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Nutritional quality of milkfat

(Translated and adapted from a document (February 2005) kindly provided by the French Dairy Board (CNIEL)

1 What's in milkfat?

Milkfat consists of 96 % triglycerides (1 molecule of glycerine and 3 of fatty acids). The remaining part consists of diglycerides (approximately 2-3 %), phospolipids (approximately 1%), monoglycerides, free fatty acids, and fat-soluble substances (cholesterol, fat-soluble vitamins (A, D, E & K) and carotenoids).

2 What is there to say about fatty acids?

Milkfat comprises more than 400 different fatty acids, of which a significant proportion are saturated (65 to 70 %), a significant quantity, about one third are monounsaturated (27-33 %, essentially oleic acid) and a relatively modest quantity of polyunsaturated (3.5 to 5 %) (see also appendix 1). Milkfat is relatively rich in short-chain saturated fatty acids (10 %) and myristic acid (9 to 12 % of total fatty acids), a concentration of branched-chain fatty acids that should not be ignored (3-5 %), trans fatty acids (2.5 to 4 %, essentially vaccenic acid) and conjugated linoleic acid isomers (0.2 to 3% CLA), notably rumenic acid.

3 What is there to say about triglycerides?

More than 116 kinds of triglycerides have been described in milkfat. The distribution of fatty acids on the three sites on the glycerol molecule is not random: position Sn-3 is occupied preferentially by a short chain saturated fatty acid (butyric C4, but also C6 and C8) and the central position Sn-2 by lauric acid (C12), myristic acid (C14) or palmitic acid (C16)*.

* This structure is important nutritionally because digestive lipases liberate the fatty acids differently according to their position.

4 What is there to say about phospholipids?

Phospholipids (sphingomyelin, lecithins, cephalins…) are complex lipids. Although they are a relatively minor component of milk fat they play an essential role in cell membranes and in cell regulation. Certain studies on animals relate to their beneficial role (sphingomyelins) in colon cancer and hypercholestrolemia.

5 What is there to say about cholesterol levels?

Cholesterol is the principal sterol in milkfat*. Whole milk contains about 130 mg/l of cholesterol and butter 240 to 280 mg/100 g. Cholesterol is essential to life. It is the precursor of bile acids, hormone steroids and pro-vitamin D. It also plays a role in the constitution of cell membranes. The intake of cholesterol via food has little influence on the blood level of cholesterol (cholesterolemia) in the normal human being**.

* Other sterols such as 7-dehydroxycholesterol or phytosterols represent less than 1 % of total sterols.

** In the body cholesterol comes from two sources: 2/3 is synthesized in the liver and 1/3 comes from food. A person in normal health has a regulatory mechanism: when intake (from food) falls more is synthesized and vice versa.

6 What is there to say about other components?

Milkfat provides useful quantities of vitamin A (as retinol and beta-carotene) which play a role in vision, protection of the skin and cell membranes, resistance to infection etc…and vitamin D which has an important role in calcium metabolism and bone growth*. In many countries dairy products (including butter and cream) provide a large part of the intake of vitamin A for adults and children.

* Milkfat also provides to a lesser extent vitamin E (antioxidant) and vitamin K (antihaemorragic).

7 How are lipids digested?

Lipids are broken down by lipases (lingual and gastric) that hydrolyse principally the Sn-1 and Sn-3 bonds of the triglycerides thereby liberating short chain fatty acids more specifically. A significant quantity of short and medium chain fatty acids is thus digested rapidly*. In the intestine other lipases, especially lipases from the pancreas, take the hydrolysis further.

The lipids then mix with the secretions from the pancreas and from the gall bladder (bile) and undergo a whole series of hydrolyses before forming small particles with the bile acids – the micelles – whose contents will be absorbed by the cells of the intestinal wall.

* Milkfat is one of the most easily digested fats (short transit time through the stomach, rapid absorption). In addition, short- chain fatty acids can supply energy rapidly.

8 How are lipids absorbed?

Short-chain free fatty acids pass directly into the blood and are transported to the liver via the portal vein. The other fatty acids, once absorbed by the cells of the intestinal wall, resynthesize triglycerides that associate themselves with apolipoproteins and phospholipids to form chylomicrons* that pass into the blood via the lymphatic system.

* The intestine and the liver also synthesize other lipoproteins that play an essential role in the transport of lipids, such as very low density lipoproteins (VLDL) and low density lipoproteins (LDL) that transport lipids and cholesterol to the cells, and high density lipoproteins (HDL) that convey surplus cholesterol to the liver (whence it is eliminated from the body via the bile and the faeces). These components are used as indicators of the risk of atherosclerosis. The content in blood plasma of total cholesterol, LDL cholesterol

and the risk of atherosclerosis are positively correlated. The content of HDL cholesterol is negatively correlated.

9 What do lipids do?

Fatty acids and lipids in general have three functions:

- *Energy supply:* 1 g of lipids provides 9 kcal. Lipids are stored in adipose tissue and form a useful source of energy for muscles, heart and liver.
- *Body structure:* lipids are incorporated into cell membranes and nerve tissue.
- *Metabolism:* lipids are essential to many enzymatic reactions, in the synthesis of steroid hormones, of prostaglandins and of leukotrienes, in the transmission of membrane signals and for the transport of fat-soluble vitamins (A, D, E, K)

10 What to say about saturated fatty acids in milk?

Saturated fatty acids have been treated as a single entity for many years, allowing them only one nutritional quality – as suppliers of energy – and, at the same time, accusing them of raising the level of cholesterol and encouraging the development of cardiovascular disease. Today we know that the situation is more complex: even if an excess of fatty acids raises the level of cholesterol, individual fatty acids have different effects*. In addition, even though these fatty acids are synthesized in the body, some of them possess essential physiological properties. In summary:

- **Saturated fatty acids and cholesterol level:** short chain fatty acids (C4 to C10) do not have a negative effect on the lipid profile; stearic acid is neutral**; the results for lauric acid (C12) and palmitic (C16) are contradictory and those for myristic acid (C14) are currently being re-examined in relation to its contribution to total energy supply and total lipid content***.
- **Examples of physiological function:**
  - Long-chain saturated fatty acids (palmitic and stearic) and their derivatives are essential to the controlled development of the brain in children (in particular they are involved in the constitution of myelin).
  - Short-chain fatty acids are easily digested and are a rapid source of energy.

- Compared to omega-6 fatty acids, saturated fatty acids (as is the case with omega-3) are only moderately involved in generating adipose tissue and have a role in regulation of body weight.
- Myristic acid can bind to 150 different proteins, thereby permitting them to exercise their physiological effects (myristoylation)****. It also interacts in the biosynthesis of polyunsaturated fatty acids (PUFA).

* The Lipid Hypothesis "*Saturated fatty acids raise the level of cholesterol and hence also raise the risk of cardiovascular disease*" rests essentially on epidemiological data and on experiments using non-physiological and non-nutritional doses of fatty acids (that is, considerably more than normal consumption) without taking the overall consumption of lipids into account or the ratio of omega-3 to omega-6 fatty acids.

** An excess of stearic acid has a negative impact on the risk of thrombosis and on the aggregation of plaque (it increases Factor 7).

*** The impact of myristic acid on serum cholesterol follows a U-shaped relationship with 'safe/low' cholesterol levels between 1.2 and 2.4% of energy. When intake corresponds to 1.8 % of total energy intake (45 g of butter or 1 litre of milk) there is an improvement in the elasticity of erythrocyte membranes and it could thus play a role in preventing cerebral vascular incidents. In addition, in physiological concentrations myristic acid increases HDL cholesterol (the "good" cholesterol), it can act on the aggregation of plaque and promote the effectiveness of alpha-linolenic acid (omega-3).

**** Myristoylation, for example, allows the insertion of proteins into cell walls. It also has an influence on the steric conformation of proteins and thus plays a role in the recognition of enzyme and substrate. Acylation of proteins by palmitic acid (palmitoylation) and by lauric acid has also been demonstrated.

11 What to say about unsaturated fatty acids?

The principal unsaturated fatty acid in milk is oleic acid (C18:1, n-9) which constitutes about 30 % of total fatty acids. It is used as a source of energy and, in the form of triglycerides, in the reserves of body fat. It is one of the precursors of very long-chain fatty acids (especially with 24 carbon atoms) used in the structure of brain tissue, especially in myelin. By integration with membrane phospholipids it could modulate the activity of enzymes, transporters and receptors. Oleic acid is relatively neutral in cardiovascular terms for a person in good health.

Milkfat contains relatively little polyunsaturated fatty acids* though some dairy products are enriched, either directly or via modification of the animal feed**.

* There are two families of essential fatty acids in man (n-6 and n-3) of which the precursors, linoleic acid and alpha-linolenic acid, are considered “essential” because they have to be obtained from food. These fatty acids are used in the production of semi-essential fatty acids including arachidonic acid, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). To simplify (or perhaps oversimplify), omega-6 fatty acids are largely concerned with the immune and reproductive functions while omega-3 act on the development of the retina, of the brain and of the nervous system and also in the prevention of cardiovascular disease.

** By increasing the alpha-linolenic acid content with linseed, rapeseed or grass and, in parallel, reducing palmitic acid and increasing rumenic acid.

12 What to say about trans fatty acids?

The scientific literature has ascribed negative health effects to *trans* fatty acids (hypercholesterolemia, atherogenicity, increased cardiovascular risk, membrane rigidity, disturbance of biosynthesis of very long-chain polyunsaturated fatty acids, disturbance of prostaglandin metabolism, carcinogenic properties). However, here again, a distinction must be made between the different *trans* fatty acids. No negative effect on human health has been shown for *trans* vaccenic acid (C18:1 11t), the principal isomer in milk products*. In addition, *trans* vaccenic acid is the precursor of the conjugated linoleic acid (CLA), rumenic acid (C18:2 9c,11t) which has many biological functions.

* Vaccenic acid represents 60 % of the *trans* fatty acids and 2 % of total fatty acids in milkfat.

13 What to say about conjugated linoleic acids?

Studies, mostly on animals, have ascribed interesting physiological properties* to conjugated linoleic acid, and rumenic acid** in particular. Nevertheless these findings mostly need to be confirmed for human beings:

- Protective role against atherosclerosis and anti-thrombotic properties.
- Inhibition of the formation and development of cancerous tumours (especially of the breast).
- Protective role against type 2 diabetes and peripheral insulin resistance.

- Various roles in the humoral and cellular immune systems, in anti-inflammatory properties, bone growth etc…

*** Caution:** The term 'conjugated linoleic acid (CLA)' brings together a series of molecules (geometric isomers and isomers differing in the position of the linoleic acid (C 18:2 n-6)) that do not have the same biological properties. The two major CLAs (possessing two successive (conjugated) double bonds of which one is in the *trans* position) are as follows:

- *Cis-9 trans-11 CLA* or rumenic acid which is the major part in dairy products (and is also found in the meat of ruminants). It is produced naturally from vaccenic acid (11 *trans* C18 :1). Vaccenic acid and rumenic acid are members of the same chemical family (n-7 *trans*).
- *Trans- 10 cis-12 CLA* produced industrially by catalytic hydrogenation of vegetable oils to render them solid (margarines and shortenings) and by heating the oils to high temperature (for deodorization). These CLAs belong to the n-6 family.

CLAs do not use the same metabolic pathways, depending on their chemical family. Thus *trans*-10 *cis*-12 CLA could end up in a metabolic dead end that made it toxic (in animals it could cause hepatic steatosis (fatty liver) and could act as a pro-carcinogen).

** Rumenic acid represents about 90 % of CLAs in milk and, on average, 0.3 to 0.9 % of total fatty acids.

14 What to say about other fatty acids?

The properties of the 400 or so fatty acids found in milk are still, for the most part, unknown. Milkfat contains 48 branched-chain fatty acids (3 % of total fatty acids, of which 0.1 % is phytanic acid). They contribute notably to its flavour but could also have interesting biological functions in relation to membrane elasticity and cell proliferation.

15 What factors influence the fatty acid profile of milk?

The main factors creating variation in fatty acid profile are the animal feed*, the breed of the animal (hence the importance of research on genetics and genomics), the stage of lactation (there is an energy deficiency in the animal at the start of lactation) and climate and geography (temperature, season, altitude…)**.

* In this connection it is important to draw attention to the dangers of drastic modifications to the diet of the cattle and modifications that are not carefully monitored. For example, when trying to increase the quantity

of rumenic acid in milk with artificial supplements to the feed there is a danger of also increasing the content of *trans-10 cis-12* fatty acids which is not desirable.

** The content of saturated long chain fatty acids is higher in winter butter while the content of polyunsaturated fatty acids is higher in summer. The average contents of vaccenic and rumenic acids are also higher in summer than in winter.

In summary

It is the milkfat that gives dairy products their smooth taste and contributes to their special flavour. Milkfat is the carrier of fat-soluble vitamins (A & D) and comprises a large variety of lipid compound (sphingolipids…) and fatty acids (myristic acid, oleic acid, rumenic acid…). Whether saturated, *trans* or conjugated, the fatty acids should no longer be considered as a single entity. Each of them has its own specific physiological properties that make milkfat in the right quantities an integral part of a balanced diet.

Appendix 1 Biochemistry

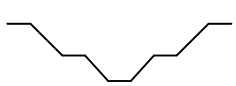
Fatty acids (FA) are chains of carbon and hydrogen molecules with a carboxyl group (COOH) on one side and a methyl group (CH_3) on the other side. Some nomenclature rules exist to identify different fatty acids.

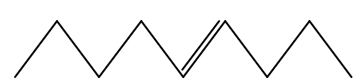
- **The length of the chain**: the number of carbon atoms (from 4 to 26) differs for the short-chain fatty acids (C4 to C10), the medium -chain fatty acids (C11 to C16), the long and very long-chain fatty acids (> C16).

- **The number of double bonds**: Saturated fatty acids (SFAs) don't have any double bonds. Mono-unsaturated fatty acids (MUFAs) have one double bond and poly-unsaturated fatty acids have two or more double bonds. These characteristics give fatty acids different physiological properties.

- **The position of the double bond** is indicated by the symbol Δ followed by the number of the first C atom involved (start counting from the COOH group). It is also indicated by 'omega' or 'n-' with an inverse count (start counting from the CH3 group). For example: linoleic acid (C18:2, $\Delta 9$, $\Delta 12$) is an 'omega-6') ($\omega 6$ or n-6)

- **The spatial configuration** defines the form of **optical isomer** (*cis* or *trans*). In *cis* isomers (the most common ones), the two carbon chains are in the same direction, while in the *trans* isomers the two chains have a position in opposite (diametrical) direction (For example: vaccenic acid, C18:1t has a *trans* double bond). Isomers have an influence on the nutritional and functional properties of the fatty acids. In foods, the majority of fatty acids are *cis*-isomers.

Cis 

Trans 

- **Conjugated bonds** with successive double bonds (-- CH2-CH=CH-CH=CH2--) give specific properties. They can be trans-cis, trans-trans, cis-trans, or cis-cis. The term 'Conjugated linoleic acid' (CLA) cover a multitude of C18:2 spatial isomers (place of the double bonds) or optical isomers (*trans* or *cis*).

Names and formulas of several fatty acids

	Name	Formula
Saturated fatty acids (SFAs)	Butyric acid	C4:0
	Lauric acid	C12:0
	Myristic acid	C14:0
	Palmitic acid	C16:0
	Stearic acid	C18:0
Mono-unsaturated fatty acids (MUFA)	Oleic acid	C18:1 9c (n-9)
Poly-unsaturated fatty acids (PUFA)	Linoleic acid	C18:2 9c, 12c (n-6)
	α-linoleic acid	C18:3 9, 12, 15c (n-3)
	Arachidonic acid	C20:4 (n-6)
	Eicosapentaenoic acid (EPA)	C20-5 5,8,11,14,17c (n-3)
	Docosahexaenoic acid (DHA)	C22:6 (n-3)
Trans fatty acids	Vaccenic acid	C18:1, 11t (n-7t)
	Elaidic acid	C18 :1, 9t
	Rumenic acid	C18 :2 9c, 11t (n-7t)

Lipid content of several dairy products (g/100g)

Product	g /100 g
Whole milk	3.5
Semi-skimmed milk	1.6
Yoghurt	1.1
Full fat yoghurt	3.7
Quark cheese (20% fat)	2.6
Quark cheese (40%	7-8
Most cheeses	20-30

Source: Ciqual/AFSSA; 2002