The Milk Fat Globule Membrane MFGM : natural source of functional compounds

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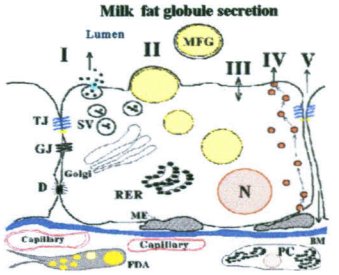
This study is funded in part by "Direction Générale de l'Agriculture / *Ministère de la Région Wallonne* "

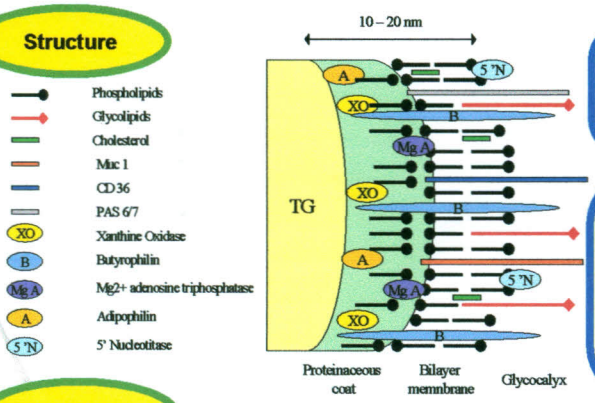
Biological origin

Milk compounds (lipids, proteins, lactose, minerals, enzyms) are synthetised by the epithelial cells of the mammary gland. Small fat droplets originate in the endoplasmatic reticulum as intracellular precursors. Upon transport through the cytoplasm, these droplets can coalesce to form larger one and are covered with a monolayer of proteins and polar lipids. Arriving at the apical pole of the secretory cell, the intracellular fat droplets are progressively envelopped by the secretory cell's plasma membrane which is a true biological bilayer of polar and proteins. Upon closure of this plasma membrane, the fat globule is released in the alveolar lumen with the others milk constituants. This membrane material surrounding and stabilizing the lipid globules in milk is called the milk fat globule membrane (MFGM).

Milk fat globule secretion



Structure



The MFGM structure is complex and multilayer. An inner monolayer of polar lipids and proteins surrounding the intracellular fat droplet, an electron dense proteinaceous coat located on the inner face of the bilayer membrane and finally a true bilayer membrane. Polar lipids and proteins are asymmetrically arranged in the MFGM.

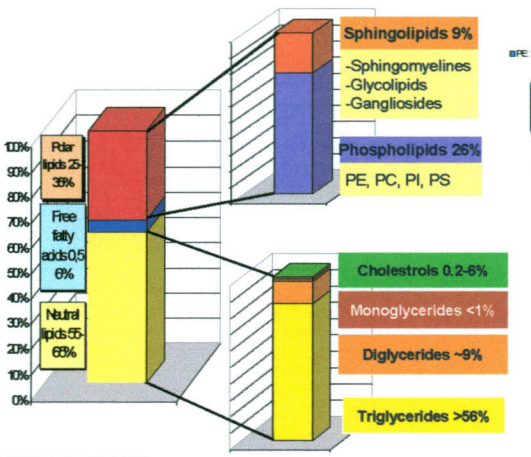
MFGM is composed of half of proteins, mainly enzymes, glycoproteins, and lipoproteins and of half of lipids of which approximately 70 % is neutral lipids mainly triacylglycerides and around 3% of cholesterol. Nearly 30% of total MFGM lipids are polar lipids composed of phospholipids (including in majority phosphatidylcholine PC and phosphatidylethanolamine PE but also phosphatidylinositol PI and phosphatidylserine PS) and sphingolipids (sphingomyeline SM, glycolipids LC / GC and gangliosides). Polar lipids having MFGM for main origin represent less than 1% of total lipids in milk.

Composition

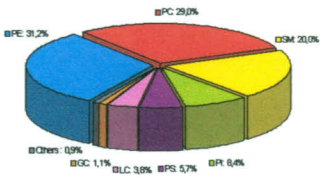
Main MFGM proteins and their functions

Protein identity	Molecular Mass (Da)	Function	pI
Fatty acid-binding protein	14.639	Lipid transport	6,34
Proteose peptone 3	17.141	Membrane associated	6,3
β-Lactoglobulin	18.281	Primary component of whey; binds a,d transport retinol	4,93
κ-caseins	18.974	Stabilises micelle formation in milk	5,93
α-caseins	24.513	Transport of Ca Phosphate	4,98
β-caseins	25.000	Micelle stability	5,26
PAS 6/7	40.791	Phospholipid binding	8,22
Actin	41.710	Cell mobility	5,29
Adipophilin	48.075	Triacylglycerol deposition	6,34
Cluster of differentiation (CD) 36	52.703		8,37
Butyrophilin	59.239	Fat globule secretion	5,32
Serum Albumin	69.248	Plasma Protein	5,82
Lactoperoxidase	80.591		8,83
Glycoprotein 2 (mucin 1)	82.913	Unclear but possibly anti-adhesion or immunoprotective	5,13
Xanthine oxydase	172.859	Redox reaction / anti-inflammatory	8,87

Lipid distribution of the MFGM

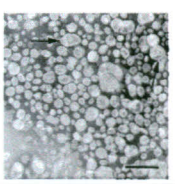


Polar lipids distribution of MFGM



Functional and health properties

The MFGM can act as a physical barrier avoiding triglycerides lipolysis. Polar lipids and proteins present functional properties as tensio-active agents; they can be used to formulate reconstituted cream or to form liposomes for the delivery of bioactive compounds. In recent years, several health-beneficial components of MFGM have been identified in addition to their excellent emulsification abilities which consequently have led to increasing interest in developping MFGM as a food ingredient with unique functional properties and health benefits.



Transmission electronic microscopy of liposomes reconstitued from MFGM (Thompson & Singh, 2006)

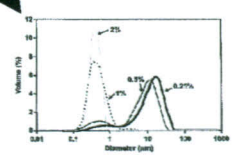
Functional properties

- Lipolytic physical barrier
- High emulsifying properties: foam, emulsion stability, emulsion capacity and whippability
- MFGM / milk serum surface tension < 2mN/m
- MFGM zeta potential = -12 mV

MFGM

Health benefits of polar lipids :

-Transmembrane transport
- Cell homeostasy, development, growth
- SM, PC: choline sources
- Long chain fatty acid source
- Anti-cancer (colon), anticholesterol, antibacteiral, antiviral properties
- development and growth of nervous and hepatic system



Integrated light scattering analysis of fat globules size distribution of reconstitued cream (10% oil) with 0.25 to 2% MFGM (Roesch et al., 2004)

Conclusion

Whey, buttermilk and butterserum are the most suitable sources of MFGM with high protein and polar lipid content but further concentrations are required. New functional food or food ingredients, rich in MFGM compounds with specific technological and nutritional properties could be derived. For many years now, MFGM studies have been carried out in Gembloux Agricultural University with the aim of innovation and valorisation. Laboratories have developped experience in native MFGM isolation, in technological properties application and in proteins / polar lipids analyse as presented in other posters.

SEE ALSO :
- Analysis of phospholipids ans sphingolipids from MFGM by SPE and HPLC-ELSD
- Proteome analysis of the bovine milk fat globule: enhancement in the membrane purification