Lecture

N.M. Shilina
Research Institute of Nutrition, Moscow, Russian Federation

Expert view of the role of fats in pediatric nutrition

Author affiliation:
Shilina Nataliya Mikhailovna, PhD, leading research scientist at the developmental threpsology laboratory of the RAMS Research Institute of Nutrition (Federal State Budgetary Institution)
Address: 2/14 Ust'inskii dr., Moscow, 109240, **tel.:** +7 (495) 698-53-63, **e-mail:** n_shilina@ion.ru
Article received: 06.11.2013. **Accepted for publication:** 14.01.2014.

The lecture presents data on various types of fats comprising saturated and unsaturated fatty acids and their trans-isomers, describes the main families of fatty acids (omega-6 and omega-3) and their bioactive derivatives, dwells upon an important role of fats as essential pediatric nutrition factors for normal neuropsychological development of children, features data on the composition of breast milk fatty acids as the standard for feeding neonates and considers medical and technological issues of breast milk fat regeneration in pediatric nutrition formulas.
***Key words**: saturated fatty acids, unsaturated fatty acids, omega-6 and omega-3, pediatric nutrition, palmitic acid, breast milk, pediatric nutrition formulas.*

Adequate nutrition is one of the primary conditions of normal child's body development [1-3]. Term "adequate" implies the nutrition balanced in terms of all the main macro- and micronutrients up to the child's age-related and caloric needs. One of the primary food factors is fats [2].

Fats (lipids) are a wide group of natural organic compounds serving as energy reserves and the main components of biological membranes. They perform the following functions in the body: take part in neurotransmission, regulation of metabolic and immune processes etc. Fats, or lipids, may be subdivided into 2 large groups for convenience: fats proper (triglycerides) and lipoids (phospholipids, sterols, sphingolipids, gangliosides etc.) [2].

Fatty acids – chains of interlinked carbon atoms - are the main structural components of fats. Depending on the chain length, fatty acids may be short-chain, medium-chain and long-chain. Fatty acids may be saturated (ordinary atom bonds) (pic. 1a) and unsaturated (more complex atom bonds) (pic. 1b).

Unsaturated fatty acids are found in all body cell membranes, as they are necessary for tissue growth and regeneration; apart from that, they also perform regulatory functions.

Saturated fatty acids may be synthesized with synthase complex; the body may also generate certain monounsaturated (with one double bond) fatty acids.

The fatty acids that cannot be synthesized by the human body are referred to as indispensable (essential) fatty acids: these acids must be ingested with food. Animals are unable to synthesize 18:2 omega-6 and 18:3 omega-3 polyunsaturated fatty acids (linoleic (pic. 2a) and α-linolenic) (pic. 2b).

Essential fatty acids are subdivided into two large kinds: omega-6 and omega-3, which are different in the position of the first double bond in relation to the omega-end carbon atom of the fatty acid molecule; if the first double bond is next to the 3rd carbon atom (from the molecule's ω-end), it is the omega-3 fatty acid; if the first double bond is next to the 6th carbon atom, it is the omega-6 fatty acid. After intake, essential fatty acids are metabolized by the enzyme system represented by a set of desaturases and elongases. Desaturases introduce additional double bonds to fatty acid molecules, whereas elongases extend the fatty acid molecule's hydrocarbonic skeleton by 2 carbon atoms. A range of long-chain polyunsaturated fatty acids (LCPUFAs) and their various bioactive derivatives (eicosanoids) is synthesized under the influence of this enzyme system. Essential linoleic acid is the source of omega-6 PUFAs, whereas essential α-linolenic fatty acid is the source of all omega-3 fatty acids. Their long-chain polyunsaturated derivatives – omega-6 arachidonic acid (20 carbon atoms long, 4 double bonds) and 2 omega-3 PUFAs – eicosapentaenoic (twenty carbon atoms, 5 double bonds) and docosahexaenoic (twenty two carbon atoms, 6 double bonds) acids – are the most important biologically. Omega-3 and omega-6 fatty acids stimulate immune system strengthening and allergy protection and are responsible for psychogeny and development of many other processes (growth, eating behavior, vascular tone control, blood coagulation regulation etc.) [4].

Occurrence of unsaturated bonds in a fatty acid molecule reduces its fusion temperature. Thus, introduction of 1 bond to an unsaturated stearic acid (18:0) molecule results in occurrence of cis-oleic acid (18:1) and reduction of fusion temperature from 60 to 16 ^{o}C [5].

Depending on the position of carbohydrate substitutes in unsaturated (double) bonds “carbohydrate-carbohydrate” in relation to the fatty acid molecule’s longitudinal axis, we may distinguish between cis- and trans-fatty acids. In the cis-position, substitutes are positioned on the one side of the molecule’s longitudinal axis, in the trans-position – on both sides. Unsaturated bonds may rotate in the cis-position; this results in bending of fatty acid molecules making them more labile and fluid. Trans-fatty acid molecules are straighter and more like saturated fatty acids (pic. 3). The fusion temperature of trans-fatty acids is higher: trans-(18:1) – 56 ^{o}C, cis-(18:1) – 16 ^{o}C [6].

Food sources of fatty acids – vegetable oils – are liquid, as they contain many unsaturated fats with low fusion temperature. Butter, meat and dairy products contain more refractory saturated fatty acids, which is why they remain solid at room temperature (like trans-unsaturated vegetable fats).

Fatty acids with double bonds, primarily in the cis-position, are found in the human body. Trans-isomers enter the body with food.

Replacement of a cis-fatty acid with its trans-isomer in the composition of more complex fats and biological membranes (pic. 4) changes their properties: fats become more refractory (due to higher fusion temperature), whereas membranes become less fluid due to reduced rotation potential of fatty acid molecule branches around double bonds in the trans-configuration.

Regularity of fatty acid molecules’ laying in the cell membranes’ bilayer increases; it results in decrease in their fluidity. The latter, in its turn, leads to alteration of biological activity of the protein molecules (serving as receptors) immersed in the membrane, ionic channels and other buildups important for cell functions; potential to transmit biological signals intracellularly and, possibly, to the alteration of the cell’s secretory activity. That is why excessive admission of trans-fatty acids is not recommended. Their content in foods for small children is restricted to 4% [7].

PUFAs take part in the following important body processes [8]:

- Lipid metabolism regulation, including genetic regulation;
- Glucose and zinc homeostasis;
- Cell proliferation and differentiation;
- Performance of brain and visual analyzer functions;
- Appetite regulation;
- Body growth.

Fats constitute up to 60% of brain dry weight in children of 1.5-2 years of age, 35% of the fats being long-chain fatty acids [9].

Brain growth and development usually take place in the last trimester of pregnancy. Child’s birth weight is ca. 5% of an adult’s weight; however, brain’s birth size is 70% of an adult’s brain size. Thus, we may accept that fats play an important role in nutrition of pregnant women, as fetuses gather resources to build central nervous system organs – brain and visual analyzer – from their mothers’ bodies. Indeed, the trials demonstrate that the main fatty acids in these central nervous system segments are long-chain polyunsaturated fatty acids – arachidonic and docosahexaenoic acids, which (in the aggregate) constitute up to 25 and 60% of brain phospholipids and visual analyzer's light sensors, respectively [9].

Within the first year of life, child's brain becomes larger by 15%. It ought to be noted that the first 24 months are the period of active visual analyzer development. The trials demonstrate that LCPUFAs affect this process [10-13], which is why it is extremely important for a child to continue taking fatty acids in either with breast milk or with infant formulas.

Indeed, the fat demand is maximal in infants – 44-49% of the diet's caloric content [1]. In order to provide high growth rate children need energy and soft-solid material to build cell membranes – fats of breast milk or formula feeding. Activity of enzyme systems in neonates is not high enough to provide their high needs, including the need in LCPUFAs. That is why breast milk contains all the necessary fatty acids for infant development (both essential and LCPUFAs) [14].

Breast milk composition is unique; it contains a wide range of fatty acids: PUFAs prevail over saturated fatty acids. Reproduction of the fatty acid composition of breast milk in infant formulas is a difficult scientific, technological and medical issue. Breast milk is considered a standard for infant formulas (pic. 5) [15]. Sources of fatty acids for infant formulas are vegetable and animal fats.

Vegetable oils contain large amounts of essential fatty acids (pic. 6). Sunflower and corn oils are rich sources of linoleic acid, the content of which in these oils reaches 50-60%. There are considerably fewer sources of omega-3 fatty acids: soybean, canola and linseed oils. Unfortunately, these oils are not widespread in diets of most Russians, although soybean and canola oils are used to produce infant formulas.

However, no vegetable oil can reproduce the unique composition of breast milk fatty acids (pic. 7).

As every vegetable oil is a source of important and essential acids for children, application of innovative technologies to various combinations thereof helps to obtain such infant formula composition, which would be as similar to breast milk composition as possible.

Sources of saturated fatty acids are palm, coconut and other vegetable oils, butter fat (in small amounts), along with cod liver and single cell oils (as LCPUFA sources).

Palm oil as a source of saturated palmitic acid shall be given special consideration. According to the cited data on breast milk composition, palmitic acid level is up to 25% of all fatty acids. Among all the vegetable oils, this fatty acid constitutes more than 30% only of palm oil (see pic. 7). Palmitic acid content in all the other oils is far lower. The main technological issue of production of breast milk substitutes is to make the fat component as similar to the breast milk fatty acid composition as possible. That is why highly purified palm oil may serve as a source of palmitic acid for the modern adapted infant formulas. If a formula does not contain palm oil, palmitic acid content in the formula is considerably lower than in breast milk (pic. 8).

A range of controlled trials demonstrated that approximation of the formula fat component to the breast milk fatty acid composition improves neuropsychic development of children (in particular, it increases mental development index (MDI) by 7 points [16]), psychomotor development of 4-month-old children [17] and cognitive development at the age of 3 and 10 months (visual memory and problem solving tests) [13, 18] and affects children's intellectual development in the long term [14].

CONCLUSION

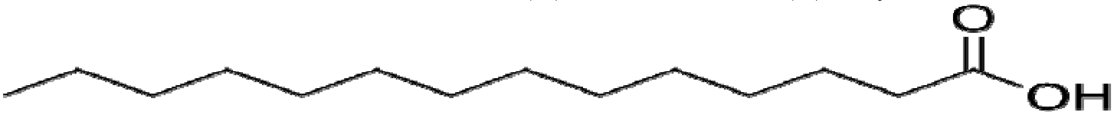
Milk infant formulas are the only dairy products in the Russian Federation, in which milk fats may be replaced by vegetable fats (legal permit). On the modern stage, all formulas registered and approved for sale in the Customs Union are safe and as similar to breast milk in terms of composition as possible [7, 19].

REFERENCES

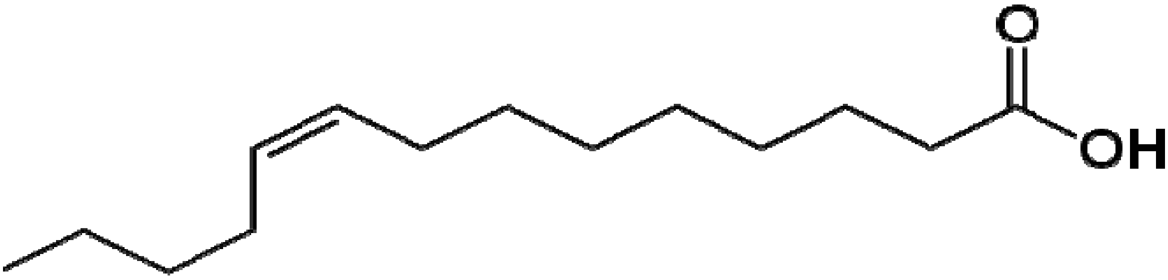
1. *Detskoe pitanie. Rukovodstvo dlya vrachei. Pod red. V.A. Tutel'yana, I.Ya. Konya* [Child Nutrition. Guideline. Edited by V.A. Tutel'yan, I.Ya. Kon']. Moscow, Meditsinskoe informatsionnoe agentstvo, 2013. 744 p.
2. Present Knowledge in Nutrition 10th Edition. Ed. by Erdman J. W. Jr., Macdonald I. A., Zeisel S. H. International Life Sciences Institute and Wiley-Blackwell of John Wiley & Sons. Ames, USA, 2012. 1305 p.
3. Namazova-Baranova L.S. Research and infrastructure platform "Pediatrics". *Pediatricheskaya farmakologiya – Pediatric pharmacology*. 2012; 9 (4): 15–24.
4. Carlson S. E. Long chain polyunsaturated fatty acids in infants and children. In: Dietary fats in infancy and childhood. *Annales Nestle*. 1997; 55 (2): 52–62.
5. Uauy R., Castillo C. Lipid requirements of infants: implications for nutrient composition of fortified complementary foods. *J Nutr.* 2003; 133 (9): 2962–2972.
6. Koletzko B. Trans-fatty acids. In: Dietary fats in infancy and childhood. *Annales Nestle*. 1997; 55 (2): 63–72.
7. *Tekhnicheskii reglament Tamozhennogo soyuza TR TS 021/2011 «O bezopasnosti pishchevoi produktsii». Utv. Resheniem Komissii Tamozhennogo soyuza ot 9 dekabrya 2011 g. № 880* [Customs Union Regulation TR TS 021/2011 "On Food Safety". Approved by Customs Union Commission Decision No. 880 of 09 December 2011].
8. Shilina N.M. *Izuchenie biomarkerov metabolizma ω-3 i ω-6 polinenasyshchennykh zhirnykh kislot u detei i beremennykh zhenshchin. Avtoref. dis. ... dokt. biol. nauk* [Study of Metabolism Biomarkers of ω-3 and ω-6 Polyunsaturated Fatty Acids in Children and Pregnant Women. Author's abstract]. Moscow, 2012. 48 p.
9. Farquharson J., Cockburn F., Patrick W. A. Infant cerebral cortex phos pho lipid fatty-acid composition and diet. Lancet. 1992; 340: 810–813.
10. Carlson S. E., Ford A. J., Werkman S. H. et al. Visual acuity and fatty acid status of term infants fed human milk and formulas with and without docosahexaenoate and arachidonate from egg yolk lecithin. *Pediatr Res*. 1996; 39: 882–888.
11. Birch E. E., Hoffman D. R., Uauy R. et al. Visual acuity and the essentiality of docosahexaenoic acid and arachidonic acid in the diet of term infants. *Pediatr Res*. 1998; 44: 201–209.
12. Hoffman D. R., Birch E. E., Birch D. G. et al. Impact of early dietary intake and blood lipid composition of long-chain polyunsaturated fatty acids on later visual development. *J Pediatr Gastroenterol Nutr*. 2000; 31: 540–553.
13. Willatts P., Forsyth J. S., Dimodugno V. R. et al. The effects of longchain polyunsaturated fatty acids on infant attention and cognitive behavior. In: David T. J. (ed). Major controversies in infant nutrition: International congress and symposium series № 215. London, Royal Society of Medicine, 1996. pp. 57–70.
14. Koletzko B., Agostoni C., Bergmann R., Ritzenthaler K., Shamir R. Physiological aspects of human milk lipids and implications for infant feeding: a workshop report. *Acta Peadiatrica*. 2011; 100: 1405–1415.
15. ESPGHAN Committee on Nutrition: Breastfeeding. *Journal of Pediatric Gastroenterology and Nutrition*. 2009; 49 (1): 112–125.
16. Birch E. E., Garfield S., Hoffman D. R. et al. A randomized controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants. *Dev Ved Child Neurol*. 2000; 42: 174–181.
17. Agostoni C., Trojan S., Bellu R. et al. Neurodevelopmental quotient of healthy term infants at 4 months and feeding practice: The role of long-chain polyunsaturated fatty acids. *Pediatr Res*. 1995; 38: 262–266.
18. Willatts P., Forsyth J. S., Dimodugno M. K. et al. Effect of longchain polyunsaturated fatty acids infant formula on problem solving at 10 months of age. *Lancet*. 1998; 352: 688–691.
19. *Edinye sanitarno-epidemiologicheskie i gigienicheskie trebovaniya k tovaram, podlezhashchim sanitarno-epidemio logicheskomu nadzoru (kontrolyu)* [Standard Sanitary

Epidemiological and Hygienic Requirements to the Products Subject to Sanitary Epidemiological Supervision (Control)].

Pic. 1. Schematic structures of saturated (A) and unsaturated (B) fatty acids

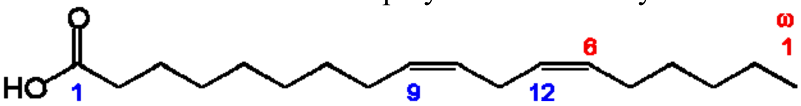


A.

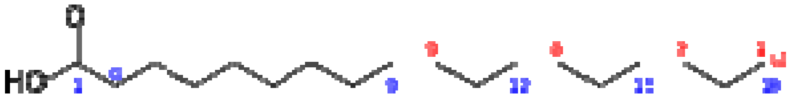


B.

Pic. 2. Essential ω-6 and ω-3 polyunsaturated fatty acids

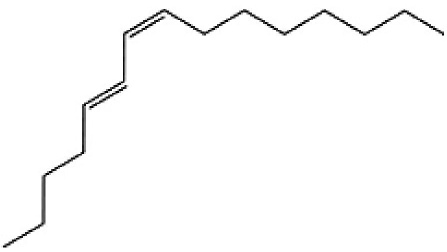
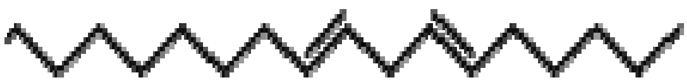


A. Linoleic acid (18:2 ω-6)

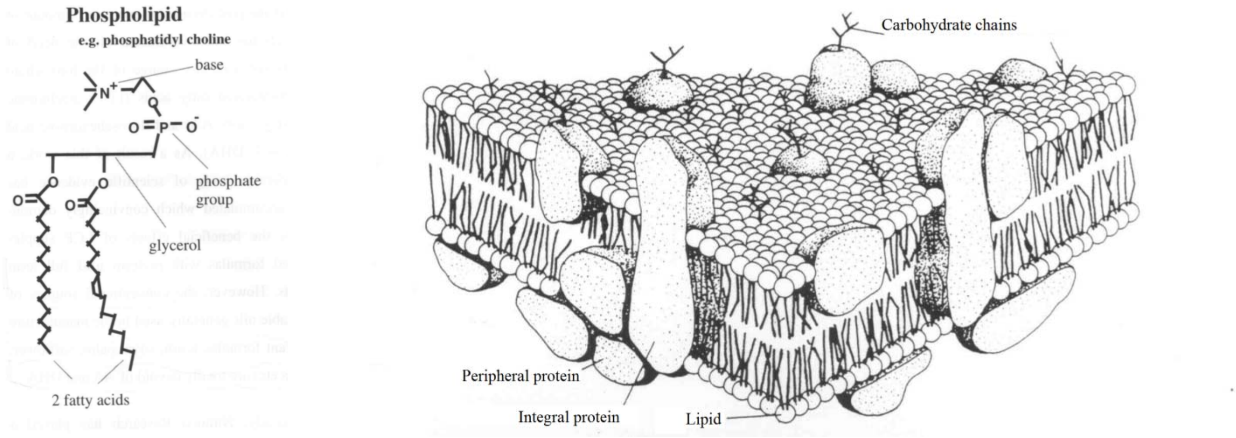


B. α-linolenic acid (18:3 ω-3)

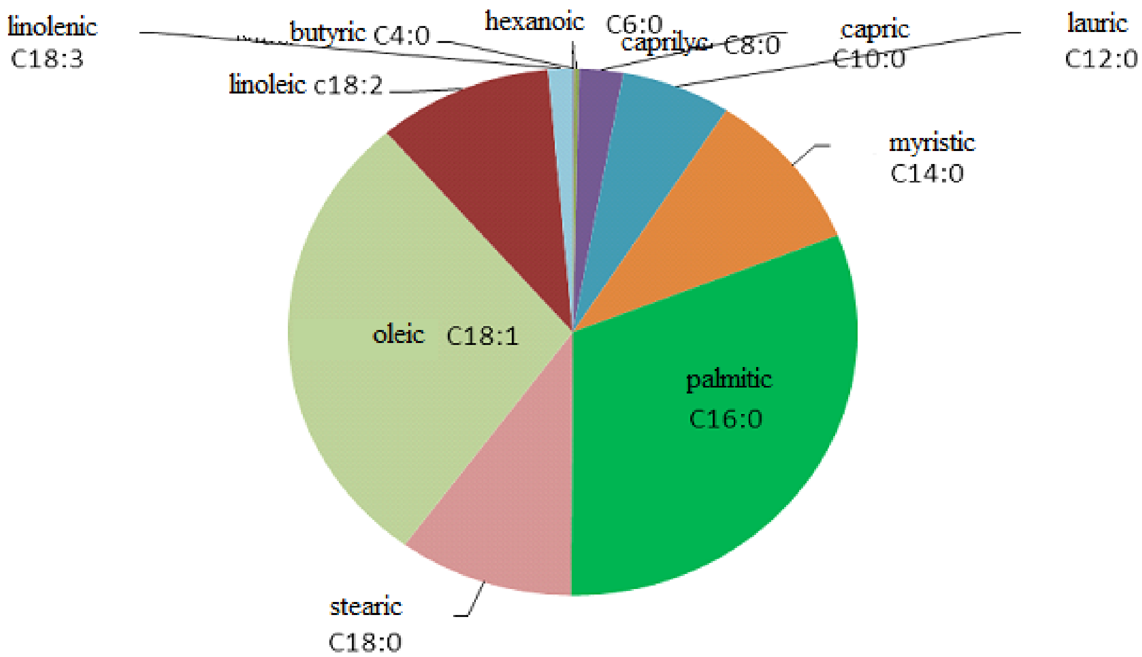
Pic. 3. Differences in structures of cis- (A) and trans-fatty (B) acids

A. Linoleic acid (C18:2 ω-6, cis, cis)	B. Linolenalaidic acid (C18:2 ω-6, trans, trans)
	

Pic. 4. Structure of a cell membrane and its constituent phospholipids containing two fatty acids

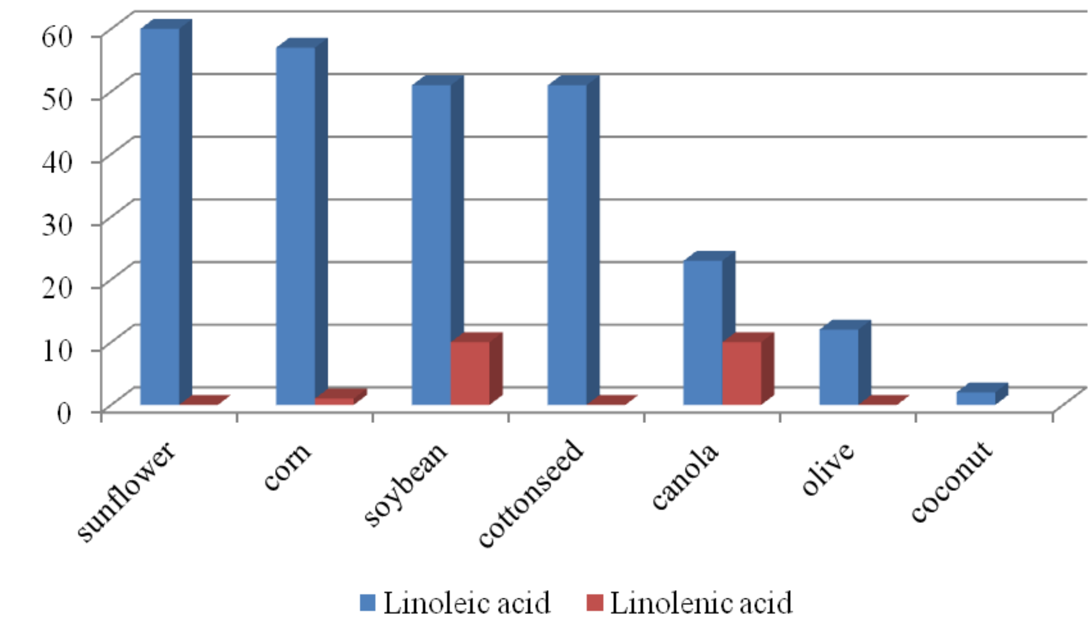


Pic. 5. Range of breast milk fatty acids

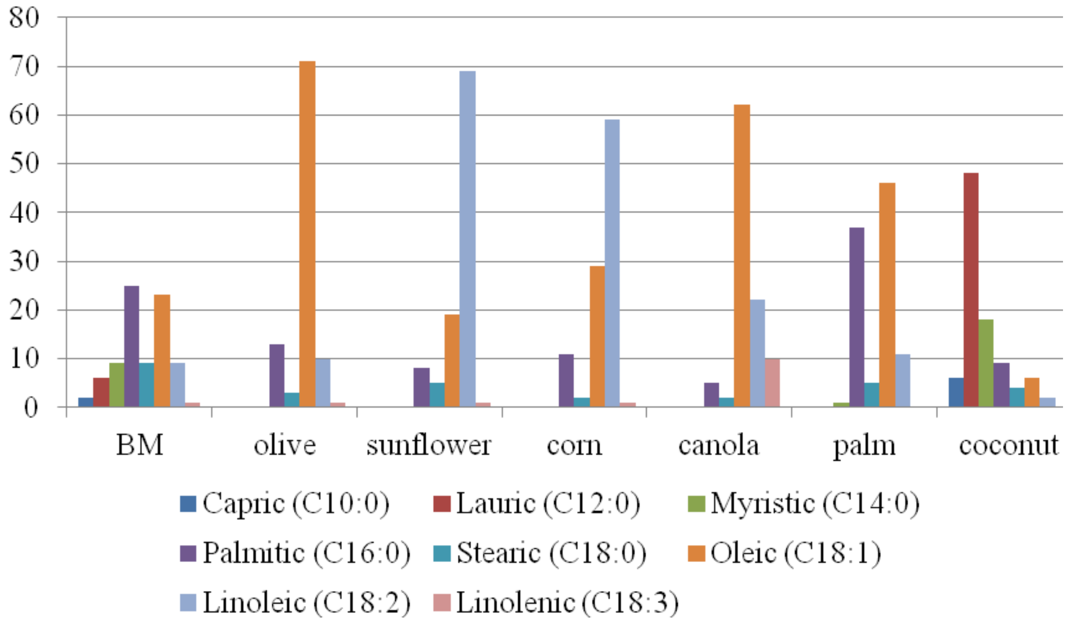


Note. Unsaturated/saturated FA = 1.5/1

Pic. 6. Vegetable oils are the main source of linoleic and α-linolenic acids



Pic. 7. Fatty acid composition of vegetable oils in comparison with breast milk fat composition



Note. BM – breast milk.

Pic. 8. Fatty acid composition of infant formulas containing and not containing palm oil according to CLF Central Laboratories Friedrichsdorf GmbH, 2013.