Matching nature's finest

From the use of animal fats such as lard to palm oil, and triglycerides produced by enzyme technology, the development of fats for infant formulae continues. Geoff Talbot writes

Breast may well still be best but modern-day oils and fats technology can now run it a close second. The nutrition that newly-born infants receive is of fundamental importance to the development of those babies in both the short- and long-term.

Not least in importance are the types of fats consumed by infants. Naturally, of course, these are provided by the mother in the form of breast milk but, for a variety of reasons, not all mothers are able to provide sufficient nutrients for the healthy development of their babies in this way.

This is where infant formulae come in. Although the fat content of human milk is only about 3-4%, the fat it contains provides about 50-60% of the energy intake of the infant, making this one of the most important nutrients in both human milk and infant formulae. Human milk fat has a fatty acid composition that is fairly easily mimicked by combinations of vegetable oils being rich in palmitic and oleic acids.

Where vegetable oils fail

However, triglyceride composition is such that simple blends of vegetable oils fall down in one major respect – they do not match the fatty acid composition of the *sn*-2 or central position of the triglyceride structures that make up the fat molecules (*see Table 1, on page 22*).

Taking palm oil itself as an example, apart from having a higher palmitic acid content and lower lauric/myristic acid content than human milk fat, it compares reasonably well in fatty acid composition. However, palmitic acid at the *sn*-2 position in palm oil is only 11% compared to 40-60% in human milk fat.

A blend of vegetable and animal fats (lard, butterfat and coconut oil) has a much closer match in terms of both total and *sn*-2 compositions but, for a variety of reasons (nutritional, ethical, religious), the use of animal fats such as lard has generally been avoided in infant formulae in recent years.

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Despite this, some early work on infant nutrition (*Filer et al, 1969*) compared lard with a high level of palmitic acid in the *sn*-2 position with randomised lard containing a much lower amount of 2-position palmitic acid. On average, 6.37 g/kg body wt/day of lard was taken in by the infants (all less than 10 days old) and 0.30g/kg/day were excreted. This compares to an average intake of 6.33g/kg/day of randomised lard of which 1.79g/kg/day were excreted.

The infants therefore excreted considerably more of the fat in which palmitic acid was in the *sn*-1 and *sn*-3 positions. In addition, the percentage absorption of the two main saturated fatty acids was considerably less when randomised lard was used compared to normal lard (94% absorption of C16:0 and 88% absorption of C18:0 with lard; 58% absorption of C16:0 and 40% absorption of C18:0 with randomised lard).

Importance of palmitic acid

Why, then, should the position of, particularly palmitic acid, be of such importance? It all comes down to the way in which fats are metabolised during digestion. The action of lipase during digestion breaks off the fatty acids in the *sn*-1 and *sn*-3 positions leaving a 2-monoglyceride which is then absorbed by the infant along with some of the free fatty acids. In breast milk this lipase action results in unsaturated fatty acids being cleaved from the *sn*-1 and *sn*-3 positions leaving a 2-monopalmitate. All of these are well-absorbed by the infant.

If a vegetable fat-based formula is used, then palmitic acid in the *sn*-1 and *sn*-3 positions breaks off under the action of lipase leaving an unsaturated 2-monoglyceride to be absorbed by the infant. This has two effects. The first is that palmitic acid, which is important as an energy source, is excreted to a greater extent from a vegetable fat-based formula. The second is that this palmitic acid is not just excreted as the free acid but combines with calcium in the diet to produce calcium soaps. Excretion of these not only removes essential calcium from the infant's diet but also can result in constipation and hard stools, a problem less commonly found in breast-fed infants.

Overcoming the problem

If, then, infant formulae cannot contain animal fats for the reasons highlighted earlier but must be made from vegetable fats, how can these problems be overcome? In simple terms, we need to exchange the kind of SUS (saturated/unsaturated/saturated) structure of triglycerides often found in oils such as palm oil, for example, for a USU (unsaturated/saturated/unsaturated) structure.

Fortunately, this is a symmetrical structure of the kind that can be produced by enzymic interesterification using lipases with 1, 3-positional specificity. Triglycerides rich in *sn*-2 palmitic acid, such as tripalmitin (or palm stearine) are interesterified using such an enzyme with oleic acid. A mix of fatty acids and triglycerides results, one of which is OPO (oleic, palmitic, oleic), the structure needed in an infant formula. The fatty acids can be removed by a range of deacidification methods while the OPO can be concentrated from the triglyceride mix by fractionation.

TABLE 1: FATTY ACID COMPOSITIONS OF HUMAN MILK FAT AND SIMPLE ANALOGUES

Fat	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2
Human milk fat[1]	7	8	23	7	38	9
Vegetable oil blend[2]	8.4	3.9	27.4	9.1	38.6	9.4
Palm oil[3]	0.2	1.0	44.0	4.4	38.6	10.0
Human milk fat – sn-2[1]	2.1	7.3	40-60	3.3	12.7	7.3
Palm oil – sn-2[3]			11	2	65	22

[1]Jensen (1989)
[2]Blend of 15% palm kernel stearine; 55% palm oil; 15% rapeseed oil; 15% shea butter
[3]Gunstone et al (1986)

TABLE 2: COMPARISON OF FATTY ACID COMPOSITIONS OF AN OPTIMISED INFANT FORMULA FAT AND OF HUMAN MILK (FROM MADUKO ET AL, 2007)

Fatty acid	Total fatty acid composition		*sn*-2 fatty acid composition	
	Infant formula fat[1]	Human milk fat[2]	Infant formula fat[1]	Human milk fat[2]
C12:0	23.6	7	16.3	2.1
C14:0	8.2	8	9.5	7.3
C16:0	24.6	23	40.8	40-60
C18:0	6.2	7	2.6	3.3
C18:1	29.6	38	14.3	12.7
C18:2	3.4	9	8.6	7.3

[1]Maduko et al (2007), [2]Jensen (1989)

Infant formula fats containing triglycerides produced by enzyme technology are available from two of the leading manufacturers of speciality fats. Betapol is available from Loders Croklaan; InFat is available from Advanced Lipids (a joint venture of AAK and Enzymotec). As a result of introducing palmitic acid into the *sn*-2 position of the triglyceride, infants fed formulae containing these fats have significant health benefits. For example, the following health benefits were found when infants were fed Betapol compared to those fed commercial infant formulae (*Lipid Nutrition, 2008*):

- 24% increase in absorption of palmitic acid from diet.
- 88% lower faecal calcium.
- 36% more dietary calcium absorbed.
- 5% improvement in bone mineral density.
- 65% reduction in hard stools.

Similar studies are being carried out on the Advanced Lipids product InFat (*ClinicalTrials.gov, 2011*).

Too simplistic

To focus solely on OPO is, though, perhaps too simplistic although this needs to be a major triglyceride in an infant formula fat. Human milk fat contains a range of fatty acids other than oleic and palmitic acids and a range of triglycerides other than OPO. To include the other fatty acids and triglycerides found in human milk fat, Maduko et al (2007) enzymically interesterified different blends of tripalmitin with a mixture of 56.8% coconut oil, 25.0% safflower oil, 18.2% soyabean oil under a range of processing conditions. Lipozyme RM IM from Novozymes was used as the enzyme and response surface methodology was used to define the optimum conditions. The compositions of the main fatty acids in the total fat and *sn*-2 positions are compared with those in human milk fat in Table 2 *(above)*.

Important fatty acids

Although, emphasis has been placed in this article on the correct positioning of palmitic acid in infant formulae, this is by no means the only acid of importance in human milk. Koletzko et al (1988) found more than 40 different fatty acids in human milk, including a number of long chain unsaturated fatty acids including 0.30-0.54% arachidonic acid (AA), up to 0.16% EPA and 0.15-0.60% DHA.

It is known that these fatty acids are important in development of the infant's brain and eyes both before and after birth. During pregnancy the baby gets these fatty acids from the mother through the placenta; after birth breast-fed infants receive them through their mother's milk.

It is important, then, that babies fed infant formulae should also receive these fatty acids, particularly DHA. It is becoming increasingly common practice for manufacturers of infant formulae to supplement them with AA and DHA (International Formula Council, 2011). The European Food Safety Authority (EFSA, 2010) recommend an adequate intake level of DHA of 100mg/day for infants aged between six and 24 months. ●

Geoff Talbot is a consultant in fats and oils