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NUTRITION

MFGM: the next evolution in lifestyle nutrition

Understanding the milk fat globule membrane and its potential health benefits in adults.

By Aaron Fanning.

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Introduction

Consumers are becoming more focused, purposive and targeted in their approach to health as their needs and lifestyles evolve. They are especially concerned about their mental and physical wellbeing, and are interested in food and nutrition options to help maintain these into older age. Most people understand that eating better will help prevent some of the issues related with ageing, and recommendations highlight starting these earlier in life may have a better likelihood of prevention (Robinson, 2018).

It is no surprise that globally fat is a hot topic of discussion in nutrition. High fat diets are currently very popular, while nutrition guidelines typically call for a reduction in fat intake to help combat obesity and some diseases.

However, fat is an essential component of the diet, it provides the essential fatty acids, long-chain polyunsaturated fatty acids, carries the essential fat-soluble vitamins, and provides energy. In addition, it also enhances the flavour and palatability of foods.

UNRAVELLING THE COMPLEXITY OF LIPIDS

Fats are a collective term for a range of molecules that contain fatty acids. Fatty acids are a reasonably simple structure molecule, containing an aliphatic carbon chain with a carboxylic acid (-COOH) group at one end and are typically described by the chain length, as number of carbons long, as well as the number of double bonds found in the chain.

For example, oleic acid, the dominant fatty acid found in olive oil, is C18:1, in that the aliphatic chain contains 18 carbons, with one double bond, as such it is known as a mono-unsaturated fatty acid. Another fatty acid, Stearic C18:0, shares the same number of carbons, but has no double bonds, showing the carbons are saturated with hydrogen atoms, so it is known as a saturated fatty acid. Finally, linolenic acid C18:2 shares the same length of carbons, but has two double bonds. This is known as a poly-unsaturated fatty acid. There are many lengths, and degrees of unsaturation of fatty acids found in the diet, from the simple Butyric acid (C4:0), a saturated fatty acid found in butter, to Docosahexaenoic acid (C22:6) one of the fatty acids commonly found in fish oil.

Fatty acids are not found in a free state in nature, commonly they exist in the form of triacylglyceride (a glycerol with three fatty acids bound to it); making up 95% of dietary lipids. The remaining 5% of fats in the diet are predominantly the phospholipids, glycerophospholipids and sphingolipids. While these can vary in the type of fatty acids found in their structure, they vary on the structure of the backbone these fatty acids bind to. The molecules can be broken into three categories, with some overlap in the overarching naming structure (figure 1).

- Glycerophospholipids, the dominant phospholipids found in the diet, are diglycerides, where two fatty acids are bound to a glycerol, like the triacylglyceride, however the third point has a phosphate group, with a base group bound, either choline, inositol, serine or ethanolamine, to form the four phospholipids, phosphatidylcholine (PC), phosphatidylinositol (PI), phosphatidylserine (PS) or phosphatidylethanolamine (PE).
- Sphingophospholipids share similar structures, with sphingomyelin sharing a base group, phosphocholine, but instead of a glycerol group, it contains a sphingosine group, which creates a unique chemical structure.
- Finally, glycosphingolipid, contains a sugar group, or a range of sugar groups including sialic acid residues. These components are a range of ganglioside molecules.

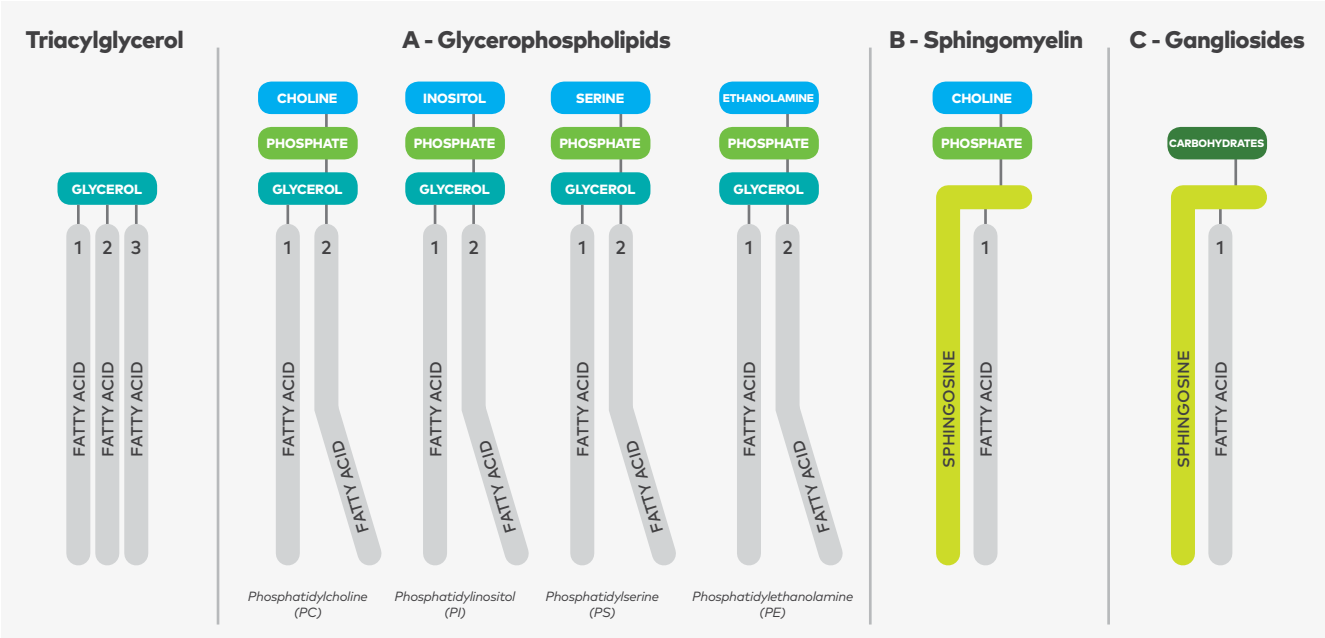

Figure 1: Structure of milk lipids: (A) glycerophospholipids, (B) sphingomyelin and (C) ganglioside.

IMPORTANCE OF COMPLEX LIPIDS IN THE HUMAN BODY

Phospholipids are an essential component of all cell membranes within the body, and especially the brain, where lipid makes up the majority of the dry weight (O'Brien & Sampson, 1965), largely phospholipids, cholesterol and gangliosides (figure 2).

Phospholipids are found in a range of plant and animal food sources and are especially rich in mammalian milk. Sphingomyelin and gangliosides are only found in animal products. Bovine milk products provide an excellent natural source of the range of phospholipids (figure 3).

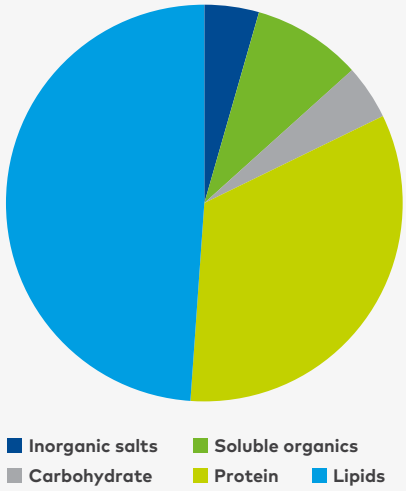

Figure 2: Dry weight composition of human brain.

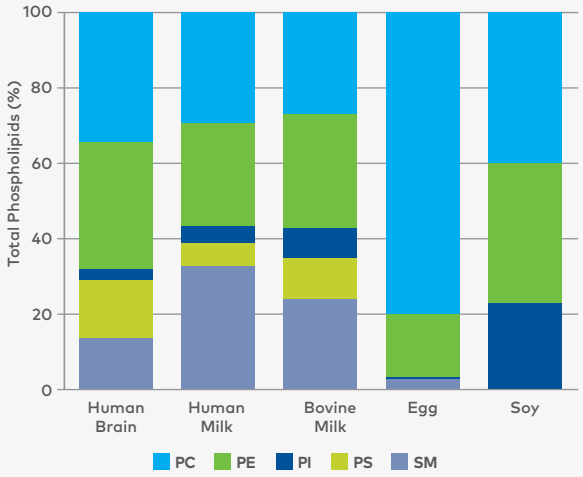

Figure 3: Phospholipids composition of brain tissue, human and bovine milk, and egg and soy lecithin's (Gallier et al., 2018a).

WHAT IS MILK FAT GLOBULE MEMBRANE?

Milk Fat Globule Membrane (MFGM) is found in every drop of mammals' milk, making up about 1% of the total fat content. The fat portion of breast milk, and other mammalian milk such as cow's milk, has a very unique structure. It consists of small globules, stabilised by a thin membrane 5-10nm thick, which is comprised of a complex structure of protein, phospholipids, sphingomyelin, gangliosides, amongst other components, called the milk fat globule membrane (figure 4). Until recently, MFGM containing products were not available on the market, however, applying modern processing technologies routinely used in the production of dairy ingredients, it allows us to produce products with a much higher concentration of MFGM components than found in standard milk, enabling the fortification of foods with MFGM.

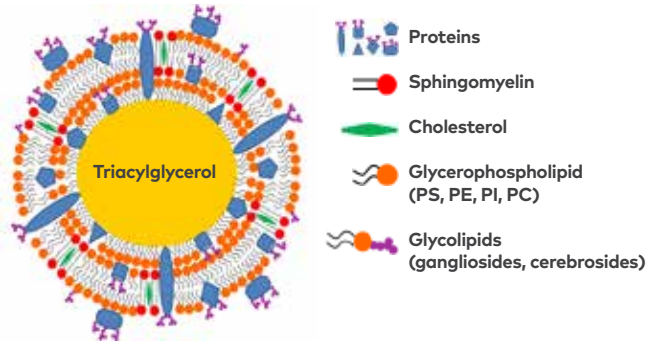

Figure 4: The complex structure and composition of milk fat globule showing the bulk triacylglycerol surrounded by the membrane.

SOURCES OF MILK FAT GLOBULE MEMBRANE

Traditionally, MFGM was isolated from buttermilk. But it is possible to obtain higher concentration MFGM products at commercial scale. The components can be enriched into dairy ingredients during the manufacture of anhydrous milk fat (AMF), to give MFGM-rich beta-serum with 7-8% phospholipids.

Another route is to harvest the MFGM components during cheese manufacturing to provide a higher-lipid content whey protein concentrate, which has an enhanced MFGM content and around 5-7% phospholipids. This product also contains high levels of high quality whey protein, enabling the combined benefits of MFGM and its components to the known benefits of whey protein.

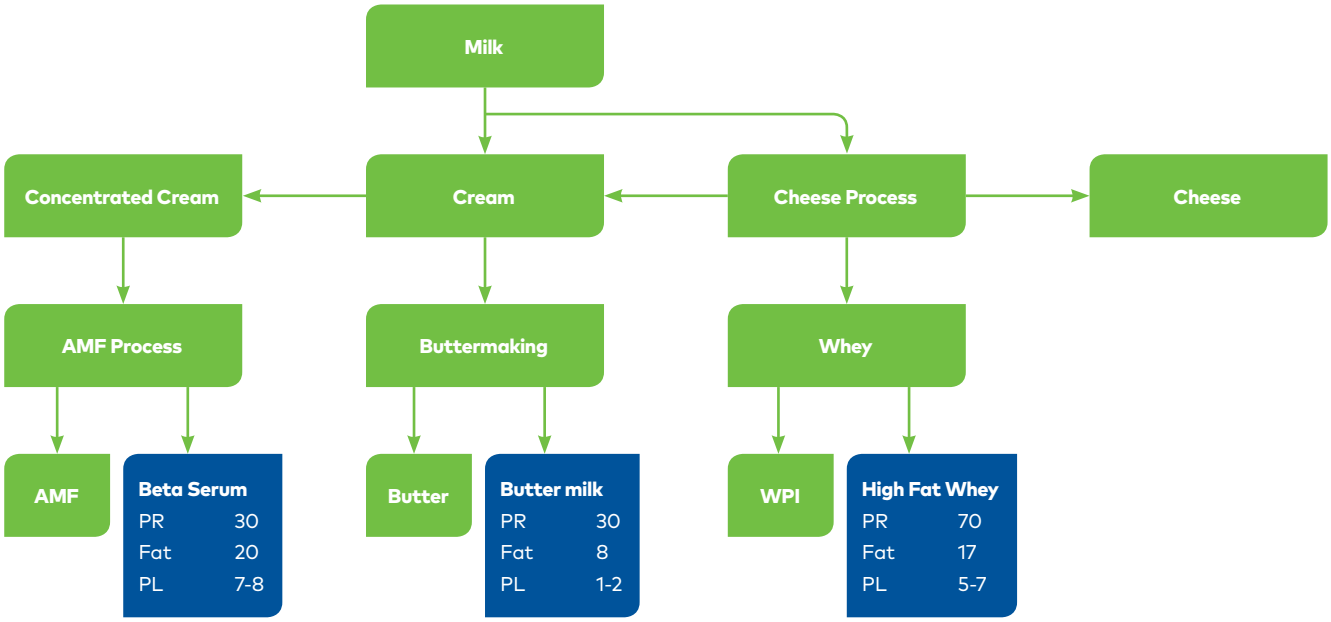

Figure 5: MFGM Lipid ingredient manufacture (Gallier et al 2018).

HEALTH BENEFITS OF MILK FAT GLOBULE MEMBRANE

The potential benefits of MFGM may result from either consumption of a product providing the individual lipids, such as sphingomyelin, and this component having a functional effect. Alternatively, it may result from consumption of a MFGM source, providing the raft of phospholipids, glycerophospholipid or sphingolipids in a ratio that are found in mammals. There is emerging evidence that dietary intake of products containing MFGM have shown effects across a range of benefit areas of interest to active lifestyle consumers. These include benefits for physical activity, cognition, and mood. Also, anti-inflammatory and protective properties.

Physical activity

One of the most interesting lines of research for MFGM has been evidence that it can potentially impact measures of mobility and physical performance. The consumption of MFGM, together with exercise, has been shown to promote a greater level of muscle activation leading to strength gains (Soga et al., 2015); and in older individuals, protective effects on balance, supporting muscle activation and greater strength and muscle size (Minegishi et al., 2016; Kokai et al., 2018). Some of these effects are thought to be modulated by sphingomyelin (Haramizu et al., 2014a), however, other research has shown phosphatidylserine to have beneficial effects on performance (Kingsley, 2006; Jäger et al., 2007b; Jäger et al., 2007a) as well as showing a benefit on oxidative stress (Kingsley et al., 2005).

Supporting these findings, animal work has shown that increased levels of MFGM sourced phospholipids has shown impacts on the neuromuscular development (Markworth et al., 2017), promoting the development of a more adult phenotype for muscle fibres. In other animal trials, MFGM has shown benefits for endurance exercise (Haramizu et al., 2014b), and shown protective effects for muscle size, strength and function (Haramizu et al., 2014a; Yano et al., 2017) that may be modulated through suppression of the ageing impact on neuromuscular junctions (Yano et al., 2017).

Cognition

Several trials have shown significant benefits of MFGM on cognitive outcomes. These benefits are broadly defined in infants (Hernell et al., 2016), where dairy ingredients that contain MFGM can be added to infant formulas to more closely match human breastmilk. Both animal and human trials have shown benefits for the improvement in cognitive development in the infant (Oshida et al., 2003; Vickers et al., 2009; Gurnida et al., 2012; Liu et al., 2014; Timby et al., 2014; Guan et al., 2015b; Mudd et al., 2016; Gallier et al., 2018b; Li et al., 2018; Mika et al., 2018). Consumption of MFGM in formulae has been shown to impact brain lipid composition in animals, along with reflex development (Moukarzel et al., 2018). In older children (2-6 years old), higher doses of products containing MFGM have shown improvements in behaviour regulation (Veereman-Wauters et al., 2012). Little direct data exists for older children or adults. However, early animal trials indicate that MFGM compounds have positive memory benefits in older rats (Guan et al., 2015a). Finally, a product containing buttermilk, a source of MFGM, in combination with polyunsaturated fats from krill oil showed positive effects on neuronal health and potential delays in cognitive decline in rats (Tomé-Carneiro et al., 2018). Other benefits of MFGM and its components appear to be related to mood.

Mood

Stress and anxiety are becoming an increasing consumer concern, with consumers looking for products that can help support their mental wellbeing, and their interventions to improve this. MFGM and its components have shown a number of benefits that indicate that products fortified with MFGM may help support mood and mental wellness. Consumption of MFGM, providing high levels of phosphatidylserine has been shown a beneficial moderation of the stress response, with consumption indicating a more relaxed response to stress (Boyle et al., 2019), and also impacts on the stress response, with improved responses to stressors, potentially mediated through a modulation of cortisol availability (Schubert et al., 2011), with some calling these effects 'stress-buffering' (Contarini & Povolo, 2013). Supporting these findings with MFGM or phosphatidylserine consumption has also shown improved endocrine responses to stress (Baumeister et al., 2008; Hellhammer et al., 2010). Earlier animal research indicates a reduction in measures of anxiety (Mika et al., 2018).

Anti-Inflammatory

A range of emerging evidence exists about the anti-inflammatory properties of MFGM or its components (Dalbeth et al., 2010; Snow et al., 2011; Dalbeth et al., 2012; Zanabria et al., 2014; Demmer et al., 2016). This potential benefit is of interest as inflammation underlies many adverse health outcomes (Libby, 2007; Franceschi & Campisi, 2014), and inflammation may be impacted by dairy nutrition (Bordoni et al., 2017). Some evidence exists of anti-inflammatory effects in humans (Demmer et al., 2016), and animals (Bhinder et al., 2017; Huang et al., 2019), and also for ganglioside rich fragments in animal or cell based work, with ganglioside rich fragments preventing the release of pro-inflammatory signals (Park et al., 2007), and indications of protective effects in gout inflammatory models (Dalbeth et al., 2010). Both in vitro and in vivo work indicate that both the phospholipid rich and ganglioside rich components impact on a range of anti-inflammatory pathways (Palmano et al., 2019).

Protection

MFGM components have shown a range of anti-infective properties, indicating they may be protective against common gastrointestinal infections. While more common in children, where much of the evidence is found (Hernell et al., 2016), rotavirus infection may be a significant contributor to travellers' diarrhoea (Anderson & Weber, 2004). MFGM and its components have shown protection against rotavirus infections in children (Zavaleta et al., 2011; Veereman-Wauters et al., 2012; Poppitt et al., 2014), as well as reduced incidence of diarrhoea. There appears to be protective effects from other infection as well (Veereman-Wauters et al., 2012; Timby et al., 2015).

Summary

The role of fat in the diet is continually being expanded. Phospholipids are an exciting new area of interest for consumers globally, and milk fat globule membrane products provide a natural high-quality way of providing concentrated sources of a balance of these phospholipids. There is emerging evidence of MFGM and its components showing beneficial effects in a range of areas of interest to consumers, including physical activity, cognition, and mood. Other potential benefits may include both MFGM's anti-inflammatory properties, and its potential protection against infection. Future research will continue to identify areas of interest, and benefits of these compounds.

REFERENCES.

Anderson E J & Weber S G (2004): Rotavirus infection in adults. The Lancet Infectious Diseases, 4, 91-99.

Baumeister J, Barthel T, Geiss K R & Weiss M (2008): Influence of phosphatidylserine on cognitive performance and cortical activity after induced stress. Nutritional Neuroscience, 11, 103-110.

Bhinder G, Allaire J M, Garcia C, Lau J T, Chan J M, Ryz N R, Bosman E S, Graef F A, Crowley S M, Celiberto L S, Berkmann J C, Dyer R A, Jacobson K, Surette M G, Innis S M & Vallance B A (2017): Milk Fat Globule Membrane Supplementation in Formula Modulates the Neonatal Gut Microbiome and Normalizes Intestinal Development. Scientific Reports, 7, 1-15.

Bordoni A, Danesi F, Dardevet D, Dupont D, Fernandez A S, Gille D, Nunes dos Santos C, Pinto P, Re R, Rémond D, Shahar D R & Vergères G (2017): Dairy products and inflammation: A review of the clinical evidence. Critical Reviews in Food Science and Nutrition, 57, 2497-2525.

Boyle N B, Dye L, Arkbåge K, Thorell L, Frederiksen P, Croden F & Lawton C (2019): Effects of milk-based phospholipids on cognitive performance and subjective responses to psychosocial stress: A randomized, double-blind, placebo-controlled trial in high-perfectionist men. Nutrition, 57, 183-193.

Contarini G & Povolo M (2013): Phospholipids in milk fat: Composition, biological and technological significance, and analytical strategies. International Journal of Molecular Sciences, 14, 2808-2831.

Conway V, Gauthier S F & Pouliot Y (2014): Buttermilk: Much more than a source of milk phospholipids. Animal Frontiers, 4, 44-51.

Dalbeth N, Gracey E, Pool B, Callon K, McQueen F M, Cornish J, MacGibbon A & Palmano K (2010): Identification of dairy fractions with anti-inflammatory properties in models of acute gout. Annals of the rheumatic diseases, 69, 766-769.

Dalbeth N, Ames R, Gamble G D, Horne A, Wong S, Kuhn-Sherlock B, MacGibbon A, McQueen F M, Reid I R & Palmano K (2012): Effects of skim milk powder enriched with glycomacropeptide and G600 milk fat extract on frequency of gout flares: a proof-of-concept randomised controlled trial. Annals of the Rheumatic Diseases, 71, 929-934.

Demmer E, Van Loan M D, Rivera N, Rogers T S, Gertz E R, Bruce German J, Smilowitz J T, Zivkovic A M, German J B, Smilowitz J T & Zivkovic A M (2016): Addition of a dairy fraction rich in milk fat globule membrane to a high-saturated fat meal reduces the postprandial insulinaemic and inflammatory response in overweight and obese adults. Journal of Nutritional Science, 5, 1-11.

Franceschi C & Campisi J (2014): Chronic inflammation (Inflammaging) and its potential contribution to age-associated diseases. Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 69, S4-S9.

Gallier S, MacGibbon A K & McJarrow P (2018a): Milk fat globule membrane (MFGM) supplementation and cognition. Agro Food Industry Hi-Tech, 29, 14-16.

Gallier S, Xia Y, Rowan A M & Wang B (2018b): Milk fat globule membrane as a source of gangliosides and phospholipids in infancy to support brain development and healthy growth. pp. N-eP-022. In ESPGHAN Congress.

Guan J, MacGibbon A, Zhang R, Elliffe D M, Moon S & Liu D-X X (2015a): Supplementation of complex milk lipid concentrate (CMLC) improved the memory of aged rats. Nutritional Neuroscience, 18, 22-29.

Guan J, MacGibbon A, Fong B, Zhang R, Liu K, Rowan A & McJarrow P (2015b): Long-Term Supplementation with Beta Serum Concentrate (BSC), a Complex of Milk Lipids, during Post-Natal Brain Development Improves Memory in Rats. Nutrients, 7, 4526-4541.

Gurnida D A, Rowan A M, Idjradinata P, Muchtadi D & Sekarwana N (2012): Association of complex lipids containing gangliosides with cognitive development of 6-month-old infants. Early Human Development, 88, 595-601.

Haramizu S, Mori T, Yano M, Ota N, Hashizume K, Otsuka A, Hase T & Shimotoyodome A (2014a): Habitual exercise plus dietary supplementation with milk fat globule membrane improves muscle function deficits via neuromuscular development in senescence-accelerated mice. SpringerPlus, 3, 339.

Haramizu S, Ota N, Otsuka A, Hashizume K, Sugita S, Hase T, Murase T & Shimotoyodome A (2014b): Dietary milk fat globule membrane improves endurance capacity in mice. American journal of physiology. Regulatory, integrative and comparative physiology, 307, R1009-1017.

Hellhammer J, Waladkhani A R, Hero T & Buss C (2010): Effects of milk phospholipid on memory and psychological stress response. British Food Journal, 112, 1124-1137.

Hernell O, Timby N, Domellöf M & Lönnerdal B (2016): Clinical Benefits of Milk Fat Globule Membranes for Infants and Children. The Journal of Pediatrics, 173 Suppl, S60-65.

Huang S, Wu Z, Liu C, Han D, Feng C, Wang S, Wang J & Song D (2019): Milk fat globule membrane supplementation promotes neonatal growth and alleviates inflammation in low-birth-weight mice treated with lipopolysaccharide. BioMed Research International, 2019,

REFERENCES *(CONT'D)*.

Jäger R, Purpura M & Kingsley M (2007a): Phospholipids and sports performance. Journal of the International Society of Sports Nutrition, 4, 5.

Jäger R, Purpura M, Geiss K-R, Weiß M, Baumeister J, Amatulli F, Schröder L & Herwegen H (2007b): The effect of phosphatidylserine on golf performance. Journal of the International Society of Sports Nutrition, 4, 23.

Kingsley M (2006): Effects of phosphatidylserine supplementation on exercising humans. Sports medicine (Auckland, N.Z.), 36, 657-669.

Kingsley M I, Wadsworth D, Kilduff L P, Mceneny J & Benton D (2005): Effects of Phosphatidylserine on Oxidative Stress following Intermittent Running. Medicine & Science in Sports & Exercise, 37, 1300-1306.

Kokai Y, Mikami N, Tada M, Tomonobu K, Ochiai R, Osaki N, Katsuragi Y, Sohma H & Ito Y M (2018): Effects of dietary supplementation with milk fat globule membrane on the physical performance of community-dwelling Japanese adults: a randomised, double-blind, placebo-controlled trial. Journal of Nutritional Science, 7, e18.

Li F, Berseth C L, Harris C L, Columbo J, Liu B, Rudolph C & Cleghorn G (2018): The cognitive and immune effects of feeding an infant formula enriched with milk fat globule membrane (MFGM) and lactoferrin in a population of Chinese infants. p. 043. In Nutrition and Growth. Paris.

Libby P (2007): Inflammatory Mechanisms: The Molecular Basis of Inflammation and Disease. Nutrition Reviews, 65, 140-146.

Liu H, Radlowski E C, Conrad M S, Li Y, Dilger R N & Johnson R W (2014): Early Supplementation of Phospholipids and Gangliosides Affects Brain and Cognitive Development in Neonatal Piglets. The Journal of Nutrition, 144, 1903-1909.

Markworth J F, Durainayagam B, Figueiredo V C, Liu K, Guan J, MacGibbon A K H, Fong B Y, Fanning A C, Rowan A, McJarrow P & Cameron-Smith D (2017): Dietary supplementation with bovine-derived milk fat globule membrane lipids promotes neuromuscular development in growing rats. Nutrition & Metabolism, 14, 9.

Mika A, Gaffney M, Roller R, Hills A, Bouchet C A, Hulen K A, Thompson R S, Chichlowski M, Berg B M & Fleshner M (2018): Feeding the developing brain: Juvenile rats fed diet rich in prebiotics and bioactive milk fractions exhibit reduced anxiety-related behavior and modified gene expression in emotion circuits. Neuroscience Letters, 677, 103-109.

Minegishi Y, Ota N, Soga S & Shimotoyodome A (2016): Effects of Nutritional Supplementation with Milk Fat Globule Membrane on Physical and Muscle Function in Healthy Adults Aged 60 and Over with Semiweekly Light Exercise: A Randomized Double-Blind, Placebo-Controlled Pilot Trial. Journal of Nutritional Science and Vitaminology, 62, 409-415.

Moukarzel S, Dyer R A, Garcia C, Wiedeman A M, Boyce G, Weinberg J, Keller B O, Elango R & Innis S M (2018): Milk Fat Globule Membrane Supplementation in Formula-fed Rat Pups Improves Reflex Development and May Alter Brain Lipid Composition. Scientific Reports, 8, 1-9.

Mudd A T, Alexander L S, Berding K, Waworuntu R V, Berg B M, Donovan S M & Dilger R N (2016): Dietary Prebiotics, Milk Fat Globule Membrane, and Lactoferrin Affects Structural Neurodevelopment in the Young Piglet. Frontiers in Pediatrics, 4, 1-10.

O'Brien J S & Sampson E L (1965): Lipid composition of the normal human brain: gray matter, white matter, and myelin. Journal of Lipid Research, 6, 537-544.

Oshida K, Shimizu T, Takase M, Tamura Y, Shimizu T & Yamashiro Y (2003): Effects of dietary sphingomyelin on central nervous system myelination in developing rats. Pediatric Research, 53, 589-593.

Palmano K, MacGibbon A, Gunn C & Schollum L (2019): In vitro and in vivo anti-inflammatory activity of bovine milkfat globule (MGFM)-derived complex lipid fractions. in draft.

Park E J, Suh M, Thomson B, Ma D W L, Ramanujam K, Thomson A B R & Clandinin M T (2007): Dietary ganglioside inhibits acute inflammatory signals in intestinal mucosa and blood induced by systemic inflammation of Escherichia coli lipopolysaccharide. Shock, 28, 112-117.

Poppitt S D, McGregor R A, Wiessing K R, Goyal V K, Chitkara A J, Gupta S, Palmano K, Kuhn-Sherlock B & McConnell M A (2014): Bovine complex milk lipid containing gangliosides for prevention of rotavirus infection and diarrhoea in Northern Indian infants. Journal of Pediatric Gastroenterology and Nutrition, 59, 167-171.

Robinson S M (2018): Improving nutrition to support healthy ageing: What are the opportunities for intervention? Proceedings of the Nutrition Society, 77, 257-264.

Schubert M, Contreras C, Franz N & Hellhammer J (2011): Milk-based phospholipids increase morning cortisol availability and improve memory in chronically stressed men. Nutrition Research, 31, 413-420.

Snow D R, Ward R E, Olsen A, Jimenez-Flores R & Hintze K J (2011): Membrane-rich milk fat diet provides protection against gastrointestinal leakiness in mice treated with lipopolysaccharide. Journal of Dairy Science, 94, 2201-2212.

Soga S, Ota N & Shimotoyodome A (2015): Dietary milk fat globule membrane supplementation combined with regular exercise improves skeletal muscle strength in healthy adults: a randomized double-blind, placebo-controlled, crossover trial. Nutrition Journal, 14, 85.

Timby N, Domellöf E, Hernell O, Lönnerdal B & Domellöf M (2014): Neurodevelopment, nutrition, and growth until 12 mo of age in infants fed a low-energy, low-proteinformula supplemented with bovine milk fat globule membranes: A randomized controlled trial. American Journal of Clinical Nutrition, 99, 860-868.

Timby N, Hernell O, Vaarala O, Melin M, Lönnerdal B & Domellöf M (2015): Infections in infants fed formula supplemented with bovine milk fat globule membranes. Journal of Pediatric Gastroenterology and Nutrition, 60, 384-389.

Tomé-Carneiro J, Carmen Crespo M, Burgos-Ramos E, Tomas-Zapico C, García-Serrano A, Castro-Gómez P, Venero C, Pereda-Pérez I, Baliyan S, Valencia A, Fontecha J, Dávalos A & Visioli F (2018): Buttermilk and Krill Oil Phospholipids Improve Hippocampal Insulin Resistance and Synaptic Signaling in Aged Rats. Molecular neurobiology, 55, 7285-7296.

United Nations Department of Economic and Social Affairs (2015): World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241.

Veereman-Wauters G, Staelens S, Rombaut R, Dewettinck K, Deboutte D, Brummer R J, Boone M & Le Ruyet P (2012): Milk fat globule membrane (INPULSE) enriched formula milk decreases febrile episodes and may improve behavioral regulation in young children. Nutrition, 28, 749-752.

Vickers M H, Guan J, Gustavsson M, Krägeloh C U, Breier B H, Davison M, Fong B, Norris C, McJarrow P & Hodgkinson S C (2009): Supplementation with a mixture of complex lipids derived from milk to growing rats results in improvements in parameters related to growth and cognition. Nutrition Research, 29, 426-435.

Yano M, Minegishi Y, Sugita S & Ota N (2017): Milk fat globule membrane supplementation with voluntary running exercise attenuates age-related motor dysfunction by suppressing neuromuscular junction abnormalities in mice. Experimental Gerontology, 97, 29-37.

Zanabria R, Tellez A M, Griffiths M, Sharif S & Corredig M (2014): Modulation of immune function by milk fat globule membrane isolates. Journal of Dairy Science, 97, 2017-2026.

Zavaleta N, Kvistgaard A S, Graverholt G, Respicio G, Guija H, Valencia N & Lönnerdal B (2011): Efficacy of an mfgm-enriched complementary food in diarrhea, anemia, and micronutrient status in infants. Journal of Pediatric Gastroenterology and Nutrition, 53, 561-568.

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