

PALM OIL

AS A KEY INGREDIENT IN INFANT FORMULA



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INTRODU

Infant and children need the right food to meet their nutritional intake, growth and development. Appropriate feeding efforts are included in the Global Strategy on Infant and Young Child Feeding by the World Health Organization (WHO). The program includes activities encouraging mothers to breastfeed their infant as soon as possible after birth and exclusively for the first 6 months, provide complementary feeding from the age of 6 months, and continue breastfeeding until the age of 2 years or more (WHO 2009). In some cases, infants do not get human milk because the mother is undergoing treatment, dies, has an infectious disease, or when the mother is working (BPOM 2009, Maduko et al. 2007). Therefore, there is a need of a substitute with similar nutrient content to human milk to meet the intake requirements of the infants.

In special condition, human milk

could be replaced by infant formula. Infant formula is included in the Food Category 13.0 i.e. food products for special purposes. Products included in this category are specifically processed or formulated to meet certain nutritional needs due to physical and physiological conditions, or due to certain diseases and health problems. Infant formula in detail is included in category 13.1; infant or starter formulas (13.1.1), follow-up formulas (13.1.2), and formulas for special medical purposes for infants (13.1.3) (Codex Stan 192-1995 Rev 2018; BPOM 2015).

The main energy source for infants in their early months of life comes from the fat content in human milk (Moduko et al. 2007). Human milk contributes 45-50% of energy to infants, hence human-milk substitute is attempted to have fat composition, character, bioavailability and functionality as similar as human milk (Delplanque et al. 2015). Fat source for infant

UCTION

formula are cow's milk, other animal milk or from plants. Fat content in cow's milk as main raw material can be reduced or eliminated and supplemented or replaced by vegetable oils to obtain more essential fatty acids and increase fat digestibility (BPOM 2015).

Palm oil with its fatty acid and triacylglycerol composition and characteristics has an important role as ingredient in formula, together with other vegetable oils. This article will review advantages of palm oil and the formulation strategy to cover its weaknesses as an ingredient in infant formula.



FOTOLIA

INFANT FORMULA INGREDIENTS



Infant formula is available in the form of powder, liquid concentrate, and ready-to-use liquids (Martinez and Ballew 2011), with most of it is sold in powder form. Cow's-milk based formula is formulated with a specific combination of protein, fat, carbohydrates, vitamins,

minerals, and other minor components (Guo et al. 1998). Nutrition safety and adequacy in infant formula must be able to support baby's growth and development and also can be proven scientifically. Sources of protein used in infant formula can be derived from cow's milk, soy protein isolates, and milk protein hydrolysis (Koletzko et

MIXTURES OF VEGETABLE OILS IN INFANT FORMULA

Source: Guo and Ahmad (2014)



PALM OIL



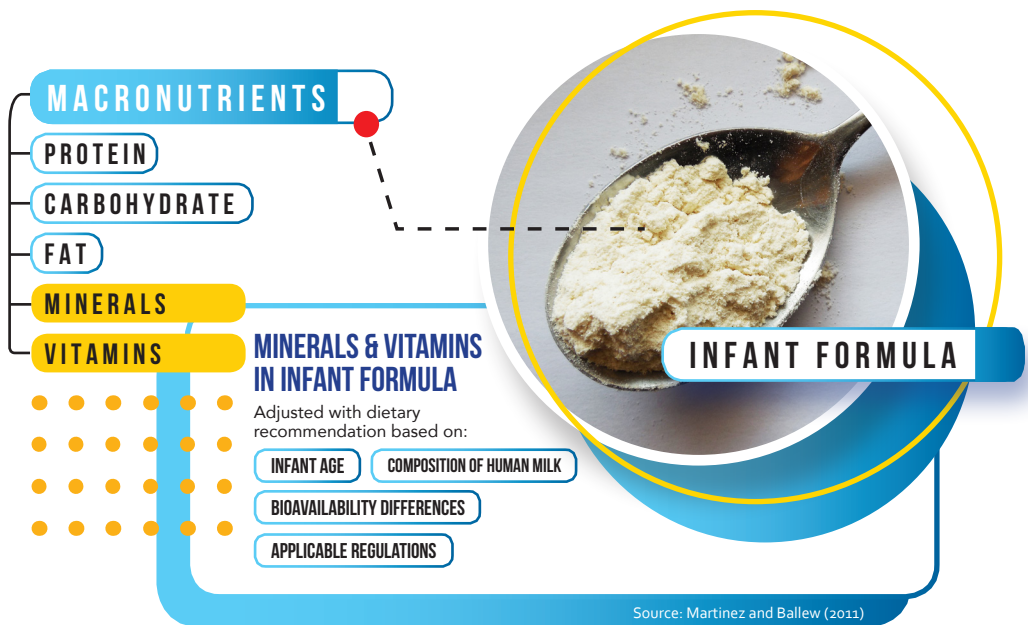
SOYBEAN OIL



COCONUT OIL



HIGH-OLEIC
SUNFLOWER OIL



al. 2005). Hydrolyzed protein was developed for infants who are unable to digest formula containing whole cow's milk protein (Martinez and Ballew 2011). The composition which is usually added as a source of carbohydrates in infant formula includes lactose, maltodextrin, corn syrup, and saccharose (powder or syrup). Fat sources in formula milk came from cow's milk or other animal milk which then added with vegetable oil mixture. Mixtures of vegetable oils that are often used include palm oil, and soybean, coconut, or high-oleic sunflower oil (Guo and Ahmad 2014).

Beside macronutrients such as protein, carbohydrate, and fat, infant formula is also completed with minerals and vitamins,

which adjusted with dietary recommendation based on infant age, composition of human milk, bioavailability differences, and applicable regulations (Martinez and Ballew 2011). Optional ingredients are also added with more specific functional and nutritional benefits according to regulatory requirements, such as prebiotics (galactooligosaccharide-GOS, fructooligosaccharide-FOS, and inulin), probiotics, special oils (docosahexaenoic acid-DHA from deodorized fish oil, LC-PUFA oil (plural long chain unsaturated fatty acids) from microorganism extracts, medium chain triglycerides (MCT), esterified palm oil, and sphingolipid, and carob bean gum and starch (corn or potato) (Guo and Ahmad 2014).



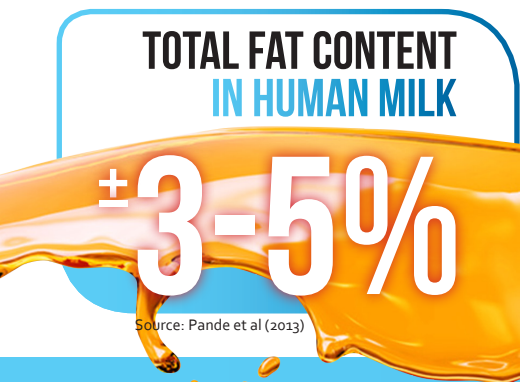
FAT CONTENT IN INFANT FORMULA

The nutrition of human milk is the most ideal reference for infant formula production. Total fat content in human milk is approximately 3-5% (Pande et al. 2013). The main fatty acids are oleic acid (C 18:1) and palmitic acid (C 16). Human milk is also rich in essential fatty acids such as linoleic acid (C 18: 2), linolenic acid (C 18: 3), and its derivative such as arachidonic acid (ARA) and docosahexanoic acid (DHA). Approximately 50% of calories from human milk comes from fat such as palmitic (15-29%), oleic (28-44%), linoleic (10-25%), and linolenic acid (0.5-1.0%) (Picciano 1998, Pande et al. 2013, Sun et al. 2016). Infant formula contains a specific mixture

of vegetable oils to mimic the content of saturated fatty acids (saturated fatty acid-SFA), monounsaturated fatty acids (monounsaturated fatty acids-MFA), and plural unsaturated fatty acids (polyunsaturated fatty acid-PUFA) in human milk and increase the content of essential fatty acids (Hashem and El-waseif 2016).

Fatty acids in infant formula are present in the form of triacylglycerol (TAG). Triacylglycerol (TAG) is the main constituent in oil, arranged from a glycerol bound to three fatty acid molecules. The position of esterified fatty acid is usually described by stereospecific number as sn-1, sn-2, or sn-3 (Berry 2009). There are two types of TAG; simple triacylglycerol, which consists of three identical fatty acids, and mixed TAG which has a combination of fatty acids. Generally, certain fat or oil are not composed by a single TAG, rather a complex mixture of several TAGs (Hart et al. 2003). The combination of fatty acids in glycerol backbone produces various types of TAG that vary in each type of oil or fat.

Characterization of fat using a



TOTAL FAT CONTENT IN HUMAN MILK

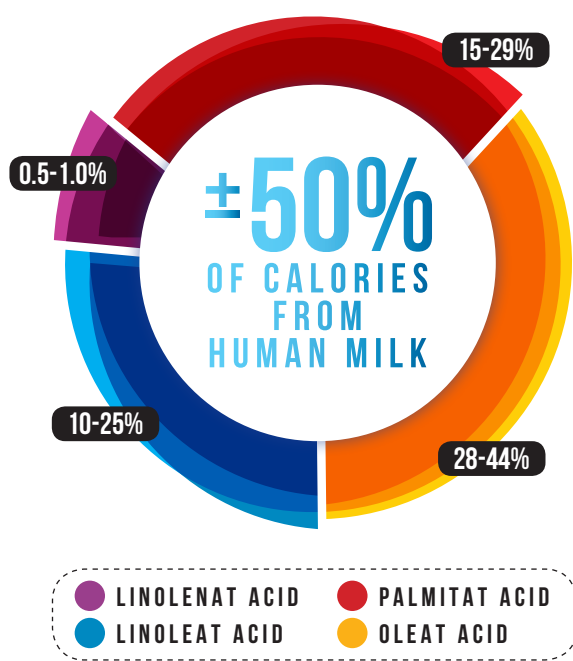
+3-5%

Source: Pande et al (2013)

TAG profile could show the distribution of fatty acids in glycerol backbone (Cunha and Oliveira 2006). TAG analysis can be done by several methods such as thin layer chromatography (TLC), reverse phase high performance chromatography (RP-HPLC), HPLC-RID, and HPLC-ELSD (Cunha and Oliveira 2006).

The difference between fatty acids composition in cow milk's TAG compared with the human milk's TAG is very distinct (Table 1). Cow milk's TAG is dominated by MCT (medium chain triacylglycerol), while human milk's TAG mainly composed by LCT (long chain triacylglycerol). Palm oil's TAG can contribute to PLO/PLP and POO TAG in the formulation. By seeing the TAG composition in Table 1, palm oil cannot be a single source of fat for infant formula. However, the data in Table 1 shows that palm oil has TAG composition that could be use dominantly in infant formula to mimic the composition of human milk's TAG.

Table 1, which also shows the type and composition of vegetable oil's TAG, is important information for the formulation of vegetable oil mixtures to mimic the composition of fatty acids and TAG in human milk. Mixtures of vegetable oils



Source: Picciano (1998), Pande et al (2013), Sun et al (2016)

commonly added to infant formula include palm oil, coconut oil, soybean oil, high oleic sunflower oil, corn oil, canola oil, safflower oil, and olive oil (Baltrope and Oppe 1973, Nelson et al. 1998, Pina-Rodriguez and Akoh 2010, Rezhak et al.2011, Delplanque et al. 2015). The results of TAG analysis in Table 1 from 50 commercial infant formulas in Indonesia showed that 44 (88%) products used palm oil (palm olein) as their ingredients. Our finding also showed that vegetable oil mixtures with palm olein in infant formulas consisted of PO-HOSO-SBO-CNO (58%), PO-SBO (16%), PO-HOSO-SBO (10%), and PO-SBO-CNO (4%) (Risma and Andarwulan 2019).



Type of TAG ^a	ECN ^b					
		AMF	ASI	PO	HOSO	CNO
CaCaLa	32	2.32	-	-	-	12.90
CaLaLa	34	5.76	-	-	-	17.4
LaLaLa	36	12.77	-	-	-	21.20
LaLaM	38	14.53	0.64	-	-	18.00
LaLaO	40	11.78	-	-	-	3.10
LaMM	40	-	-	-	-	10.20
LLLn	40	-	-	-	-	-
LLL	42	8.27	-	-	-	-
OLLn	42	-	-	-	-	-
PLLn	42	-	-	-	-	-
OLL	44	-	1.65	0.80	0.70	-
OLPo	44	-	-	-	-	-
PLL	44	7.58	1.57	3.00	-	-
OLnO	44	-	-	-	-	-
OLO	46	-	5.01	2.10	1.30	-
PLO	46	8.28	16.65	11.80	-	-
PLP	46	-	-	11.00	-	-
OOO	48	-	5.26	4.30	91.30	-
POO/OPO	48	9.37	27.24	25.40	4.40	-
POP	48	-	5.13	30.60	-	-
PPP	48	-	-	0.80	-	-
SOO	50	-	-	2.80	2.30	-
POS	50	9.65	4.54	5.60	-	-
PPS	50	-	-	0.10	-	-
SSO	52	7.91	-	0.5	-	-
Others		1.78	32.31	1.2	0	17.2

^afatty acid in TAG, Ca (caprat; C10), La (laurat; C12), M (miristat; C14), P (palmitat; C16), S (stearat; C18), O (oleat; 18:1), L (linoleat; C18:2), Ln (linolenat; C18:3)

^bECN (equivalent carbon number)

^cType of fats/oils, anhydrous milk fat (AMF), human milk (ASI), palm olein (PO), high oleic sunflower oil (HOSO), coconut oil (CNO),

Table 1

Type and Composition of TAG (%) in fats/oils

Type of Fat/Oil^c

SBO	CaO	FB (n=11)	FL (n=16)	FP (n=15)	FK (n=8)
-	-	-	-	-	-
-	-	1.57	1.53	1.22	1.83
-	-	2.24	2.01	1.74	2.63
-	-	3.64	4.48	3.30	4.59
-	-	-	-	-	-
-	-	3.91	4.14	3.39	4.09
-	-	0.33	0.34	0.75	0.98
32.00	5.83	7.91	6.63	8.83	8.98
-	-	0.36	1.23	1.05	1.03
-	-	-	0.02	-	0.04
30.50	10.61	8.28	7.12	9.21	8.06
-	-	0.18	0.27	0.77	-
8.00	-	2.38	2.25	3.82	3.31
-	-	-	-	-	-
9.80	21.74	6.46	6.18	7.29	6.04
9.50	7.40	6.97	7.74	7.35	4.95
1.00	-	4.63	5.32	4.08	2.71
3.00	31.85	14.24	9.90	11.21	15.17
3.80	-	13.91	15.06	12.58	8.22
0.50	-	12.03	14.28	10.25	6.35
1.00	-	0.40	0.28	0.25	0.33
0.50	2.70	2.42	2.42	2.32	1.70
0.20	-	2.78	2.98	2.42	2.12
0.20	-	-	-	0.20	-
-	-	-	-	-	-
0	19.87	5.36	5.82	7.97	16.87

soybean oil (SBO), canola oil (CaO), infant formula (FB), follow-on formula (FL), growing-up milk formula (FP), and formula for medical purposes (FK)

Source: Tan and Man 2002, Morera et al. 2003, Li et al. 2010, Clereq et al. 2012, Fauziet al. 2013, Alvarez and Akoh 2016, Risma and Andarwulan 2019



TRIACYLGLYCEROL FORMULATION STRATEGY IN INFANT FORMULA

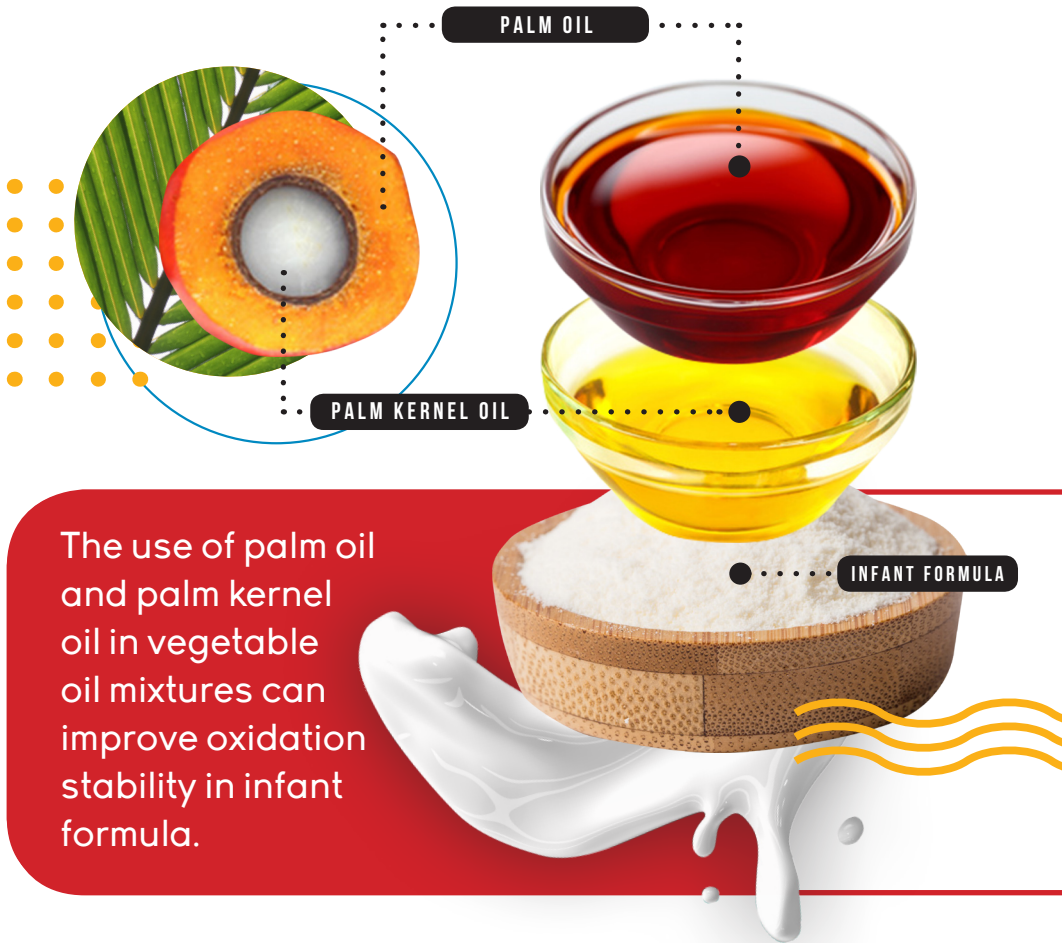
The dominant TAG in human milk, from the study of Sun et al. 2018 of 10 samples of human milk in China, include OPO (10.28 - 27.85), OPL (20.34 - 30.12%), OLL (3.12 - 8.11%), MOL (4.07 - 9.86%), and LOO (2.67 - 9.34%). Stereospecific structure of TAG in human milk is different from vegetable oil and cow's milk as a source of fat in infant formula. In human milk, the palmitic acid is dominantly esterified on sn-2 whereas in vegetable oils and cow milk is on sn-1 and sn-3 respectively (Pande et al. 2013). Sn-2 palmitic acid is more absorbable, whereas sn-1 or sn-3 will form free fatty acids that could bind to minerals such as calcium, hence make them not as absorbable and excreted in infant stool. This lead to a problem of fat and calcium absorption in infants (Nelson et al. 1998, Lopez-Lopez

et al. 2001, Pande et al. 2013, Mendonca 2017). From clinical point of view, reducing the intake of palmitic acid from vegetable oils, especially type sn-1 or sn-3 from palm oil, can overcome the problem. SFA sources can be provided from coconut oil or medium chain triglyceride (MCT) (Innis 2011). Coconut oil and MCT are rich in medium chain fatty acids. Infants can digest medium chain fatty acids more easily (Rodriguez et al. 2003).

Research on the use of vegetable oils in infant formula has been done quite a lot with the aim of obtaining a composition similar to human milk, achieving clinical purposes or extending product shelf-life. Some examples on research for clinical purposes are conducted by Nelson et al. (1998) and Lopez-Lopez et al. (2001). One study from Maduko et al. (2007) which is fat modification of

infant formula containing palmitic, oleic, and linoleic acids similar to human milk through enzymatic interesterification between tripalmitin and vegetable oil mixtures containing 2.5 : 1.1 : 0.8 ratio of coconut, safflower, and soybean oil. Hashem and El-Waseif (2016) also

conducted a study to determine the oxidation stability of eight vegetable oil mixtures prepared from palm, palm kernel, soybean, and sunflower oil. The results showed that the use of palm oil and palm kernel oil in vegetable oil mixtures can improve oxidation stability in infant formula.



The use of palm oil and palm kernel oil in vegetable oil mixtures can improve oxidation stability in infant formula.



REFERENCES

- [BPOM] Badan Pengawas Obat dan Makanan. 2009. Peraturan Kepala Badan Pengawas Obat dan Makanan Republik Indonesia Nomor HK.00.05.1.52.3920 Tahun 2009 tentang Pengawasan Formula Bayi dan Formula Bayi untuk Keperluan Medis Khusus. Jakarta (ID): BPOM.
- [BPOM] Badan Pengawas Obat dan Makanan. 2015. Peraturan Kepala Badan Pengawas Obat dan Makanan Republik Indonesia Nomor 1 Tahun 2015 tentang Kategori Pangan. Jakarta (ID): BPOM.
- Alvarez CA, Akoh CC. 2016. Preparation of infant formula fat analog containing capric acid and enriched with DHA dan ARA at the sn-2 position. *Journal of American Oil Chemistry Society* 93: 531-542.
- Baltrope D, Oppe TE. 1973. Absorption of fat and calcium by low birth weight infants from milks containing butterfat and olive oil. *Archives of Disease in Childhood*. 48: 496 – 501.
- Berry SEE. 2009. Triacylglycerol structure and interesterification of palmitic and stearic acid-rich fats: an overview and implications for cardiovascular disease. *Nutrition Research Review* 22: 3-17.
- Clereq ND, Danthine S, Nguyen MT, Gibon V, Dewettinck K. 2012. Enzymatic Interesterification of palm oil and fractions: monitoring the degree of interesterification using different methods. *Journal of American Oil Chemistry Society*. 89: 219-229.
- Cunha SC, Oliveira MBPP. 2006. Discrimination of vegetable oils by triacylglycerols evaluation of profile using HPLC/ELSD. *Food Chemistry* 95: 518-524.
- Delplanque B, Gibson R, Koletzko B, Lapillonne A, Strandvik. 2015. Lipid quality in infant nutrition: current knowledge and future opportunities. *Journal of Pediatric Gastroenterology and Nutrition* 6 (1): 8-17.



- Guo M, Ahmad S. 2014. Ingredients selection for infant formula. Di dalam: Guo M, editor. *Human Milk Biochemistry and Infant Formula Manufacturing Technology*. Cambridge (UK): Woodhead Publishing Ltd.
- Fauzi SHM, Rashid NA, Omar Z. 2013. Effects of chemical interesterification on the physicochemical, microstructural, and thermal properties of palm stearin, palm kernel oil, and soybean oil blends. *Journal of Food Chemistry* 137: 8-17.
- Hart H, Craine LE, Hart DJ. 2003. *Kimia Organik Suatu Kuliah Singkat Edisi Kesebelas*. Jakarta (ID): Erlangga.
- Hashem HA, El-Waseif MA. 2016. Using palm oils in improving oxidative stability and covering lipid requirements of oil blends used in manufacturing infant formula. *Journal of Oil Palm, Environment and Health*. 7: 34-42.
- Innis SM. 2011. Dietary triacylglycerol structure and its role in infant nutrition. *Advance Nutrition* 2: 275-283.
- Koletzko B, Baker S, Cleghom G, Neto UF, Gopalan S, Hernell O, Hock QS, Jirapinyo P, Lonnerdal B, Pencharz P, Pzyrembel H, Mayans JR, Shamir R, Turk D, Yamshiro Y, Yi DZ. 2005. Global standard for the composition of infant formula: recommendations of an ESPGHAN coordinated international expert group. *Journal of Pediatric Gastroenterology and Nutrition*. 41: 584-599.
- Lopez-Lopez A, Castellote-Bargallo AI, Campoy-Folgoso C, Rivero-Urgel M, Tormo-Carnice R, Infante-Pira D, Lopez-Sabater MC. 2001. The influence of dietary palmitic acid triacylglyceride position on the fatty acid, calcium, magnesium contents of at term newborn faeces. *Early Human Development* S84-S94.



REFERENCES

- Li D, Adhikari P, Shin JA, Lee JH, Kim YJ, Zhu XM, Hu JN, Jin J, Akoh CC, Lee KT. 2010. Lipase-catalyzed interesterification of high oleic sunflower oil and fully hydrogenated soybean oil comparison of batch and continuous reactor for production of zero trans shortening fats. *LWT- Food Science and Technology*. 43: 458-464.
- Maduko CO, Akoh CC, Park YW. 2007. Enzymatic interesterification of tripalmitin with vegetable oil blends for formulation of caprine milk infant formula analogs. *Journal of Dairy Science* 90: 594-601.
- Martinez JA, Ballew MP. 2011. Infant formulas. *Pediatrics in Review*. 32 (5): 179-189.
- Mendonca MA, Araujo WMC, Borgo LA, Alencar ER. 2017. Lipid profile of different infant formulas for infants. *PLOS ONE*. 12 (6): 1-14.
- Morera S, Castellote AI, Jauregui O, Casals I, Lopez-Sabater MC. 2003. Triacylglycerol markers of mature human milk. *European Journal of Clinical Nutrition* 57: 1621-1626
- Nelson SE, Frantz JA, Ziegler EE. 1998. Absorption of fat and calcium by infants fed based formula containing palm olein. *Journal of the American College of Nutrition*. 17 (4): 327-332.
- Pande G, Sabir JSM, Baeshen NA, Akoh CC. 2013. Synthesis infant formula fat analogs enriched with DHA from extra virgin olive oil and tripalmitin. *Journal of American Oil Chemistry Society* 90: 1311-1318.
- Picciano MF. 1998. Human milk: nutritional aspects of dynamic food. *Biology of the Neonate* 74: 84-93.
- Pina-Rodriguez AM, Akoh CC. 2010. Composition and oxidative stability of structured lipid from amaranth oil in milk based infant formula. *Journal Food Science*. 75 (2): 140-146.



- Rezhak P, Koletzko B, Sausenthaler S, Reinhardt D, Grubla, Bauer CR, Kramer U, Bollrath C, Bergh AV, Berdel D, Wichmann H, Heinrich J. 2011. Growth of infants fed formula rich in canola oil (low erucic acid rapeseed oil). *Clinical Nutrition*. 30: 339-345.
- Risma RY, Andarwulan N. 2019. Triacylglycerol profile of commercial infant formulas in Indonesia. Asian Congress of Nutrition (ACN). Bali 4-7 August 2019.
- Rodriguez M, Funke S, Fink M. 2003. Plasma fatty acids and [^{13}C]linoleic acid metabolism in preterm infant fed a formula with medium-chain triglycerides. *Journal of Lipid Research* 8: 41-44.
- Sun C, Zou X, Yao Y, Jin J, Xia Y, Huang J, Jin Q, Wang X. 2016. Evaluation of fatty acid composition in commercial infant formulas on the Chinese market: a comparative study based on fat source and stage. *International Dairy Journal*. 63: 42-5.
- Sun C, Wei W, Zou X, Huang J, Jin Q, Wang X. 2018. Evaluation of triacylglycerol composition in commercial infant formulas on the Chinese market: a comparative study based on fat source and stage. *Food Chemistry* 252: 154-162.
- Tan CP, Man YBC. 2002. Differential scanning calorimetric analysis of palm oil, palm oil based products and coconut oil: effect of scanning rate variation. *Food Chemistry* 76: 89-102.
- [WHO] World Health Organization. 2009. *Infant and Young Child Feeding: Model Chapter for Text Books for Medical Students and Allied Health Professionals*. Geneva (CHE): WHO Press.





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