty acids was 52-54%, 37-40% monounsaturated and the proportion of polyunsaturated fatty acids was 1.8-2%. There was

never a significant difference between the different sexes. The same is observed when looking at the ratio between C18:0 and C18:1 which was from about 0.62 to 0.67. This ratio may indicate how soft the fat is, the lower the ratio the softer the fat. Sañudo *et al.* (1998) observed significant differences between males and females in subcutaneous fat in the proportions of C12:0, C14:0 and C16:0 which were higher in males than in females, and in C17:0, C18:0 and C20:0 which were higher in females than in males. In general, subcutaneous fat of males was significantly more saturated than in females. The proportion of polyunsaturated fat was almost the same in both sexes. In a study by Kemp *et al.* (1981), the subcutaneous fat of rams had a higher percentage of C16:1 and total unsaturated fatty acids but a lower percentage of C18:0 than did subcutaneous fat of wethers. They noted that rams had softer fat because the subcutaneous fat contained more unsaturated fatty acids. Crouse *et al.* (1972) did not find differences in fatty acid content attributed to carcass weight, which was associated with increasing quantities of fat. Similarly, the findings of Solomon *et al.* (1992) did not indicate significant differences due to sex in total unsaturated fatty acids. There can be a sex difference in the fatty acid composition of lamb. A study in Wyoming, USA, showed that the melting point of ram fat decreased with increasing weight, no such effect was observed in wethers. Subjective evaluation showed wethers to have firmer, flakier fat than rams. Flavour intensity was greater for rams than for wethers (Vimini *et al.*, 1984). The Icelandic ram lambs and Christmas ram lambs in the EU-Fair project also had softer subcutaneous fat than the ewe lambs.

Ewes

The fatty acid composition of subcutaneous fat in ewes is shown in Table 3.5. No significant differences were detected between the groups ($P>0.05$). As in lambs, the three main fatty acids in subcutaneous fat were C16:0, C18:0 and C18:1 which were on the average 84.4% of the total fatty acid composition.

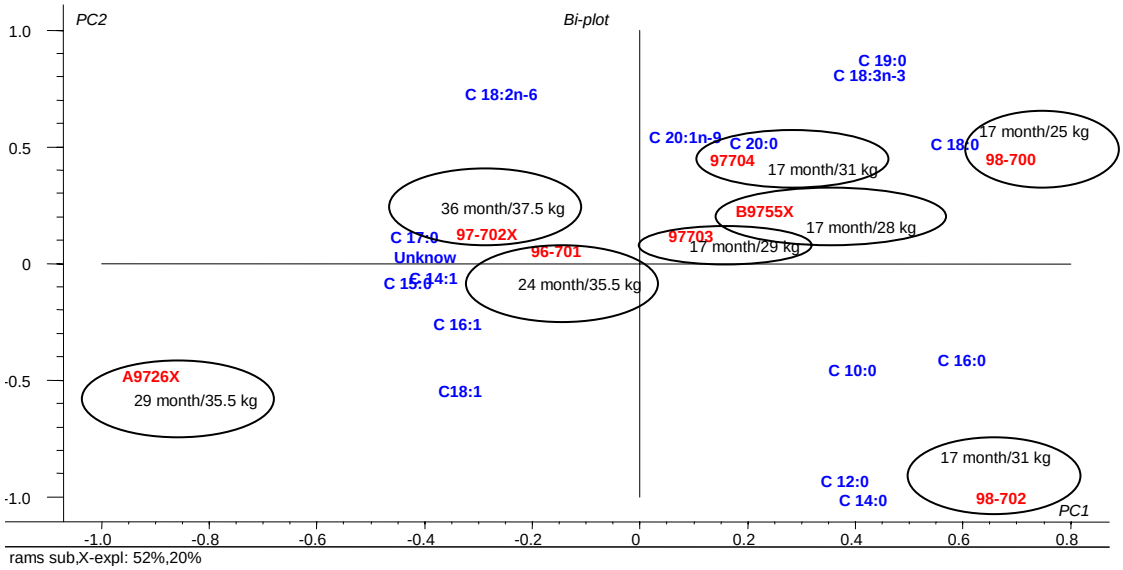

Figure 3.1. PCA biplot of fatty acid composition (% fatty acid methyl esters) of subcutaneous adipose tissue in each ram in the project, labelled with age, weight and an identification number.

Rams

The fatty acid composition of subcutaneous fat in each ram in the project is shown in Table 3.6. Rams A9726X, 97-703 and 98-700 were sires in group V the year 1997, 1998, and 1999, respectively and rams B9755X, 97-704 and 98-702 in group T in the same order. Two rams, 97-702X and 96-701, were not sires. Principal component analysis (PCA) was used (Figure 3.1) to examine the main difference between the fatty acid composition of the rams. The first two principal components explain 72% of the variance in the data set, 52% by PC1 and 20% by PC2, respectively. PC1 mainly describes the difference in the carcass weight and age of the rams. The heavier and older rams are located on the left side of the plot but they contained higher contents of the odd-chain saturated fatty acids C15:0 and C17:0 and the total concentration of unknown was also higher. This is in agreement with Busboom *et al.* (1981) who found that fat from rams was higher in branched chain fatty acids and shorter chain fatty acids with odd numbers of carbon atoms, but lower in 16:0 and 18:0 compared to fat from wethers. The monounsaturated fatty acids C16:1 and C18:1, which were the dominating fatty acids, were in higher concentration in the heavier and older rams. The concentration of the saturated fatty acids C16:0 and C18:0 were higher in the younger and lighter rams which are located on the right side on the PCA plot. They were all at the same age when slaughtered but at different weight, the ram 98-700 being lightest and leanest and with a similar fatty acid compostition as the ewes.

The ratio between C18:0 and C18:1 was lowest in the older and heavier rams, indicating softer fat. Vimini *et al.* (1984) noticed that as ram lambs became heavier, softer fat with lower melting points was observed, but this change with weight was not apparent for wethers.

3.3 Intramuscular fat

Lambs

The fatty acid content of muscle in lambs is shown quantitatively (mg/100 g muscle) for each year in Table 3.7, 3.8, and 3.9, and the composition qualitatively (per cent of total fatty acids) in Tables 3.10, 3.11, and 3.12. PCA biplots for the same results (%FAME) can be seen in Appendix 3 (Figures A4, A5 and A6).

Carcass weight significantly affected the quantity (mg/100 g muscle) of many fatty acids, although the influence was not the same between years. In the first year (1997, Table 3.7), the content of C10:0, C12:0, C14:0, C14:1, C15:0, C16:0 and C16:1 increased significantly with increased carcass weight. The carcass weight did not have an effect on the content of long chain polyunsaturated fatty acids. In the second year (1998, Table 3.8), the influence of carcass weight was seen for more fatty acids showing increased content with increased carcass weight. In the last year (1999, Table 3.9), the effect of carcass weight was not as obvious as had been detected earlier . When looking at the qualitative composition, the results were inconsistent. In the first and the last years (Table 3.10 and 3.12), the effect of carcass weight was more obvious than for the quantitative results but in the second year (Table 3.11) the effect of carcass weight on the qualitative content was insignificant.

As for the subcutaneous fat, the major fatty acids in intramuscular fat were C16:0, C18:0, and C18:1 (76.1%). There was no significance difference between progeny groups or sexes in the concentration of intramuscular fat (total methyl ester, Table 3.7, 3.8, and 3.9) although female lambs tend to have more fat than males. The first year the quantitative content of C10:0, C16:0, C16:1, C20:5n-3 C22:5n-3 and unidentified fatty acids were higher in progeny group T1 than in progeny group V1. There were no differences in the proportion of saturated or unsaturated fatty acids between progeny group. Significant differences between sexes were observed in the content of C10:0, C12:0, C14:0, C14:1, C16:0 and C16:1 which were higher in females than in males, and in C22:5n-3 which was higher in males than in females. The later years the difference between progeny groups and sexes was insignificant but the last year some interaction between progeny groups and sexes was observed.

When looking at the composition qualitatively, the difference between progeny group and sexes is more obvious. The difference between progeny group is mainly in the content of C10 to C18 fatty acids. The main difference between sexes is in the content of polyunsaturated fatty acids that appears to be somewhat higher in males compared to females.

Effects of sex on fatty acid composition were demonstrated by Solomon *et al.* (1992) who found that rams had greater proportion of 18:1, as well as 18:0, in lipids of longissimus muscle than ewes. Kemp *et al.* (1981) compared rams and wethers and found that

intramuscular fat of rams contained a higher percentage of 16:1, 18:2 and 18:3 than wethers. Sañudo *et al.* (1998) did not find any significant differences between males and females in intramuscular fat.

Ewes

The quantitative (mg/100 g) fatty acid composition of muscle in ewes is shown in Table 3.13 and the qualitatively (per cent of total fatty acids) fatty acid composition in Table 3.14. The only qualitative difference between groups was seen in the content of C18:0 which was higher in group V but no significant difference was detected between the groups for other fatty acids.

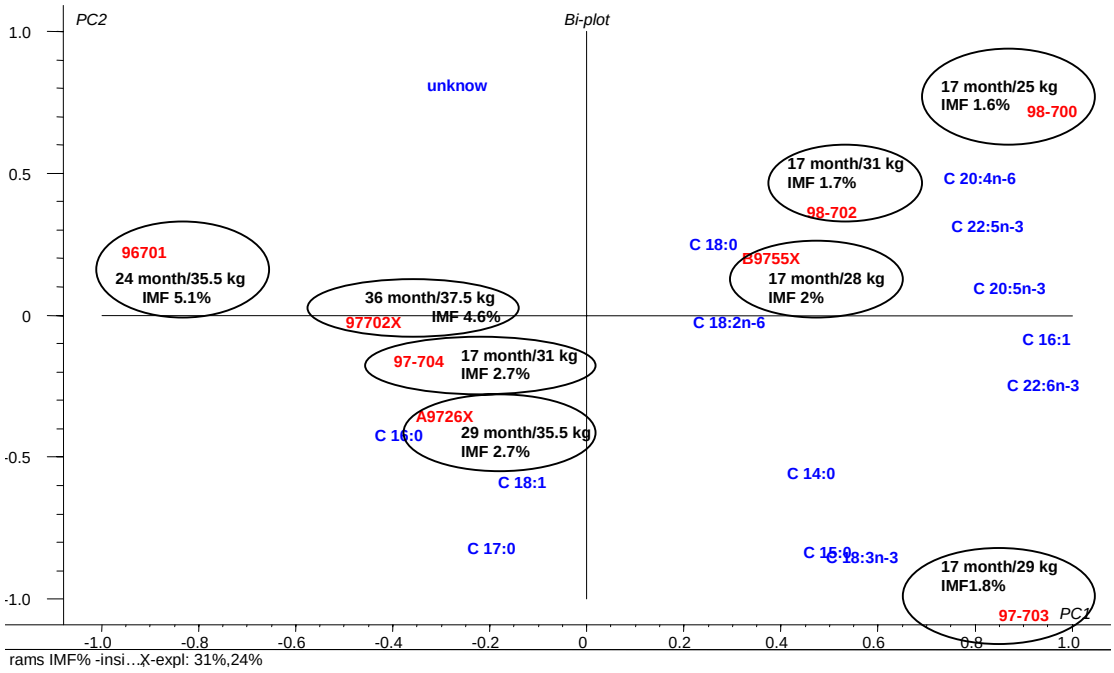

Figure 3.2. PCA biplot of fatty acid composition (% fatty acid methyl esters) of muscle tissue in each ram in the project, labelled with age, weight, % intramuscular fat (IMF) and an identification number. Some fatty acids in minor quantity were eliminated from the PCA.

Rams

The quantitative (mg/100 g) fatty acid composition of muscle in rams is shown in Table 3.15 and the qualitative (per cent of total fatty acids) fatty acid composition in Table 3.16. Figure 3.2 shows a PCA biplot for the qualitative results. Some fatty acids with insignificant quantity were left out. The first two principal components explain 54% of the variance in the data set, 30% by PC1 and 24% by PC2. PC1 describes to some extent the difference in carcass weight and age of the rams, similar to that which was seen for the subcutanous fat. However, the intramuscular fat content appears to be more important for the distribution of the samples, since the ram with the highest content of intramuscular fat lies on the left side of

the plot and the rams with the lowest amount on the right side and the content decreases from left to right.

3.4 Comparison between lambs, ewes and rams

Subcutaneous fat

Figure 3.3 shows a PCA biplot of fatty acid composition (%FAME) in subcutaneous fat in lambs from 1999, in ewes and in rams. To simplify the comparison, only lambs from 1999 were selected. The first two PCs explained 62% of the variation in the data set, 36% by PC1 and 26% by PC2. PC1 mainly describes the difference between ewes versus lambs and rams while PC2 describes the difference between lambs and rams. The samples can be classified into these three groups, i.e. ewes, lambs and rams, although two of the rams (98-700 and 98-702) fall into the two other groups. From the picture, it can be seen that ewes contain higher concentration of C18:0 than lambs and rams but lower concentration of C18:1. Solomon *et al.* (1990) found that at higher slaughter weights, rams had a higher percentage of unsaturated fatty acids than ewes. Lambs contain more of C10:0 and particularly C12:0 and C14:0, fatty acids presumably derived from the milk (Sañudo *et al*., 1998). The concentration of unknown and the odd chain saturated fatty acid C17:0 were higher in rams compared to ewes and lambs.

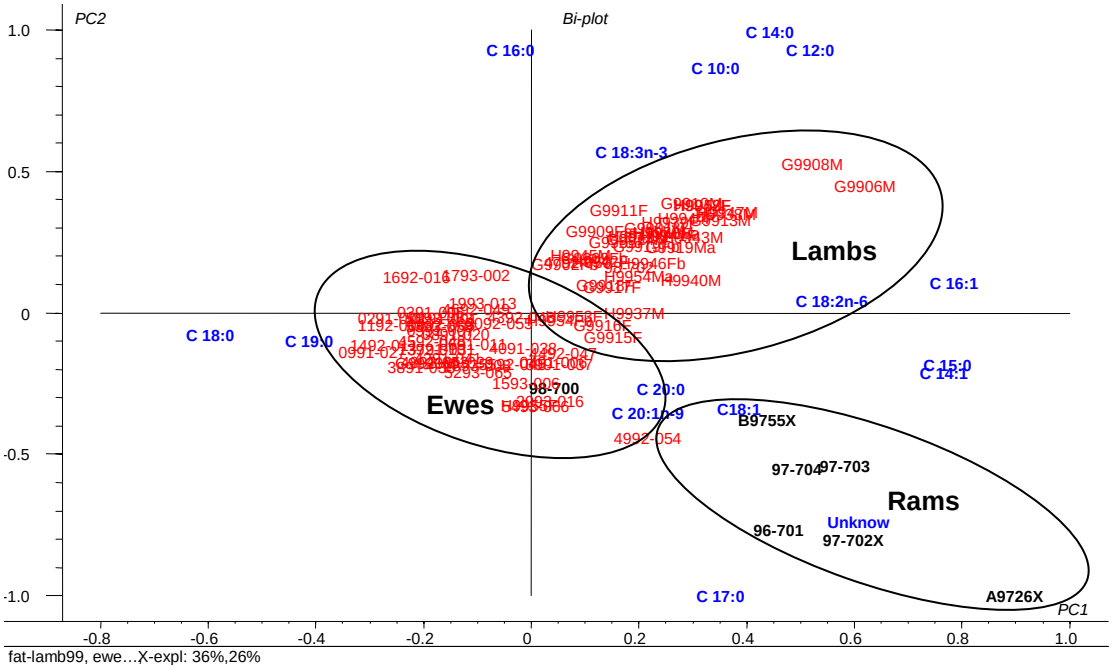

Figure 3.3. PCA biplot of fatty acid composition (%FAME) of subcutaneous fat in lambs from 1999 and in ewes and rams. The first letter in each mark of the lambs indicate the progeny group (G=progeny group V3 and H=progeny group T3). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

Intramuscular fat

Figure 3.4 shows a PCA biplot of fatty acid composition (%FAME) in muscle tissue in lambs from 1999, in ewes and in rams. The comparison was done in the same way as for subcutaneous fat. The first two PCs explained 56% of the variation in the data set, 45% by PC1 and 11% by PC2. PC1 mainly describes the difference between ewes and lambs as can be seen in the figure. The difference can be explained by a higher content of long chain polyunsaturated fatty acids in lambs and also in a higher content of saturated fatty acids that are derived from the milk (C12:0, C14:0 and C10:0). The concentration of C16:0 and C18:0 were higher in ewes compared to lambs. Rams (bold letter in Figure 3.4) are not classified as easily from ewes and lambs but they all lie in the lower part of the plot. High proportion of C18:1 and low proportion of C10:0 in rams seems to be the main difference between rams versus ewes and lambs.

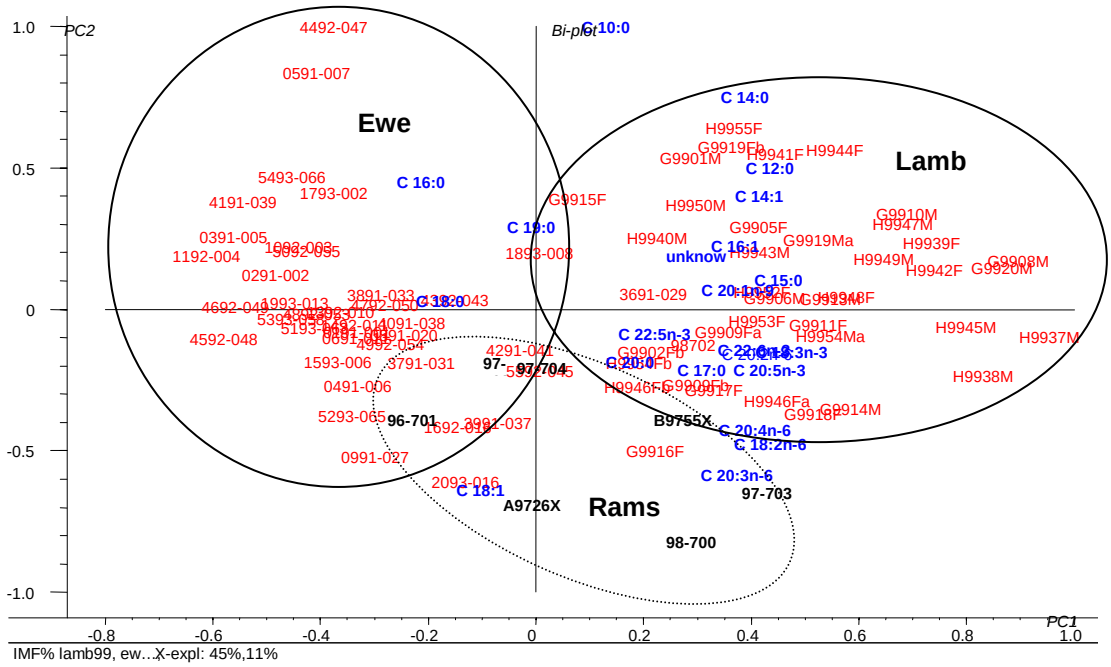

Figure 3.4. PCA biplot of fatty acid composition (%FAME) of muscle tissue in lambs from 1999 and in ewes and rams (bold letter). The first letter in each mark for the lambs indicate the progeny group (G=progeny group V3 and H=progeny group T3). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

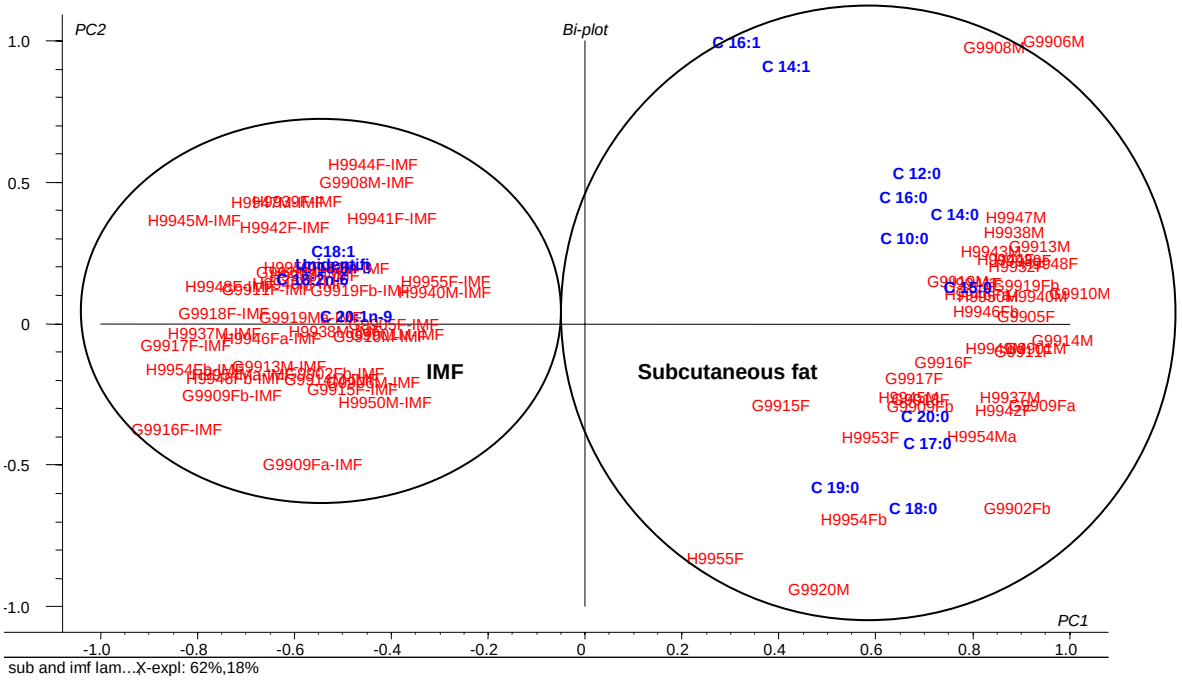

Figure 3.5 PCA biplot of fatty acid composition (%FAME) of intramuscular fat (IMF) and subcutaneous fat in lambs from 1999. The first letter in each mark indicate the progeny group (G=progeny group V3 and H=progeny group T3). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

Subcutaneous fat versus intramuscular fat

To study the main difference between the subcutaneous fat and intramuscular fat, a PCA was done on fatty acid composition (%FAME) of lambs from 1999 as shown in Figure 3.5. The most obvious difference was in the content of C20 and C22 polyunsaturated fatty acids which were not in measurable quantities in subcutaneous fat. Therefore, those fatty acids were not included in the PCA. The first two PCs explained 80% of the variation in the data set, 62% by PC1 and 18% by PC2. PC1 explains clearly the difference in fatty acid composition between intramuscular fat and subcutaneous fat. The intramuscular fat is described by higher content of C18:0, C18:2n-6, C18:3n-3, C20:1 and unidentified and all the samples lie close together on the left side of the plot. Subcutaneous fat is characterised by higher content of saturated fatty acid and the monounsaturated fatty acids C14:1 and C16:1. There seems to be more variation in the fatty acid composition of subcutaneous fat as described by PC2. Kemp *et al.* (1981) found out that the primary difference between subcutaneous fat and intramuscular fat seemed to be in the relative proportions of C16:0, C18:0 and C18:1, subcutaneous fat containing more of C18:0.

4 Remarks on fatty acid composition and the quality of "skerpikjöt"

It is beyond the scope of this study to link the differences found in fatty acid composition to lipolysis and texture and flavour differences in air dried sheep meat. But one can speculate to explain in a scientific way the observation mentioned in the introduction.
The first one was that “skerpikjöt” made from rams and ram lambs have a softer fat (better) than that made from ewes and ewe lambs and that this difference is greater in the surface fat than inside the muscle. The results of this study both agree and disagree with this statement. Ewes had a higher concentrations of C18:0 and lower concentrations of C18:1 than rams and lambs in the subcutaneous fat. But ewe lambs had higher concentration of C18:1 than ram lambs. There was also a qualitative difference between the sexes in the fatty acid composition of intramuscular fat with the polyunsaturated fatty acids being higher in males than females. Rams had a higher proportion of C18:1 compared to ewes and lambs. Ewes had the highest concentration of C18:0 and C16:0. These differences in the composition of both subcutaneous and intramuscular fat could explain the observed differences in the quality of “skerpikjöt” with meat from ram lambs and especially rams being more sensitive to fat degradation and lypolysis and the formation of “glærfiti”.

The second observation was that the subcutaneous fat of lambs, which have grazed on high mountain areas, mountain facing north or mountains with many seabirds, has a softer fat (better) than other lambs. It is hardly possible to explain this observation by the results of this study. There was no group in the project that was defined well enough to compare these different grazing treatments. But there might be an indirect explanation. These grazing areas have a good and very rich upland flora and the lambs which graze there tend to yield heavier carcasses than other lambs. In this project, the amount of polyunsaturated fatty acids increased and the amounts of saturated and monounsaturated fatty acid decreased with increased carcass weight. But this is perhaps farfetched and a new study is needed to address this statement. The influence of feed can be explained with the differences in the vegetation the lambs eat and differences in energy levels.
In a study in Wyoming, a high-energy diet gave a much lower average fat melting point (30.1°C) than a low-energy diet (average 38.6 °C) (Vimini *et al.*,1984). Fisher *et al.* (2000) showed that breeds finished on grass had high levels of C18:3 and long-chain n-3 polyunsaturated fatty acids.

The third observation is about possible heredity. The heredity factor can neither be rejected or confirmed in this study. Much more detailed and constructed trial is needed for that.

In this trial, there was no connection to the processing and actual quality parameters of “skerpikjöt”. No definitions are available on qualitative (flavour profiles) and quantitative (chemical) parameters of “skerpikjöt”. These parameters are needed and there might even be definitions for the different categories of “skerpikjöt”. A project like that would complement this study very well.

5 Conclusions

The effect of carcass weight on the composition of many fatty acids in subcutaneous fat was statistically significant although the influence was not the same between years. In general, with increased carcass weight the total proportion of saturated fatty acids and polyunsaturated fatty acids decreased, while the total proportion of monounsaturated fatty acids and unidentified increased.

Three main fatty acids (C16:0, C18:0 and C18:1) represent the major part of the total fatty acid composition in subcutaneous fat in lambs, ewes and rams. The fat did not contain measurable quantities of C20 and C22 polyunsaturated fatty acids.

A significant difference between progeny groups was only detected in the first year. The concentration of C16:0 and C16:1 were higher in progeny group T1 than in progeny group V1, but the concentration of C 17:0 and C 18:0 were higher in progeny group V1 than in progeny group T1. Minor differences between the sexes were observed in the proportions of C15:0, C19:0 and C20:0 which were higher in male lambs than in female lambs, and in C18:1 which was higher in females than in males. No significant difference between the sexes was observed in the total concentration of saturated, monounsaturated or polyunsaturated fatty acids.

The main difference between the fatty acid composition of subcutaneous fat in lambs, ewes and rams was a higher concentration of C18:0 in ewes, compared to lambs and rams, but lower concentration of C18:1. Lambs contained more of C10:0 and particularly C12:0 and C14:0, fatty acids that presumably derived from the milk. The concentration of unknown and the odd chain saturated fatty acid C17:0 were higher in rams compared to ewes and lambs.

The major fatty acids in intramuscular fat of lambs, ewes and rams were C16:0, C18:0, and C18:1. There was no significant difference between progeny groups or sexes in the total concentration of intramuscular fat in lambs, although female lambs tend to have more fat than male lambs. The difference in the qualitative fatty acid composition between progeny groups and sexes was more obvious than quantitative difference. The difference between progeny groups was mainly in the content of C10 to C18 fatty acids. The main difference between the sexes was in the content of polyunsaturated fatty acids which appears to be somewhat higher in males compared to females.

The intramuscular fat of lambs had higher content of long chain polyunsaturated fatty acids and higher content of saturated fatty acids that are derived from the milk (C12:0, C14:0 and C10:0) compared to ewes and rams. The concentration of C16:0 and C18:0 were higher in ewes compared to lambs. High proportion of C18:1 and low proportion of C10:0 in rams seems to be the main difference between rams versus ewes and lambs.

The most obvious difference between the subcutaneous fat and intramuscular fat of lambs was in the content of C20 and C22 polyunsaturated fatty acids, which were not in measurable quantities in subcutaneous fat. The intramuscular fat had higher content of C18:0, C18:2n-6, C18:3n-3, C20:1 and unidentified fatty acids. Subcutaneous fat was characterised by higher content of saturated fatty acid and the monounsaturated fatty acids C14:1 and C16:1. There appears to be more variation in the fatty acid composition of subcutaneous fat.

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Tables

TABLE 3.2. Effect of group (G) from two areas (V1 and T1) and sex (S) on fatty acid composition (% fatty acid methyl esters) of subcutaneous adipose tissue in lambs born in 1997 (mean±standard error), corrected for carcass weight.

	Group (G)		Sex (S)			Significance		
	V	**T**	**Females**	**Males**		**G**	**S**	**carcass weight**
n	20	20	20	20				
C10:0	0.31	0.35	0.33	0.33	±0.02			
C12:0	0.47	0.50	0.48	0.49	±0.02			***
C14:0	5.66	5.95	5.88	5.73	±0.13			***
C14:1	0.20	0.22	0.23	0.19	±0.01			***
C15:0	0.82	0.86	0.77	0.92	±0.02		***	
C16:0	20.4	21.7	21.0	21.1	±0.24	**		**
C16:1	2.12	2.33	2.25	2.20	±0.05	**		***
C17:0	1.51	1.34	1.39	1.45	±0.02	***		***
C18:0	22.9	21.3	21.6	22.7	±0.34	**		***
C18:1	35.0	34.8	35.4	34.4	±0.38		*	**
C18:2n-6	0.57	0.57	0.55	0.60	±0.03			
C19:0	0.20	0.19	0.18	0.21	±0.01		*	*
C18:3n-3	0.84	0.87	0.84	0.87	±0.03			
C20:0	0.25	0.26	0.24	0.28	±0.01		*	***
C20:1	0.10	0.08	0.08	0.10	±0.01			*
Unidentified	8.07	8.12	8.29	7.90	±0.20			*
Saturated	52.6	52.5	51.9	53.2	±0.45			***
Monounsaturated	39.4	39.4	39.8	38.9	±0.41			**
Polyunsaturated	1.97	2.03	1.96	2.04	±0.05			
C18:0/C18:1	0.66	0.62	0.62	0.66	±0.02			***

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.3. Effect of group (G) from two areas (V2 and T2) and sex (S) on fatty acid composition (% fatty acid methyl esters) of subcutaneous adipose tissue in lambs born in 1998 (mean±standard error) corrected for carcass weight.

	Progeny group (G)		Sex (S)		Significance		
	V2	T2	Females	Males	G	S	Carcass weight
n	23	32	25	30			
C10:0	0.48 ±0.06	0.49 ±0.05	0.49 ±0.05	0.48 ±0.05			
C12:0	0.49 ±0.03	0.46 ±0.03	0.47 ±0.03	0.48 ±0.03			
C14:0	5.69 ±0.23	5.41 ±0.20	5.62 ±0.22	5.47 ±0.20			
C14:1	0.44 ±0.01	0.44 ±0.01	0.44 ±0.01	0.44 ±0.01			
C15:0	0.89 ±0.03	0.83 ±0.03	0.83 ±0.03	0.90 ±0.03			*
C16:0	21.9 ±0.32	21.3 ±0.27	21.7 ±0.31	21.6 ±0.28			
C16:1	2.21 ±0.06	2.12 ±0.05	2.17 ±0.05	2.16 ±0.05			*
C17:0	0.76 ±0.04	0.75 ±0.04	0.75 ±0.04	0.76 ±0.04			**
C18:0	21.9 ±0.39	22.1 ±0.33	22.0 ±0.37	22.0 ±0.34			***
C18:1	34.3 ±0.38	34.0 ±0.32	34.1 ±0.37	34.2 ±0.34			
C18:2n-6	1.10 ±0.04	1.14 ±0.04	1.14 ±0.04	1.10 ±0.04			
C19:0	0.27 ±0.06	0.38 ±0.04	0.36 ±0.05	0.29 ±0.05			
C18:3n-3	0.82 ±0.04	0.85 ±0.04	0.80 ±0.04	0.88 ±0.04			*
C20:0	1.35 ±0.08	1.31 ±0.07	1.33 ±0.08	1.33 ±0.07			
C20:1	0.47 ±0.05	0.47 ±0.04	0.50 ±0.05	0.44 ±0.05			
Unidentified	7.14 ±0.37	8.0 ±0.31	7.11 ±0.35	8.01 ±0.32			
Saturated	53.6 ±0.56	53.0 ±0.47	53.6 ±0.53	53.0 ±0.49			*
Monounsaturated	37.2 ±0.38	36.9 ±0.33	37.2 ±0.37	37.0 ±0.34			*
Polyunsaturated	1.92 ±0.10	1.93 ±0.07	1.88 ±0.09	1.96 ±0.09			
C18:0/C18:1	0.64 ±0.02	0.65 ±0.01	0.65 ±0.02	0.65 ±0.01			***

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.4. Effect of group (G) from two areas (V3 and T3) and sex (S) on fatty acid composition (% fatty acid methyl esters) of subcutaneous adipose tissue in lambs born in 1999 (mean±standard error) corrected for carcass weight.

	Group (G)		Sex (S)		Significance		
	V3	T3	Females	Males	G	S	Carcass weight
n	18	20	21	17			
C10:0	0.26 ±0.02	0.23 ±0.01	0.24 ±0.01	0.25 ±0.02			
C12:0	0.39 ±0.03	0.37 ±0.03	0.35 ±0.03	0.42 ±0.03			
C14:0	5.35 ±0.25	5.19 ±0.24	5.03 ±0.23	5.52 ±0.26			
C14:1	0.17 ±0.01	0.16 ±0.01	0.15 ±0.01	0.18 ±0.01			
C15:0	0.73 ±0.02	0.72 ±0.02	0.67 ±0.02	0.78 ±0.02		**	
C16:0	22.0 ±0.27	22.3 ±0.26	22.0 ±0.25	22.3 ±0.28			*
C16:1	1.87 ±0.05	1.90 ±0.05	1.81 ±0.05	1.97 ±0.06		*	
C17:0	1.29 ±0.04	1.32 ±0.04	1.32 ±0.03	1.29 ±0.04			
C18:0	23.4 ±0.68	22.3 ±0.64	23.3 ±0.63	22.9 ±0.70			*
C18:1	34.6 ±0.31	35.4 ±0.29	35.2 ±0.28	34.8 ±0.32			*
C18:2n-6	1.07 ±0.02	1.08 ±0.02	1.05 ±0.02	1.10 ±0.02			*
C19:0	0.21 ±0.01	0.20 ±0.01	0.21 ±0.01	0.20 ±0.01			*
C18:3n-3	0.78 ±0.02	0.80 ±0.02	0.77 ±0.02	0.82 ±0.02			
C20:0	0.23 ±0.01	0.24 ±0.01	0.22 ±0.01	0.25 ±0.01			***
C20:1	0.07 ±0.01	0.04 ±0.01	0.07 ±0.01	0.04 ±0.01			
Unidentified	7.56 ±0.13	7.69 ±0.12	7.60 ±0.12	7.65 ±0.13			
Saturated	53.7 ±0.04	53.0 ±0.38	53.6 ±0.37	53.2 ±0.41			
Monounsaturated	36.7 ±0.35	37.5 ±0.33	37.2 ±0.32	37.0 ±0.36			*
Polyunsaturated	1.86 ±0.04	1.87 ±0.04	1.80 ±0.04	1.93 ±0.04			*
C18:0/C18:1	0.68 ±0.02	0.63 ±0.02	0.67 ±0.02	0.65 ±0.02			*

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.5. Effect of group from two areas (V and T) on fatty acid composition (% FAME) of subcutaneous adipose tissue in ewes (mean±standard error), corrected for carcass weight..

	Group (G)				Significance
	V		T		G
n	18		20		
C10:0	0.18	±0.02	0.16	±0.02	
C12:0	0.09	±0.01	0.10	±0.02	
C14:0	2.58	±0.11	2.66	±0.10	
C14:1	0.07	±0.02	0.11	±0.01	
C15:0	0.46	±0.03	0.52	±0.02	
C16:0	21.7	±0.31	21.3	±0.30	
C16:1	1.36	±0.04	1.45	±0.04	
C17:0	1.43	±0.05	1.41	±0.05	
C18:0	28.8	±0.73	27.2	±0.69	
C18:1	34.4	±0.62	35.5	±0.59	
C18:2n-6	0.92	±0.03	0.99	±0.02	
C19:0	0.24	±0.01	0.23	±0.01	
C18:3n-3	0.71	±0.04	0.74	±0.04	
C20:0	0.21	±0.04	0.28	±0.04	
C20:1	0.07	±0.04	0.10	±0.04	
Unidentified	6.88	±0.21	7.32	±0.20	
Saturated	55.6	±0.7	53.7	±0.7	
Monounsaturated	35.9	±0.6	37.2	±0.6	
Polyunsaturated	1.63	±0.07	1.73	±0.06	
C18:0/C18:1	0.85	0.03	0.77	0.03	

There was no significant difference between progeny groups

TABLE 3.6. Fatty acid composition (% fatty acid methyl esters) of subcutaneous adipose tissue in each ram in the project.

	Group V			Group T				
Ram no.	**A9726X**	**97703**	**98-700**	**B9755X**	**97704**	**98-702**	**96-701**	**97-702X**
from the year:	1997	1998	1999	1997	1998	1999		
age (month):	29	17	17	17	17	17	24	36
carcass weight (kg):	35.5	29	25	28	31	31	35.5	37.5
C10:0	0.14	0.20	0.14	0.22	0.20	0.26	0.08	0.09
C12:0	0.08	-	0.08	0.09	0.10	0.34	0.06	0.08
C14:0	2.09	2.40	2.11	2.39	2.10	5.03	1.69	1.82
C14:1	0.47	0.30	0.10	0.37	0.30	0.16	0.38	0.27
C15:0	1.61	1.20	0.59	1.02	1.00	0.63	1.07	1.05
C16:0	16.6	18.8	20.4	19.8	18.4	22.4	18.4	17.5
C16:1	3.13	2.20	1.88	2.13	2.30	1.91	1.82	2.17
C17:0	2.93	2.00	1.59	2.18	1.70	1.21	2.61	2.97
C18:0	8.5	20.2	26.5	21.8	22.9	22.2	19.1	16.0
C18:1	39.7	36.3	30.5	36.0	36.3	36.4	37.1	39.1
C18:2n-6	1.22	1.20	1.01	1.22	1.30	0.87	1.08	1.26
C19:0	0.10	0.20	0.23	0.23	0.20	0.16	0.18	0.16
C18:3n-3	0.46	0.60	0.81	0.79	0.70	0.61	0.56	0.72
C20:0	0.09	1.30	0.37	0.29	1.30	0.31	0.13	0.14
C20:1	0.12	0.10	0.08	0.08	0.40	0.05	0.04	0.08
Unidentified	22.7	13.0	13.6	11.4	10.8	7.4	15.7	16.6
Saturated	32.2	46.3	52.1	48.0	47.9	52.5	43.3	39.8
Monounsaturated	43.5	38.9	32.6	38.6	39.3	38.6	39.5	41.6
Polyunsaturated	1.69	1.80	1.82	2.00	2.00	1.48	1.64	1.97
C18:0/C18:1	0.21	0.56	0.87	0.61	0.63	0.61	0.51	0.41

TABLE 3.7. Effect of group (G) from two areas (V1 and T1) and sex (S) on fatty acid composition (mg/100 g muscle) of muscle in lambs born in 1997, corrected for carcass weight.

	Group (G)		Sex (S)			Significance		
	V1	**T1**	**Females**	**Males**		**G**	**S**	**Carcass weight**
n	20	20	20	20				
C10:0	4.02	5.15	4.96	4.21	±0.16	***	***	*
C12:0	5.01	5.30	5.75	4.56	±0.30		*	***
C14:0	67.2	76.9	81.5	62.6	±3.44		**	***
C14:1	3.21	3.39	4.27	2.33	±0.30		**	***
C15:0	9.22	9.80	10.15	8.87	±0.51			*
C16:0	452	526	531	447	±23	*	*	*
C16:1	45.9	54.3	56.4	43.8	±2.67	*	**	**
C17:0	22.3	22.0	23.2	21.1	±1.1			
C18:0	348	360	367	341	±16			
C18:1	935	1051	1055	931	±52			
C18:2n-6	58.7	60.4	58.5	60.7	±2.2			
C19:0	2.28	2.20	2.35	2.16	±0.23			
C18:3n-3	34.4	38.2	35.4	37.2	±1.4			
C20:0	2.95	3.78	3.53	3.20	±0.40			
C20:1	2.51	2.74	2.80	2.44	±0.29			
C20:2n-6	7.80	8.77	8.28	8.29	±0.50			
C20:3n-6	3.32	3.31	3.24	3.39	±0.29			
C20:4n-6	30.7	29.7	29.3	31.1	±1.22			
C20:3n-3	2.30	2.31	2.32	2.30	±0.27			
C20:5n-3	20.6	24.6	21.8	23.4	±0.89	**		
C22:5n-3	16.3	19.6	16.4	19.4	±0.95	*	*	
C22:6n-3	5.53	6.46	5.74	6.25	±0.44			
Unidentified	207	225	224	208	±9.4	**		
Total methyl esters	2267	2551	2520	2295	±107			
Saturated	897	1023	1004	916	±44			
Monounsaturated	984	1112	1114	981	±55			
Polyunsaturated	177	190	178	190	±5.8			
C18:0/C18:1	0.37	0.35	0.34	0.38	±0.01		**	***

There was no significant G×S interaction effect ($p > 0.05$). Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.8. Effect of group (G) from two areas (V2 and T2) and sex (S) on fatty acid composition (mg/100 g muscle) of muscle in lambs born in 1998 corrected for carcass weight.

	Group (G)		Sex (S)		Significance		
	V2	T2	Females	Males	G	S	carcass weight
n	23	32	25	30			
C10:0	3.2 ±0.21	2.7 ±0.18	3.0 ±0.20	2.9 ±0.18			
C12:0	4.6 ±0.33	3.4 ±0.27	4.26 ±0.31	3.69 ±0.29	**		*
C14:0	61.1 ±0.40	54.3 ±3.3	62.1 ±3.7	53.3 ±3.4			**
C14:1	3.8 ±0.25	3.1 ±0.20	3.4 ±0.2	3.5 ±0.2			*
C15:0	8.6 ±0.53	7.4 ±0.45	8.3 ±0.51	7.7 ±0.46			**
C16:0	422 ±25.8	435 ±21.9	444 ±24.8	413 ±22.6			**
C16:1	40.1 ±2.3	39.7 ±2.0	41.8 ±2.2	38.0 ±2.0			***
C17:0	18.8 ±1.2	18.0 ±1.0	18.6 ±1.1	18.3 ±1.0			*
C18:0	278 ±17.1	290 ±14.5	281 ±16.4	288 ±15.0			
C18:1	807 ±50.1	850 ±42.6	852 ±48.0	804 ±43.8			*
C18:2n-6	44.8 ±2.6	47.2 ±2.2	44.0 ±2.5	47.9 ±2.3			
C19:0	1.7 ±1.0	2.7 ±2.0	2.6 ±1.4	1.8 ±1.2			
C18:3n-3	30.5 ±2.0	31.3 ±1.7	29.9 ±1.9	32.0 ±1.8			
C20:0	11.4 ±1.7	13.9 ±1.4	13.6 ±1.6	11.8 ±1.5			*
C20:1	1.5 ±0.0	1.0 ±0	1.3 ±0	1.2 ±0.0			
C20:2n-6	6.9 ±0.6	7.3 ±0.8	7.0 ±0.8	7.0 ±0.6			
C20:3n-6	2.0 ±0.20	2.9 ±0.2	2.5 ±0.2	2.4 ±0.2	*		
C20:4n-6	23.1 ±1.20	24.5 ±1.0	23.6 ±1.1	24.1 ±1.0			*
C20:5n-3	17.5 ±1.0	18.4 ±0.8	18.0 ±0.9	17.9 ±0.8			
C22:5n-3	15.2 ±0.7	15.0 ±0.6	14.9 ±0.7	15.4 ±0.6			*
C22:6n-3	5.6 ±0.3	4.7 ±0.3	5.1 ±0.3	5.3 ±0.3			
Unidentified	154 ±9.4	152 ±8.0	152 ±9.0	154 ±8.2			*
Total methyl esters	1952 ±113	2015 ±96	2028 ±108	1939 ±99			*
Saturated	807 ±48.3	827 ±41.0	840 ±46.4	795 ±42.3			*
Monounsaturated	850 ±52.4	893 ±44.4	897 ±50.3	845 ±45.9			**
Polyunsaturated	141 ±7.3	143 ±6.2	137 ±7.0	147 ±6.4			
C18:0/C18:1	0.34 ±0.01	0.35 ±0.01	0.34 ±0.01	0.36 ±0.01		*	**

There was no significant G×S interaction effect ($p > 0.05$). Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.9. Effect of group (G) from two areas (V3 and T3) and sex (S) on fatty acid composition (mg/100 g muscle) of muscle in lambs born in 1999, corrected for carcass weight.

	Group (G)		Sex (S)		Significance			
	V3	T3	Females	Males	G	S	G×S	carcass weight
n	18	20	21	17				
C10:0	2.9 ±0.4	2.6 ±0.3	2.8 ±0.3	2.7 ±0.4				
C12:0	3.9 ±0.5	3.5 ±0.4	4.0 ±0.4	3.3 ±0.5				*
C14:0	48.9 ±5.4	48.0 ±5.1	55.7 ±5.0	41.2 ±5.5				*
C14:1	2.2 ±0.3	2.5 ±0.2	2.7 ±0.2	1.9 ±0.3				*
C15:0	6.6 ±0.6	6.1 ±0.6	6.9 ±0.6	5.8 ±0.7				*
C16:0	383 ±35.0	343 ±33.3	399 ±32.4	327 ±36.0				
C16:1	33.0 ±3.2	31.6 ±3.1	35.8 ±3.0	28.9 ±3.3				
C17:0	16.4 ±1.4	13.9 ±1.4	16.1 ±1.3	14.2 ±1.5				
C18:0	300 ±26.9	238 ±25.5	288 ±24.9	250 ±27.6				
C18:1	760 ±64.5	659 ±61.2	790 ±59.7	629 ±66.4				
C18:2n-6	46.2 ±3.3	40.0 ±3.1	43.8 ±3.1	42.3 ±3.4				
C19:0	2.8 ±0.4	1.5 ±0.4	2.3 ±0.4	2.0 ±0.4	*			
C18:3n-3	28.9 ±2.1	25.1 ±2.0	26.3 ±1.9	27.7 ±2.1				
C20:0	2.4 ±0.3	2.2 ±0.2	2.4 ±0.2	2.1 ±0.3				
C20:1	4.6 ±0.6	3.8 ±0.5	4.9 ±0.5	3.5 ±0.6				
C20:2n-6	7.1 ±0.5	5.6 ±0.5	6.8 ±0.5	5.9 ±0.6				
C20:3n-6	2.2 ±0.2	1.9 ±0.1	2.1 ±0.1	2.0 ±0.2			*	
C20:4n-6	25.4 ±1.8	21.8 ±1.7	24.5 ±1.7	22.8 ±1.8			*	
C20:3n-3	0.3 ±0.05	0.2 ±0.04	0.3 ±0.05	0.2 ±0.04				
C20:5n-3	18.4 ±1.2	16.0 ±1.1	16.8 ±1.1	17.6 ±1.2			*	
C22:5n-3	15.9 ±1.1	13.9 ±1.1	14.9 ±1.0	14.9 ±1.2				
C22:6n-3	3.9 ±0.4	3.1 ±0.4	3.5 ±0.3	3.6 ±0.4			**	
Unidentified	227 ±18.7	193 ±17.7	226 ±17.3	194 ±19.2				
Total methyl esters	1946 ±165	1674 ±156	1972 ±152	1648 ±169				
Saturated	770 ±69.8	657 ±66.3	774 ±64.7	654 ±71.9				
Monounsaturated	800 ±68.3	697 ±64.8	833 ±63.3	664 ±70.3				
Polyunsaturated	148 ±9.8	128 ±9.3	139 ±9.0	137 ±10.1				
C18:0/C18:1	0.40 ±0.01	0.36 ±0.01	0.35 ±0.01	0.40 ±0.01	**	**		**

Significance level: *p<0.05, **p<0.01; ***p<0.001

TABLE 3.10. Effect of group (G) from two areas (V1 and T1) and sex (S) on fatty acid composition (% fatty acid methyl esters) of muscle in lambs born in 1997 (mean±standard error), corrected for carcass weight.

	Group (G)		Sex (S)			Significance		
	V1	**T1**	**Females**	**Males**		**G**	**S**	**carcass weight**
n	20	20	20	20				
C10:0	0.18	0.21	0.19	0.19	±0.01	**		
C12:0	0.22	0.21	0.22	0.20	±0.01			***
C14:0	2.89	3.02	3.16	2.75	±0.06		***	***
C14:1	0.13	0.13	0.17	0.09	±0.01		***	***
C15:0	0.40	0.39	0.39	0.40	±0.02			
C16:0	19.5	20.8	20.5	19.8	±0.16	***	**	***
C16:1	1.97	2.13	2.17	1.94	±0.04	*	**	***
C17:0	0.97	0.88	0.91	0.94	±0.02	**		
C18:0	15.2	14.3	14.2	15.3	±0.26	*	*	***
C18:1	41.0	41.0	41.7	40.3	±0.46			
C18:2n-6	2.64	2.45	2.32	2.78	±0.11		**	*
C19:0	0.10	0.09	0.09	0.10	±0.01			*
C18:3n-3	1.58	1.52	1.46	1.65	±0.07			
C20:0	0.13	0.15	0.14	0.14	±0.01			
C20:1	0.11	0.11	0.11	0.11	±0.01			
C20:2n-6	0.35	0.35	0.34	0.37	±0.02			
C20:3n-6	0.16	0.13	0.14	0.15	±0.01			
C20:4n-6	1.43	1.19	1.22	1.40	±0.08	*		*
C20:3n-3	0.10	0.09	0.09	0.10	±0.01			
C20:5n-3	0.92	1.02	0.84	1.11	±0.05		**	**
C22:5n-3	0.73	0.77	0.60	0.91	±0.05		***	*
C22:6n-3	0.25	0.26	0.24	0.28	±0.02			
Unidentified	9.26	8.90	9.04	9.12	±0.28			
Saturated	39.5	40.1	39.8	39.8	±0.36			
Monounsaturated	51.2	51.0	51.2	51.1	±0.32			
Polyunsaturated	8.03	7.74	7.06	8.71	±0.33		**	*
C18:0/C18:1	0.37	0.35	0.34	0.38	±0.01		**	***

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.11. Effect of group (G) from two areas (V2 and T2) and sex (S) on fatty acid composition (% fatty acid methyl esters) of muscle in lambs born in 1998 (mean±standard error), corrected for carcass weight.

	Group (G)		Sex (S)		Significance		
	V2	T2	Females	Males	G	S	carcass weight
n	23	32	25	30			
C10:0	0.16 ±0.01	0.13 ±0.01	0.15 ±0.01	0.14 ±0.01	**		
C12:0	0.23 ±0.01	0.17 ±0.01	0.21 ±0.01	0.19 ±0.01	***		
C14:0	3.12 ±0.10	2.64 ±0.09	3.01 ±0.09	2.75 ±0.09	***		
C14:1	0.18 ±0.01	0.15 ±0.01	0.17 ±0.01	0.17 ±0.01	**		
C15:0	0.44 ±0.01	0.37 ±0.01	0.40 ±0.01	0.40 ±0.01	***		
C16:0	21.6 ±0.20	21.4 ±0.17	21.7 ±0.19	21.2 ±0.18		*	
C16:1	2.06 ±0.04	1.94 ±0.03	2.03 ±0.04	1.97 ±0.03	*		
C17:0	0.96 ±0.02	0.90 ±0.02	0.92 ±0.02	0.94 ±0.02	*		
C18:0	14.1 ±0.26	14.7 ±0.22	14.3 ±0.25	14.6 ±0.23			
C18:1	41.3 ±0.45	41.9 ±0.38	41.9 ±0.43	41.3 ±0.40			
C18:2n-6	2.30 ±0.07	2.42 ±0.06	2.25 ±0.07	2.47 ±0.06		*	
C19:0	0.11 ±0.00	0.21 ±0.00	0.15 ±0.00	0.18 ±0.00			
C18:3n-3	1.55 ±0.05	1.60 ±0.04	1.47 ±0.05	1.68 ±0.05		**	**
C20:0	0.56 ±0.07	0.68 ±0.06	0.63 ±0.07	0.61 ±0.06			
C20:1	0.12 ±0.00	0.08 ±0.00	0.11 ±0.00	0.09 ±0.00			
C20:2n-6	0.40 ±0.04	0.37 ±0.05	0.35 ±0.05	0.42 ±0.04			
C20:3n-6	0.12 ±0.02	0.17 ±0.02	0.15 ±0.02	0.14 ±0.02			
C20:4n-6	1.22 ±0.05	1.26 ±0.05	1.19 ±0.05	1.29 ±0.05			
C20:3n-3	1.55 ±0.05	1.60 ±0.04	1.47 ±0.05	1.68 ±0.05		**	**
C20:5n-3	0.91 ±0.05	0.97 ±0.04	0.93 ±0.04	0.94 ±0.04			
C22:5n-3	0.80 ±0.04	0.78 ±0.03	0.76 ±0.04	0.83 ±0.03			
C22:6n-3	0.03 ±0.02	0.24 ±0.02	0.25 ±0.02	0.28 ±0.02	*		
Unidentified	8.05 ±0.03	7.62 ±0.26	7.57 ±0.30	8.10 ±0.27			
Saturated	41.1 ±0.24	41.0 ±0.21	41.3 ±0.23	40.8 ±0.21			
Monounsaturated	43.5 ±0.45	44.0 ±0.38	44.1 ±0.43	43.4 ±0.39			
Polyunsaturated	7.30 ±0.27	7.40 ±0.23	7.03 ±0.26	7.67 ±0.23			
C18:0/C18:1	0.34 ±0.01	0.35 ±0.01	0.34 ±0.01	0.36 ±0.01		*	**

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.12. Effect of group (G) from two areas (V3 and T3) and sex (S) on fatty acid composition (% fatty acid methyl esters) of muscle in lambs born in 1999 (mean±standard error), corrected for carcass weight.

	Group (G)		Sex (S)		Significance		
	V3	T3	Females	Males	G	S	carcass weight
n	18	20	21	17			
C10:0	0.15 ±0.01	0.15 ±0.01	0.14 ±0.01	0.16 ±0.01		*	
C12:0	0.20 ±0.01	0.20 ±0.01	0.19 ±0.01	0.21 ±0.01			***
C14:0	2.56 ±0.09	2.74 ±0.08	2.66 ±0.08	2.64 ±0.09			***
C14:1	0.11 ±0.01	0.14 ±0.01	0.13 ±0.01	0.13 ±0.01	**		***
C15:0	0.35 ±0.01	0.36 ±0.01	0.33 ±0.01	0.37 ±0.01		**	**
C16:0	19.7 ±0.16	20.3 ±0.16	20.4 ±0.15	19.7 ±0.17	*	*	**
C16:1	1.69 ±0.03	1.89 ±0.03	1.83 ±0.03	1.75 ±0.03	***		**
C17:0	0.85 ±0.01	0.84 ±0.01	0.82 ±0.01	0.86 ±0.01		*	
C18:0	15.7 ±0.33	14.0 ±0.32	14.4 ±0.31	15.4 ±0.34	**		**
C18:1	39.5 ±0.32	39.3 ±0.31	40.4 ±0.30	38.5 ±0.33		***	
C18:2n-6	2.46 ±0.08	2.49 ±0.07	2.32 ±0.07	2.63 ±0.08		**	
C19:0	0.14 ±0.02	0.09 ±0.02	0.11 ±0.02	0.12 ±0.02			
C18:3n-3	1.54 ±0.06	1.58 ±0.05	1.39 ±0.05	1.73 ±0.06		***	
C20:0	0.12 ±0.01	0.13 ±0.01	0.12 ±0.01	0.13 ±0.01			
C20:1	0.24 ±0.01	0.22 ±0.02	0.24 ±0.02	0.22 ±0.02			
C20:2n-6	0.38 ±0.02	0.35 ±0.02	0.35 ±0.02	0.37 ±0.02			
C20:3n-6	0.12 ±0.01	0.12 ±0.01	0.11 ±0.01	0.12 ±0.01			
C20:4n-6	1.37 ±0.07	1.37 ±0.07	1.31 ±0.06	0.43 ±0.07			
C20:3n-3	0.01 ±0.00	0.01 ±0.00	0.0 ±0.0	0.01 ±0.00			
C20:5n-3	0.99 ±0.05	1.03 ±0.05	0.91 ±0.05	1.11 ±0.05		**	
C22:5n-3	0.88 ±0.05	0.90 ±0.05	0.81 ±0.05	0.96 ±0.05		*	
C22:6n-3	0.21 ±0.02	0.21 ±0.02	0.18 ±0.02	0.24 ±0.02			
Unidentified	10.7 ±0.30	11.5 ±0.28	10.9 ±0.27	11.3 ±0.30	*		
Saturated	39.8 ±0.38	38.8 ±0.38	39.1 ±0.35	39.5 ±0.39			
Monounsaturated	41.6 ±0.32	41.6 ±0.31	42.5 ±0.30	40.6 ±0.33		***	
Polyunsaturated	7.95 ±0.30	8.04 ±0.29	7.39 ±0.28	8.60 ±0.31		**	
C18:0/C18:1	0.40 ±0.01	0.36 ±0.01	0.35 ±0.01	0.40 ±0.01	**	**	**

There was no significant G×S interaction effect ($p > 0.05$).
Significance level: *$p<0.05$, **$p<0.01$; ***$p<0.001$

TABLE 3.13. Effect of group from two areas (V and T) on fatty acid composition (mg/100 g muscle) of muscle in ewes (mean±standard error), corrected for carcass weight.

	Group (G)			
	V		**T**	
n	18		20	
C10:0	3.0	±0.5	3.5	±0.5
C12:0	1.2	±0.2	1.5	±0.2
C14:0	37.5	±7.1	44.7	±6.7
C14:1	1.4	±0.3	1.9	±0.3
C15:0	3.8	±0.8	4.5	±0.7
C16:0	501	±94.8	594	±89.9
C16:1	33.0	±6.5	40.8	±6.2
C17:0	16.0	±2.7	17.3	±2.5
C18:0	395	±63.3	411	±60
C18:1	921	±172	1068	±163
C18:2n-6	37.8	±7.1	44.3	±6.7
C19:0	3.7	±0.8	3.5	±0.8
C18:3n-3	19.7	±3.7	23.4	±3.5
C20:0	1.7	±0.5	2.6	±0.5
C20:1	2.5	±0.5	2.4	±0.5
C20:2n-6	5.0	±0.6	5.2	±0.6
C20:3n-6	1.6	±0.1	1.8	±0.1
C20:4n-6	21.8	±3.1	24.7	±3.0
C20:3n-3	0.6	±0.2	0.7	±0.1
C20:5n-3	14.3	±1.8	15.2	±1.7
C22:5n-3	11.0	±3.8	16.3	±3.6
C22:6n-3	1.5	±2.0	3.8	±1.3
Unidentified	229	±35.1	230	±33.3
Total methyl esthers	2261	±398	2556	±377
Saturated	963	±169	1082	±160
Monounsaturated	958	±179	1113	±170
Polyunsaturated	111	±18.2	132	±17.3
C18:0/C18:1	0.43	±0.01	0.39	±0.01

There was no significant difference between progeny groups

TABLE 3.14. Effect of group (G) from two areas (V and T) on fatty acid composition (% FAME) of muscle tissue in ewes (mean±standard error) corrected for carcass weight.

	Group (G)				Significance
	V		T		G
n	18		20		
C10:0	0.13	±0.01	0.14	±0.01	
C12:0	0.05	±0.01	0.06	±0.01	
C14:0	1.68	±0.07	1.73	±0.07	
C14:1	0.06	±0.01	0.07	±0.01	
C15:0	0.17	±0.01	0.17	±0.01	
C16:0	22.6	±0.4	22.9	±0.3	
C16:1	1.51	±0.04	1.59	±0.04	
C17:0	0.71	±0.02	0.68	±0.02	
C18:0	17.6	±0.4	16.3	±0.4	*
C18:1	41.3	±0.5	41.7	±0.5	
C18:2n-6	1.70	±0.07	1.79	±0.07	
C19:0	0.16	±0.03	0.15	±0.03	
C18:3n-3	0.89	±0.04	0.93	±0.04	
C20:0	0.09	±0.02	0.12	±0.02	
C20:1	0.11	±0.01	0.09	±0.01	
C20:2n-6	0.23	±0.01	0.21	±0.01	
C20:3n-6	0.09	±0.01	0.09	±0.01	
C20:4n-6	1.03	±0.06	1.06	±0.05	
C20:3n-3	-		-		
C20:5n-3	0.67	±0.04	0.66	±0.03	
C22:5n-3	0.51	±0.21	0.78	±0.20	
C22:6n-3	0.02	±0.03	0.06	±0.02	
Unidentified	8.8	±0.4	8.8	±0.4	
Saturated	43.2	±0.7	42.3	±0.7	
Monounsaturated	43.0	±0.5	43.4	±0.5	
Polyunsaturated	5.12	±0.3	5.6	±0.3	
C18:0/C18:1	0.43	±0.01	0.39	±0.01	

Significance level: *p<0.05

TABLE 3.15. Fatty acid composition (mg/100 g muscle) of muscle in each ram in the project.

	Group V			Group T				
Ram no.	**A9726X**	**97703**	**98-700**	**B9755X**	**97704**	**98-702**	**96-701**	**97-702X**
from the year:	1997	1998	1999	1997	1998	1999		
C10:0	2.91	1.49	1.05	3.49	3.12	1.87	4.22	4.63
C12:0	1.62	1.62	0.66	1.77	1.10	1.68	2.34	3.06
C14:0	36.8	36.0	17.0	31.5	48.9	35.4	59.7	69.7
C14:1	2.05	2.85	0.65	-	3.19	2.38	2.59	3.32
C15:0	8.72	7.62	4.73	6.09	8.46	6.03	16.3	16.5
C16:0	518	372	288	404	590	355	1071	1000
C16:1	43.6	34.7	27.2	35.4	45.0	35.0	80.3	64.9
C17:0	26.7	17.7	14.2	18.1	27.0	14.9	47.9	44.8
C18:0	431	258	273	321	451	237	701	767
C18:1	1221	786	629	804	1120	714	2281	1841
C18:2n-6	86.2	44.0	39.7	66.0	62.7	43.0	114.6	118.0
C19:0	2.59	-	1.73	1.39	-	0.21	4.78	5.52
C18:3n-3	35.1	28.3	18.4	24.3	30.8	20.6	56.3	65.1
C20:0	3.20	18.7	1.53	2.71	3.18	1.76	3.56	4.67
C20:1	3.07	-	4.91	1.67		4.14	6.22	10.8
C20:2n-6	3.45	-	7.79	5.33	7.58	4.88	8.73	7.14
C20:3n-6	4.16	-	2.26	3.91	3.41	1.81	3.80	4.18
C20:4n-6	26.6	21.8	26.8	27.3	24.5	21.9	45.2	45.2
C20:3n-3	-	-	-	-	-	-	-	-
C20:5n-3	11.0	14.9	13.2	12.2	16.9	14.2	21.2	22.8
C22:5n-3	6.89	12.2	13.1	10.4	8.05	11.9	17.6	22.4
C22:6n-3	3.85	3.72	3.46	3.32	3.70	0.97	-	2.37
Unidentified	200	116	202	174	243	207	586	516
Total methyl esthers	2680	1777	1590	1960	2702	1736	5135	4639
Saturated	1031	713	601	790	1133	654	1911	1916
Monounsaturated	1269	823	662	841	1168	756	2370	1920
Polyunsaturated	179	125	125	154	158	119	267	287
C18:0/C18:1	0.35	0.33	0.43	0.40	0.40	0.33	0.31	0.42

-not detectable

TABLE 3.16. Fatty acid composition (% fatty acid methyl esters) of muscle in each ram in the project.

	Group V			Gsroup T				
Ram no.	**A9726X**	**97703**	**98-700**	**B9755X**	**97704**	**98-702**	**96-701**	**97-702X**
from the year:	1997	1998	1999	1997	1998	1999		
C10:0	0.11	0.08	0.07	0.18	0.12	0.11	0.08	0.10
C12:0	0.06	0.09	0.04	0.09	0.04	0.10	0.05	0.07
C14:0	1.37	2.02	1.10	1.61	1.81	2.04	1.16	1.50
C14:1	0.08	0.16	0.04	-	0.12	0.14	0.05	0.07
C15:0	0.33	0.43	0.31	0.31	0.31	0.35	0.32	0.35
C16:0	19.3	20.9	18.7	20.6	21.8	20.5	20.9	21.6
C16:1	1.63	1.95	1.77	1.80	1.67	2.02	1.56	1.40
C17:0	0.99	0.99	0.92	0.92	1.00	0.86	0.93	0.97
C18:0	16.1	14.5	17.7	16.4	16.7	13.7	13.7	16.5
C18:1	45.6	44.2	40.9	41.0	41.5	41.2	44.4	39.7
C18:2n-6	3.22	2.47	2.58	3.37	2.32	2.48	2.23	2.54
C19:0	0.10	-	0.11	0.07	-	0.01	0.09	0.12
C18:3n-3	1.31	1.59	1.19	1.24	1.14	1.19	1.10	1.40
C20:0	0.12	1.05	0.10	0.14	0.12	0.10	0.07	0.10
C20:1	0.11	-	0.32	0.09	-	0.24	0.12	0.23
C20:2n-6	0.13	-	0.51	0.27	0.28	0.28	0.17	0.15
C20:3n-6	0.16	-	0.15	0.20	0.13	0.10	0.07	0.09
C20:4n-6	0.99	1.23	1.74	1.39	0.91	1.26	0.88	0.97
C20:3n-3	-	-	-	-	-	-	-	-
C20:5n-3	0.41	0.84	0.86	0.62	0.62	0.82	0.41	0.49
C22:5n-3	0.26	0.69	0.85	0.53	0.30	0.68	0.34	0.48
C22:6n-3	0.14	0.21	0.23	0.17	0.14	0.06	-	0.05
Unidentified	7.46	6.54	9.81	8.90	9.00	11.9	11.4	11.1
Saturated	38.5	40.1	39.1	40.3	41.9	37.7	37.2	41.3
Monounsaturated	47.4	46.3	43.0	42.9	43.2	43.5	46.2	41.4
Polyunsaturated	6.68	7.03	8.11	7.88	5.83	6.87	5.21	6.19
C18:0/C18:1	0.35	0.33	0.43	0.40	0.40	0.33	0.31	0.42

Appendix 1

Raw data

Appendix 2

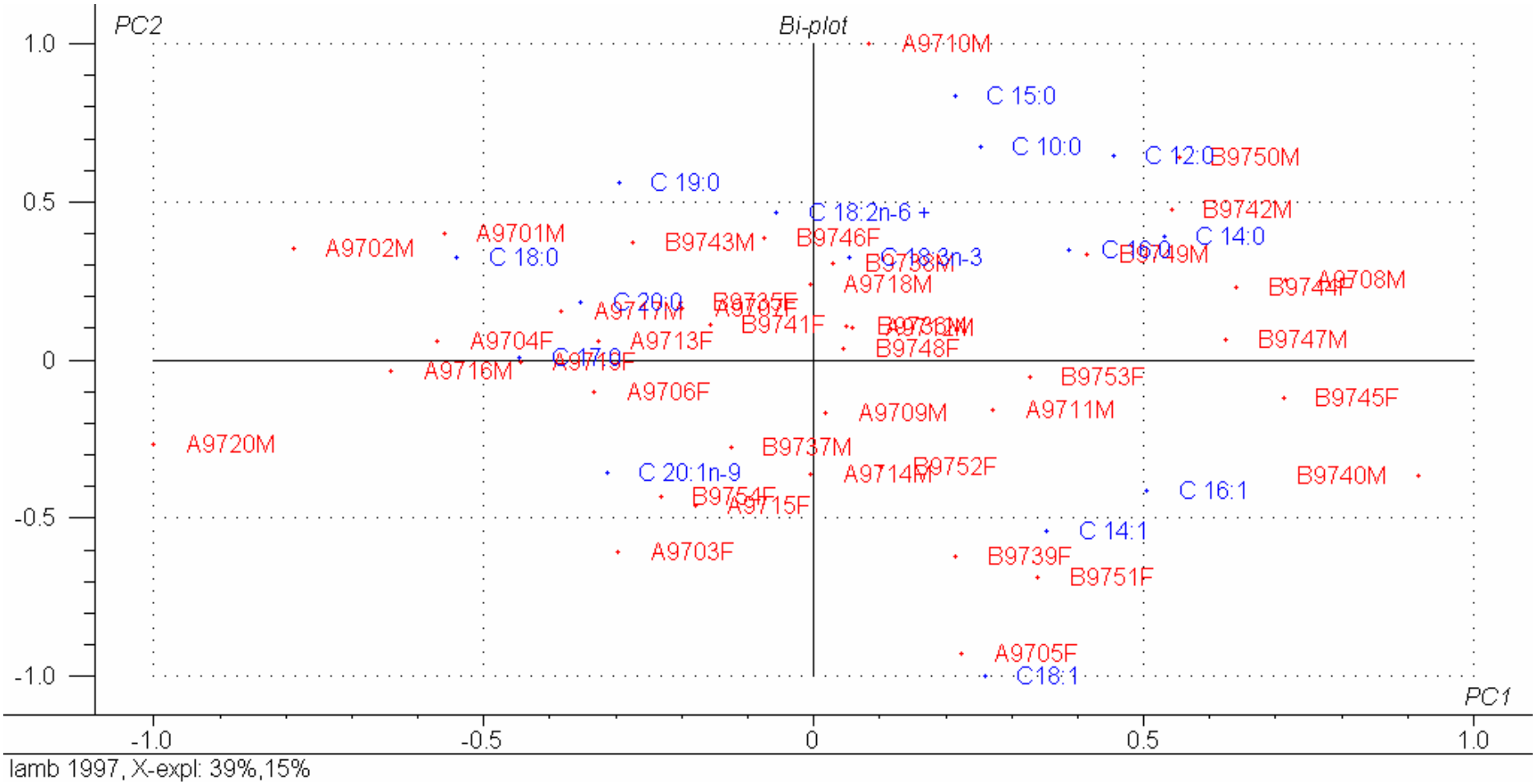
A list of fatty acids

Table A4. Systematic and trivial names of fatty acids analysed in the project.

Shorthand designation	Systematic name	Trivial name
C10:0	decanoic	capric
C12:0	dodecanoic	lauric
C14:0	tetradecanoic	myristic
C14:1	*cis*-9-tetradecenoic	myristoleic
C15:0	pentadecanoic	-
C16:0	hexadecanoic	palmitic
C16:1n-7	*cis*-9-hexadecenoic	palmitoleic
C17:0	heptadecanoic	margaric
C18:0	octadecanoic	stearic
C18:1n-9	*cis*-9-octadecenoic	olecic
C18:1n-7	*cis*-11-octadecenoic	*cis*-vaccenic
C18:2n-6	9,12-octadecadienoic	linoleic
C19:0	nonadecanoic	-
C18:3n-3	9,12,15-octadecatrienoic	α-linolenic
C20:0	eicosanoic	arachidic
C20:1n-11	*cis*-9-eicosenoic	gandoleic
C20:1n-9	*cis*-11-eicosenoic	gondoic
C20:2n-6	11,14-eicosadienoic	-
C20:3n-6	8,11,14-eicosatrienoic	homo-γ-linolenic
C20:4n-6	5,8,11,14,-eicosatetraenoic	arachidonic
C20:3n-3	11,14,17-eicosatrienoic	-
C20:5n-3	5,8,11,14,17-eicosapentaenoic	-
C22:5n-3	7,10,13,16,19-docosapentaenoic	-
C22:6n-3	4,7,10,13,16,19-docosahexaenoic	-

Appendix 3

PCA plots



lamb 1997, X-expl: 39%,15%

Figure A1. PCA biplot of fatty acid composition (%FAME) in subcutaneous fat in lambs born 1997. The first letter in each mark indicate the progeny group (A=progeny group V and B=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

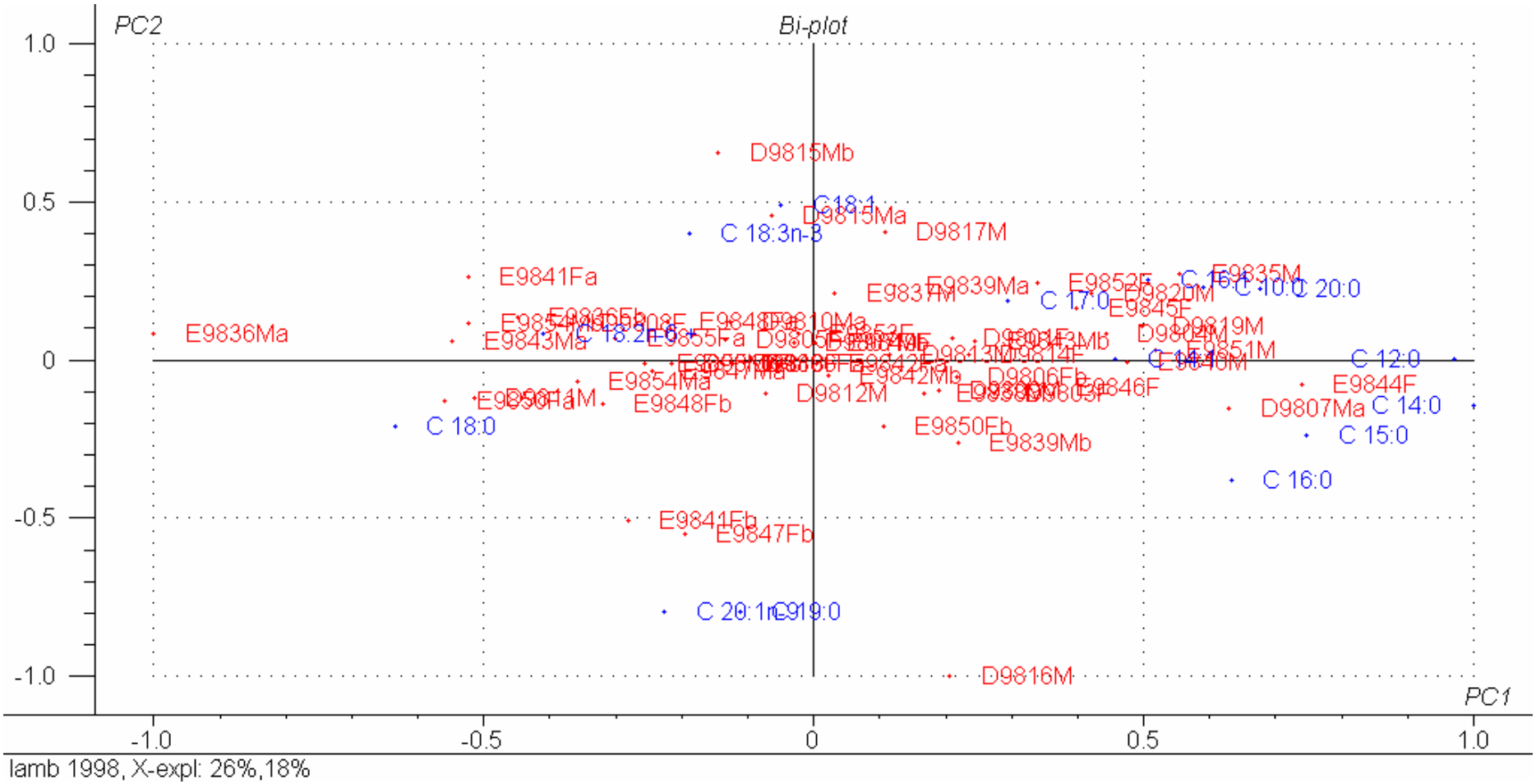


Figure A2. PCA biplot of fatty acid composition (%FAME) in subcutaneous fat in lambs born 1998. The first letter in each mark indicate the progeny group (D=progeny group V and E=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

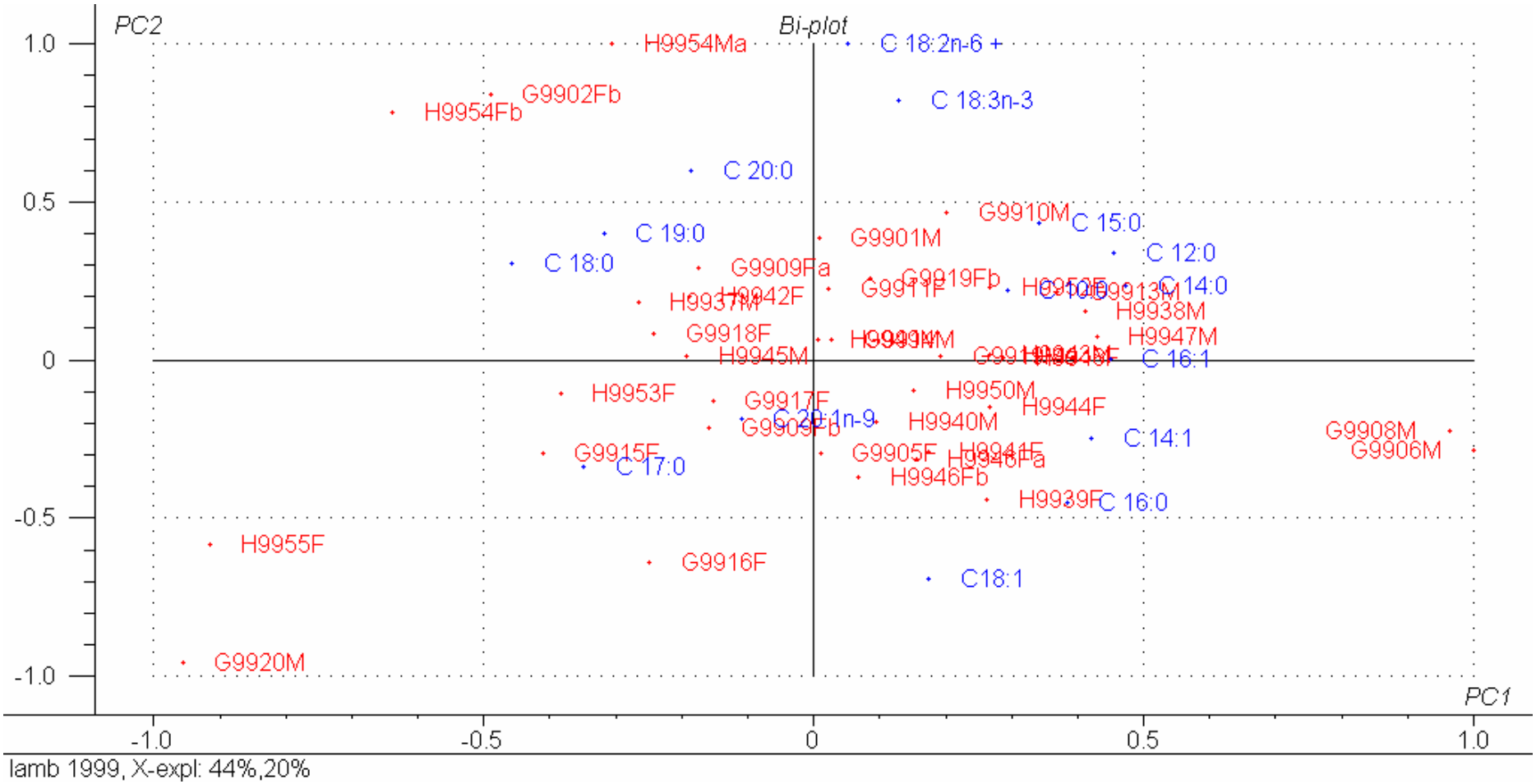


Figure A3. PCA biplot of fatty acid composition (%FAME) in subcutaneous fat in lambs born 1999. The first letter in each mark indicate the progeny group (G=progeny group V and H=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

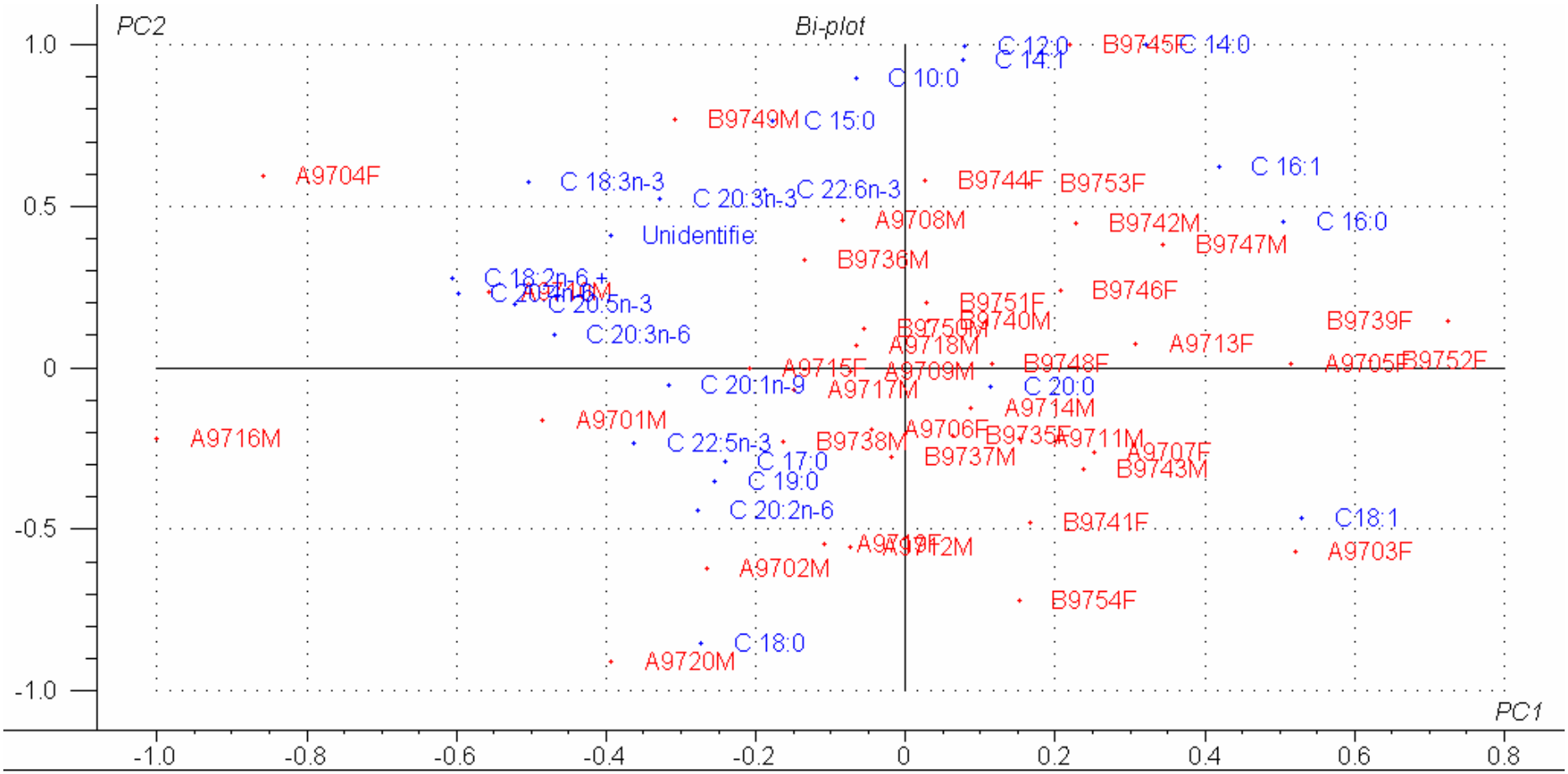
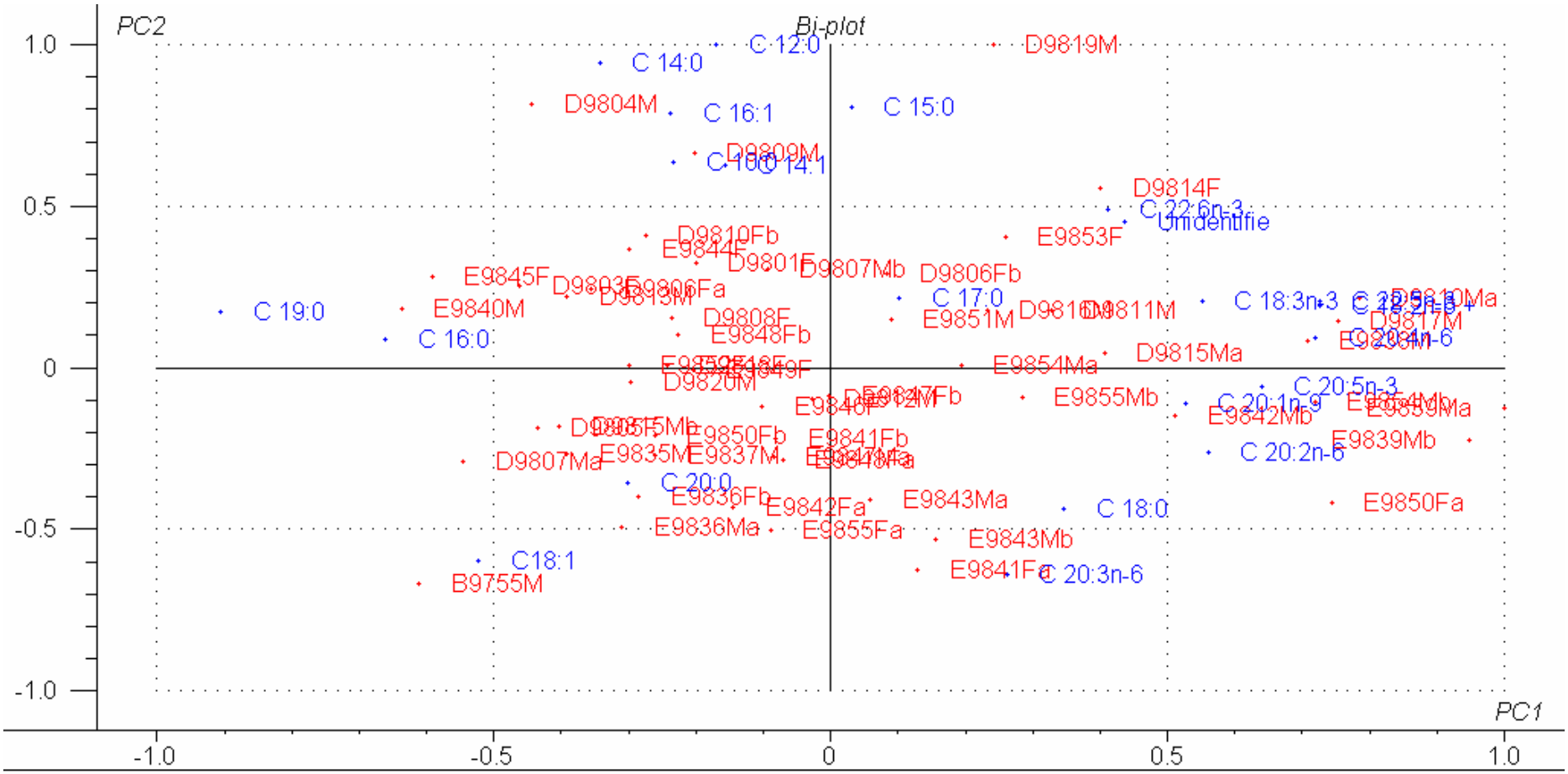
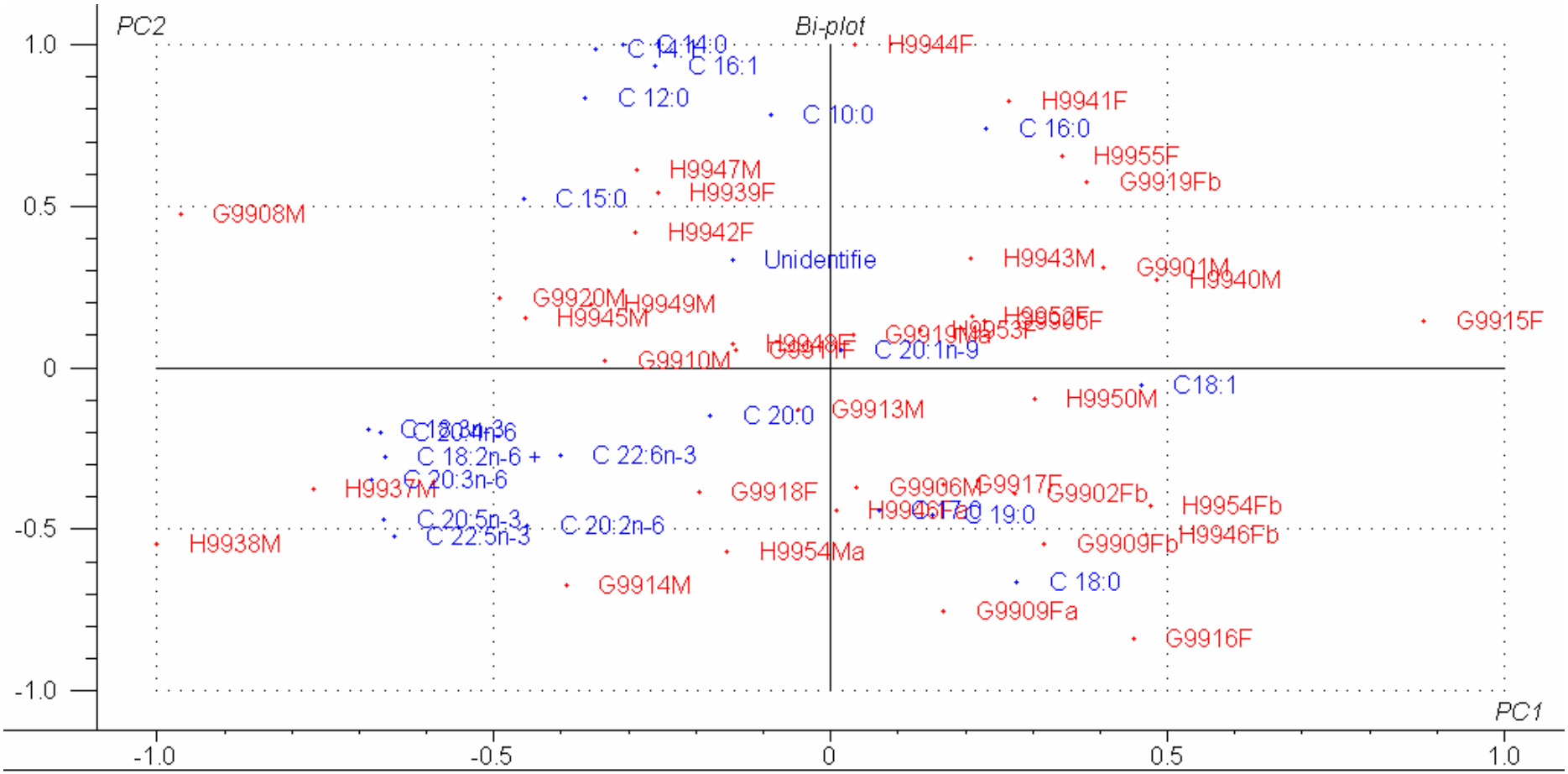


Figure A4. PCA biplot of fatty acid composition (%FAME) in muscle in lambs born 1997. The first letter in each mark indicate the progeny group (A=progeny group V and B=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.



lamb 1998 %musc..., X-expl: 33%,24%

Figure A5. PCA biplot of fatty acid composition (%FAME) in muscle in lambs born 1998. The first letter in each mark indicate the progeny group (D=progeny group V and E=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.



lamb 1999 %musc..., X-expl: 30%,22%

Figure A6. PCA biplot of fatty acid composition (%FAME) in muscle in lambs born 1999. The first letter in each mark indicate the progeny group (G=progeny group V and H=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born.

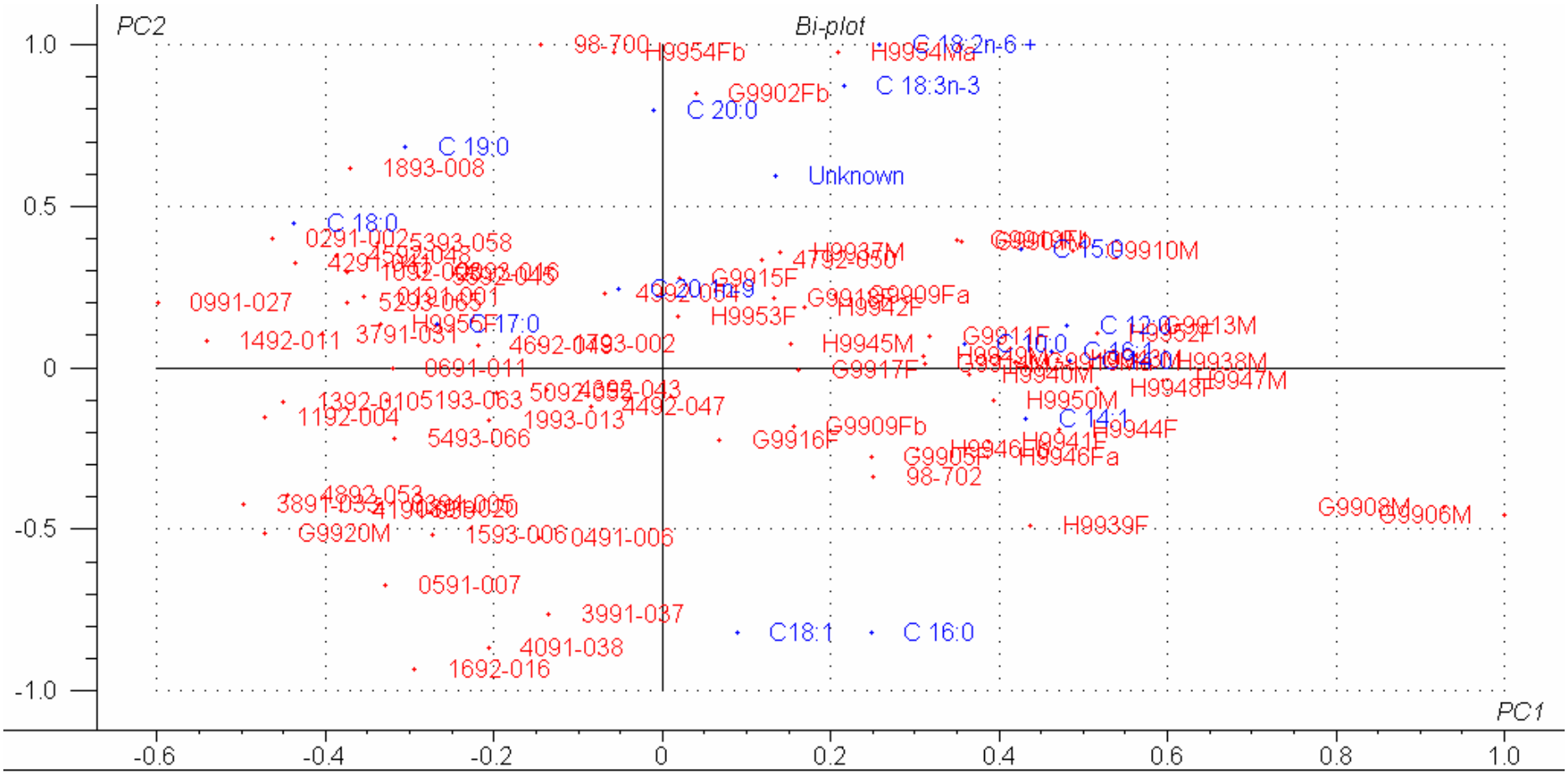


Figure A7. PCA biplot of fatty acid composition (%FAME) of subcutaneous fat in all samples from 1999 (lambs, ewes and two rams, 98-700 and 98-702). The first letter in each mark for lambs indicate the progeny group (A, D or G=progeny group V and B, E or H=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born. Ewes are marked with seven-numbered digit.

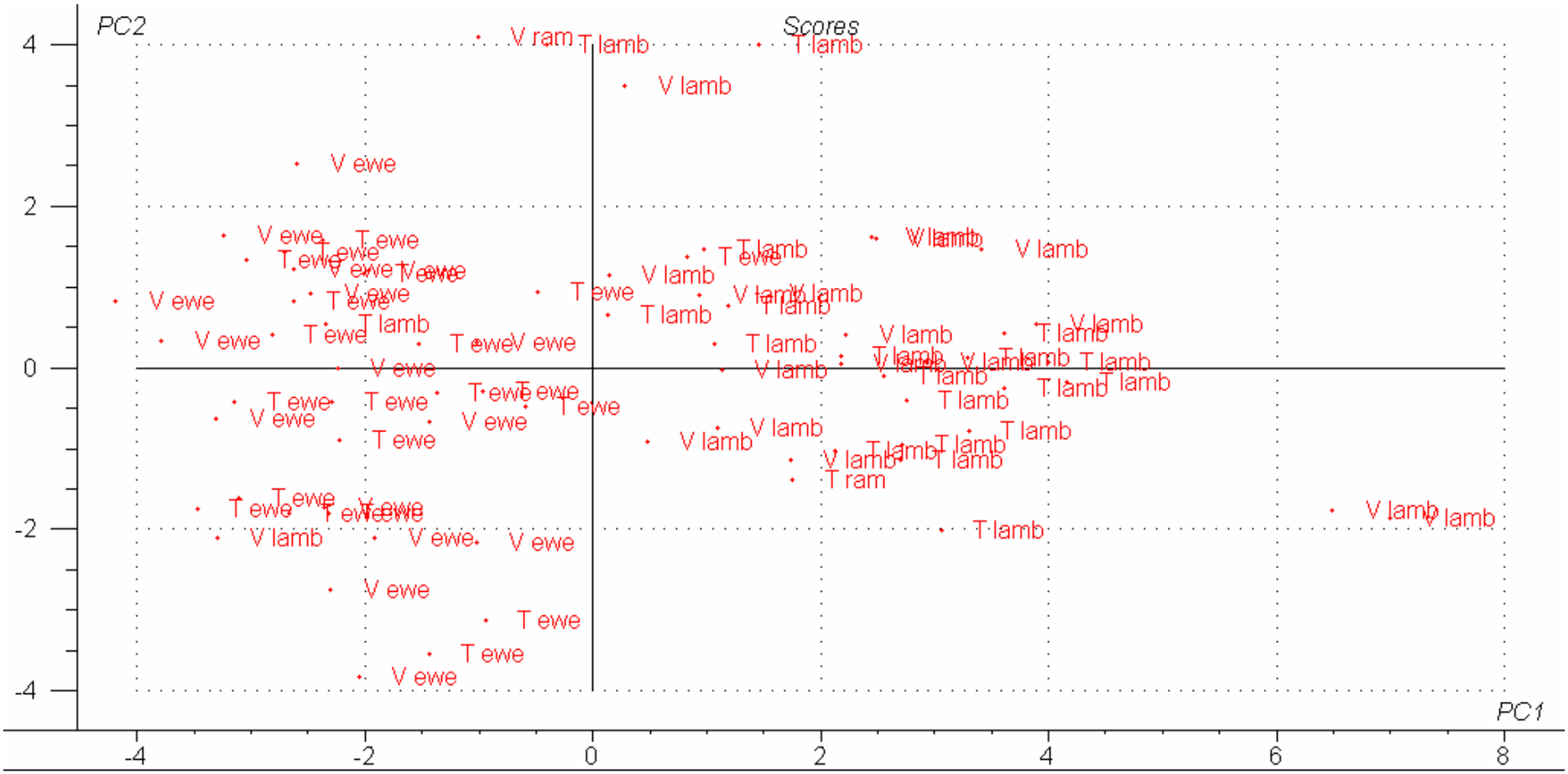
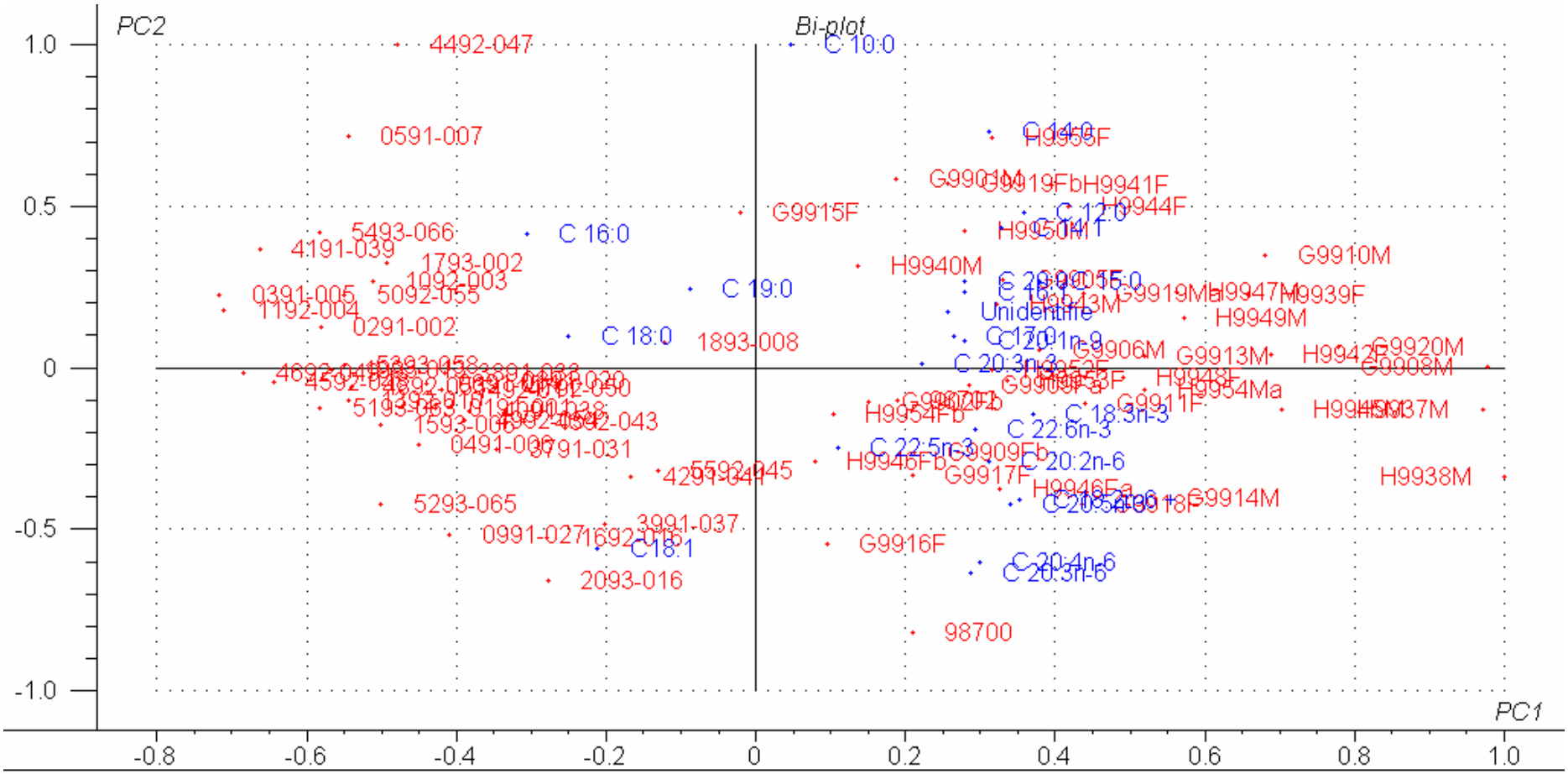


Figure A8. PCA biplot of fatty acid composition (%FAME) of subcutaneous fat in all samples from 1999 (lambs, ewes and two rams, 98-700 and 98-702) grouped by sprogeny group V or T. The figure is showing the same results as Figure A7.



all %muscle 1999, X-expl: 49%,11%

Figure A9. PCA biplot of fatty acid composition (%FAME) of muscle fat in all samples from 1999 (lambs, ewes and two rams, 98-700 and 98-702).
The first letter in each mark for lambs indicate the progeny group (G=progeny group V and H=progeny group T). The last letter indicate whether it is a male (M) or female (F). If the last letter is a or b the lamb was a two-born. Ewes are marked with seven-numbered digit.

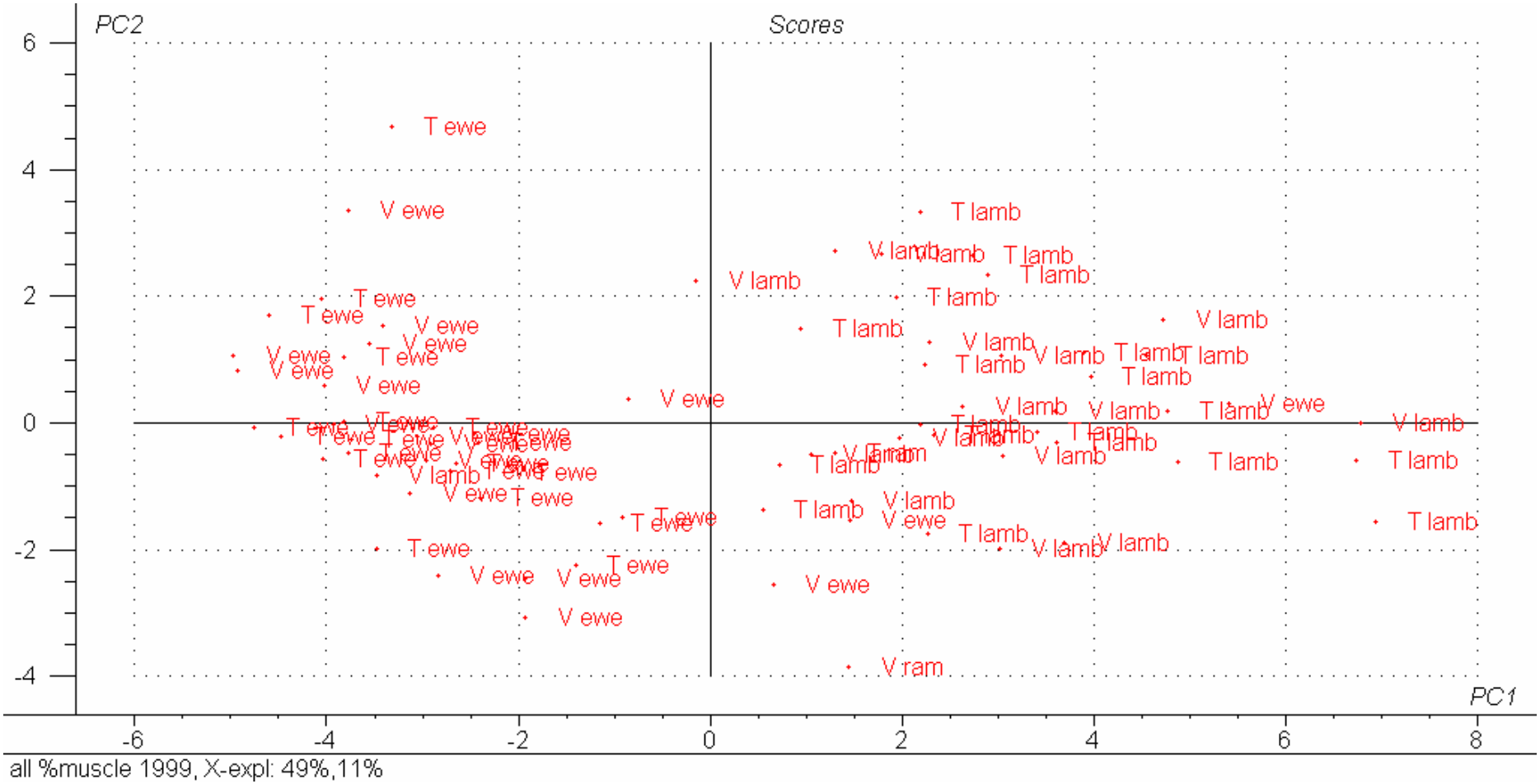


Figure A10. PCA biplot of fatty acid composition (%FAME) of muscle fat in all samples from 1999 (lambs, ewes and two rams, 98-700 and 98-702) grouped by progeny group V or T. The figure is showing the same results as Figure A9.