

# Palm-based *Trans*-free Whipped Topping as an Alternative to Dairy Cream

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## INTRODUCTION

Vegetable fat-based whipped toppings is used as a replacement for whipped dairy cream are commonly called whipped toppings, non-dairy cream, imitation cream and vegetable cream (Neil and Hogg, 2003). Whipped cream is an aerated food emulsion which is normally produced from milk fat. It has a white opaque appearance and low density due to the high inclusion of gas bubbles in the system. The emulsion droplets usually contain partially crystallized fats (Aken, 2001).

Whipped toppings have become popular both for commercial and consumer use on puddings, sodas, cakes, ice cream, fruit and pastries such as cream pie bases. Consumers and manufacturers have certain expectations for the quality of whipped toppings with regard to taste, shelf-life and whipping characteristics, such as speed of whipping, overrun and stability (Shamsi *et al.*, 2002).

In dairy cream, the whipping process forms air cells that are stabilized by fat globules at the air-water interface. During whipping, the oil-in-water emulsion is transformed into a three-phase system in which air bubbles are incorporated into a fat globule network. When air is initially incorporated, high surface tension at the air-water interface results in the adsorption of the fat globules and then of protein. Fat adsorption involves the partial loss of the fat globule membrane (FGM) and the spreading of fat, especially if it is predominantly liquid, at the air-water interface (Brooker *et al.*,

1986). As whipping continues, at least three changes may occur: coalescence, size reduction or collapse of structure. Reduction of the surface area of the air-water interface of some bubbles encourages the formation of clumps, and some are released from the interface either by the collapse of air bubbles or as a result of shearing effects (Smith *et al.*, 2000). The partly destabilized fat globules in the whipped cream are important for stability of the foam structure. If the emulsion is too stable, it will not whip. On the other hand, if it is not stable enough, the foam formed will collapse after a short whipping period. There is thus a delicate balance between emulsion stability and instability. The whipped cream should be

stable, at least for a limited period, at room temperature.

Many researchers agree that fat content, cream temperature, the homogenization process and pasteurization condition, and the presence of stabilizers and emulsifiers influence the functional properties of whipped creams (Nielson, 1984; Nesaretnam *et al.*, 1993). The industry prefers to process whipped cream by ultra-high temperature (UHT) sterilization to improve the shelf-life, but this heat treatment impairs foam stability (Smith *et al.*, 2000). The foam prepared from UHT-processed cream exhibits larger fat globules than foams whipped from a high-temperature-short-time (HTST) condition, and contributes to low overrun, poor stability and an increased aggregation of fat globules in the whipped cream. During storage (24 hr, 5°C), the UHT-treated cream exhibits a more solid-like structure, that is, a foam with lower visco-elasticity, which is less able to withstand the overall destabilization process (Smith *et al.*, 2000).

Functional properties of whipped toppings can be more variable than whipped cream because manufacturers can choose a more desirable fat characterized by a specific fat profile with suitable hydrocolloids. The commercial dairy

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# Significance of the SN-2 Hypothesis

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## INTRODUCTION

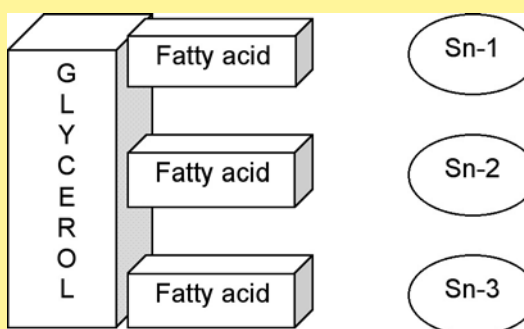
The body uses fats for long-term energy storage because they provide about six times as much energy as an equal weight of stored, hydrated glycogen (McMurray, 2000). Many different fats and oils exist as sources of triacylglycerols in the human diet. These oils originate from fruits (palm oil and olive oil) or from seeds (corn oil, rapeseed oil and soyabean oil). Animal and fish fats are other examples of fats. Animal fats like butter and lard are solid at room temperature while vegetable oils like corn, soyabean and peanut oils are liquid. However, their structures are closely related.

Fats and oils are made up of a mixture of triacylglycerols (TAG), which in turn consist of a glycerol backbone to which three fatty acids are esterified. The distribution of the fatty acids on the glycerol backbone of the TAG which is referred to as the stereospecific number, (sn) -1, -2 and -3, plays a significant role as a marker of its composition and properties (Goh, 2006). *Figure 1* shows the schematic structure of the TAG where three fatty acids are bonded to a glycerol backbone.

The fatty acids in fats and oils are classified as saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) or polyunsaturated fatty acids (PUFA). With this classification, palm kernel oil, which is made up of 88% SFA (lauric acid, C12:0 and myristic acid, C14:0) and has very little MUFA and PUFA, is considered a saturated fat. Olive oil on the other hand has 80% oleic acid (C18:1) and only 9% PUFA and 10% SFA, and is therefore classified as an oil that is predominantly monounsaturated. Sunflower oil has 70% linoleic acid (C18:2) and only 12% SFA, and hence is termed a polyunsaturated oil.

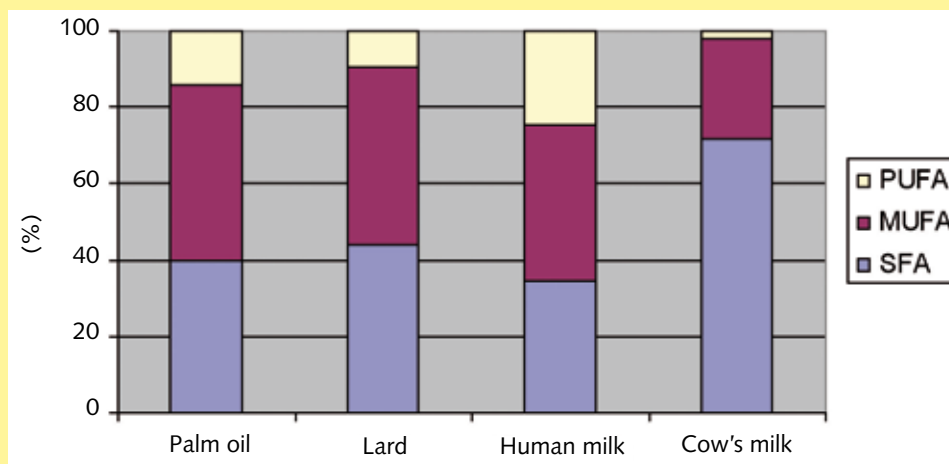
In vegetable oils, oleic acid (C18:1, a member of MUFA) is predominantly situated at the sn-2 position, while in animals fats it is predominantly palmitic acid or stearic acid (C16:0 or C18:0-saturated fat) at this position. *Figure 2* shows the fatty acids composition (FAC) for palm olein, lard, human milk and cow's milk. Even though

palm olein and lard have similar proportion of SFA, MUFA and PUFA, they differ significantly in the positional distribution of the fatty acids on the TAG molecule (*Figure 3*). Palm olein triglycerides contain only 7%-11% palmitic acid at the sn-2 position while 60%-70% is oleic acid. On the other hand, in human milk, palmitic acid is predominantly present in the sn-2 position (53%-57%) while cow's milk fat contains less palmitic acid (38%) at that position, as reported by Straarup *et al.* workers (2006). They found that infant formulations in the Danish market did not match human milk although they were formulated to mimic its FAC. Most of the palmitic acid in the TAG molecules was located at the sn-1 and sn-3 positions (75%-97%). It has become apparent that the FAC alone does not tell you the whole story. The positional distribution of the fatty acids in the TAG is more important.



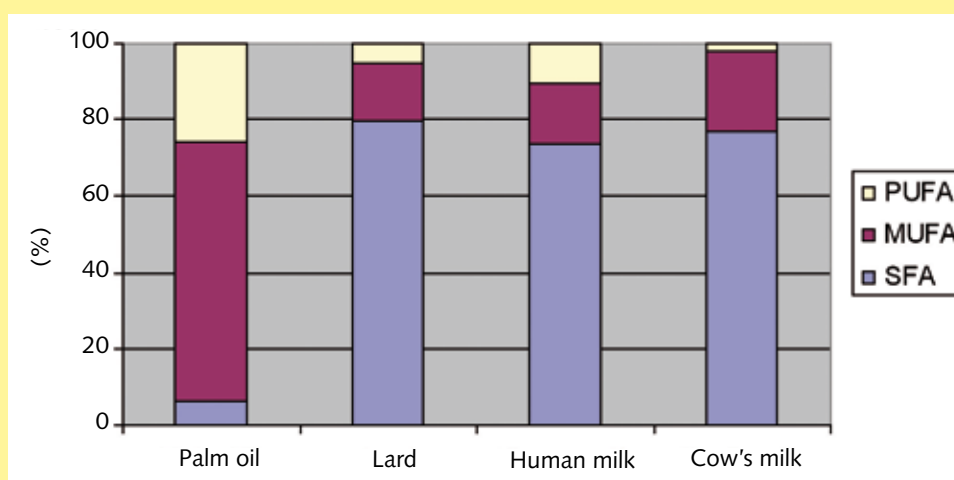
*Figure 1. Triacylglycerols (TAG) structure showing the stereospecific numbering of sn-1, -2 and -3.*

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Source: Straarup *et al.* (2006).

Figure 2. Fatty acid compositions of palm olein, lard, human milk and cow's milk.



Source: Straarup *et al.* (2006).

Figure 3. Sn-2 fatty acid composition of palm olein, lard, human milk and cow's milk.

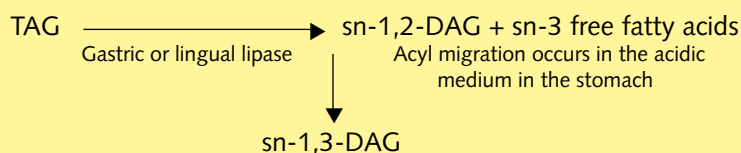
## LIPID DIGESTION AND METABOLISM

The digestion of fat occurs when the enzyme lipase is present. The lipases involved in this process are lingual, gastric, pancreatic and co-pancreatic lipases that are found in the mouth, stomach and small intestine, respectively.

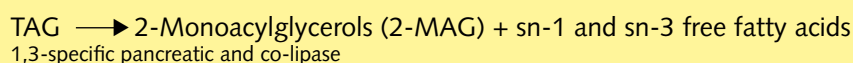
In the stomach, pre-digestion of 10%-30% of fat occurs in the presence of lingual and gastric lipases, and bile salts produced from the liver. Lingual and gastric lipases prefer to cleave the sn-3 fatty acids, resulting in the

formation of 1,2-diacylglycerols (1,2-DAG) and sn-3 free fatty acids. The acidic medium in the stomach will facilitate the conversion of sn-1,2-DAG to sn-1,3-DAG. The sn-1,3-DAG and sn-3 free fatty acids (if <12 carbons) are readily absorbed in the intestine. The schematic diagram below shows the hydrolysis route of TAG at different locations.

In the stomach,



In the small intestine, particularly in the duodenum,



In the small intestine, particularly in the duodenum, digestion of 70%-90% of the fats takes place in the presence of pancreatic and co-pancreatic lipases. Pancreatic lipase hydrolyse the sn-1 fatty acids, while co-pancreatic lipase prefers to hydrolyse sn-3 fatty acids in TAG. The products from the hydrolysis of TAG are 2-MAG, sn-1 and sn-3 free fatty acids.

The sn-2 fatty acid in the form of 2-MAG is transported by a type of lipoprotein called the chylomicrons. Chylomicrons contain 93% of new TAG (solely from the food source) in its core. These new TAG are result of the resynthesis of 2-MAG and free fatty acids (majority long-chain SFA) present in the intestine. Short and medium chain fatty acid absorption is not via chylomicrons. Chylomicrons are then secreted into the blood stream via the lymphatic system. The presence of lipoprotein lipase which lines on the blood vessel walls will hydrolyze the new TAG in chylomicron. Chylomicron remnants, 2-MAG and free fatty acids are then produced. Chylomicron remnants which carry the cholesterol ester and TAG will be transported back to the liver, while 2-MAG and free fatty acids will be used for the liver TAG synthesis or energy supply and storage. Eating long-chain SFA and elaidic acid (*trans* isomer of oleic acid) situated at the sn-2 position of TAG might slow down the hydrolysis of chylomicron TAG, liver uptake and the clearance of chylomicron remnants. The presence of a large amount of chylomicron remnants in the blood could lead to an increased plasma cholesterol level and atherogenesis which can cause detrimental effects to health.

In the intestines, sn-1 and sn-3 short and medium chain free fatty acids are absorbed directly after

hydrolysis. Long chain SFA will either be absorbed or predominantly react with 2-MAG for the resynthesis of new TAG and chylomicron formation. Sn-1 and sn-3 long chain free SFA will not be absorbed or have a delayed absorption as their melting points are higher than body temperature. Furthermore, with the presence of calcium in the intestine, these long chain free SFA tend to precipitate as calcium soaps and are then excreted (*Table 1*).

Surprisingly, pancreatic lipase and its co-lipase have low activity on long chain PUFA that have more than 20 carbons, especially arachidonic acid (ARA, C20:4n-6), eicopentaenoci acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3), although they are located at the sn-3 position (Bottino *et al.*, 1967). These longchain PUFA are present in the form of 2,3-DAG instead of sn-3 fatty acid itself. These 2,3-DAG will only be hydrolyzed by hepatic lipase in the liver. They are retained in the chylomicron remnants that will be transported to the liver to produce 2-MAG and free long chain PUFA. The slow hydrolysis of the long chain PUFA at the sn-3 position in TAG reduces the supply of sn-2 MAG and delays the resynthesis of new TAG in the intestine. Hence, sn-3 positioned long chain PUFA are not directly absorbed by the body,

while the sn-2 long chain PUFA will be directly absorbed in the form of 2-MAG. This is important especially when introducing DHA in infant formula for better and faster absorption.

The absorption and digestion of fat in infants are slightly different from those of adults. At birth, infants have to adapt to the high fat content of breast milk after relying mainly on glucose as an energy source during fetal development. The pancreatic secretion of lipase is low and the immature liver is unable to provide sufficient bile salts to solubilize the digested lipids. Hence, newborn babies digest fats less efficiently than adults. However, breast milk contains lipoprotein lipase and bile-salt-stimulated-lipase that might be able to assist the baby to digest milk TAG. In addition, the baby also secretes a TAG lipase from glands in the stomach and tongue. The presence of milk lipase (only in babies) in the intestinal lumen will hydrolyse 2-MAG to glycerol and free fatty acids for direct absorption before the resynthesis of new TAG happens. This milk lipase will shorten the route of digestion and absorption of sn-2 long chain SFA in infants. Besides, human milk with palmitic acid (long chain SFA) predominantly at the sn-2 position forms mixed micelles with bile salts in the milk itself. This again

**TABLE 1. SUMMARY OF ABSORPTION FOR SOME COMMON FATTY ACIDS AT SN-1 AND SN-3 POSITIONS IN TRIACYLGLYCEROLS**

Common name	Fate after hydrolysis
Short chain fatty acids (C4-C6)	Absorbed directly
Medium chain fatty acids ( C8-C10)	Absorbed directly
Long chain saturated fatty acids	Delayed absorption by minor phosphatidic acid pathway or form calcium soaps and are excreted
Long chain polyunsaturated fatty acids	Delayed formation of TAG and reduced supply of 2-MAG

**TABLE 2. STUDIES ON THE NUTRITIONAL IMPACTS OF COMMON DIETARY FATTY ACIDS IN HUMAN, INFANT AND ANIMAL MODELS**

Model	Test fats or fatty acids involved	Results	References
Infant nutrition	Palmitic acid at sn-1 and sn-3 positions in infant formula vs. human milk.	Infant formula with palmitic acid in sn-1 and sn-3 positions causes the formation of calcium-fatty acid complexes that are poorly absorbed by infant compared to human milk.	Lewis <i>et al.</i> (1977), Chappel <i>et al.</i> (1986)
	Palmitic acid at the sn-2 position in a formula called Betapol.	Palmitic acid at the sn-2 position reduces the excretion of palmitate and associated calcium soaps in stools and stool hardness, increases calcium absorption, resulting in greater skeletal mineral deposition as compared to normal infant formula. However, higher levels of HDL-cholesterol were seen in infants fed with breast milk compared to infants fed with formula milk which have less palmitic acid at the sn-2 position.	Nelson <i>et al.</i> (1999), Kennedy <i>et al.</i> (1999)
Adult nutrition	Palm olein vs. lard (~7% and 70% palmitic acid at the sn-2 position, respectively).	Palm olein group results showed lower serum total cholesterol, LDL-cholesterol and total cholesterol/HDL ratio compared to the lard group in normocholesterolemic subjects. However, the intake of dietary cholesterol from lard was higher than palm olein group with 313 mg day <sup>-1</sup> and 226 mg day <sup>-1</sup> respectively could also explain this.	Jian <i>et al.</i> (1997)
	Palmitic acid at sn-2 vs. palmitic acid at sn-1 and sn-3 positions in the presence of n-6 PUFA.	Dietary fats containing palmitic acid at the sn-2 position may result in a slightly lower fasting total cholesterol than diets with palmitic acid at the sn-1 and sn-3 positions, while the level of n-6 PUFA influences endogenous cholesterol synthesis.	Forsythe <i>et al.</i> (2007)
	Palmitic vs. lauric vs. myristic vs. stearic acids at sn-2 position.	No significant changes were detected in the blood lipids and lipoprotein parameters in all the fats.	Meijer <i>et al.</i> (1997)
	Stearic acid at sn-2 position (postprandials' trial).	Consumption of stearic acid in the form of structured TAG leads to elevated plasma triglycerides and factor FVII:c than a meal enriched with cocoa butter or oleate. The stereospecific structure of the ingested TAG was largely preserved in chylomicron-TAG.	Lucinda <i>et al.</i> (1999); Sanders <i>et al.</i> (2001)
	EPA and DHA at sn-2 position.	It is recommended to add DHA at the sn-2 position for preferential and rapid supply into plasma TAG and phospholipids.	Sadou <i>et al.</i> (1995)
Animal nutrition	Different amounts of palmitic acid at sn-2 position.	Piglets fed with higher sn-2 palmitic acid have higher plasma total cholesterol and triglycerides concentration.	Innis <i>et al.</i> (1997)
	Different amounts of palmitic acid at sn-2 position.	Atherogenicity increased in rabbits fed with 8%-14% sn-2-palmitic acid compared to rabbits fed with 2% sn-2 palmitic acid.	Kritchevsky <i>et al.</i> (1998)
	Palm oil vs. interesterified palm oil (palmitic acid at sn-2 vs. palmitic acid at sn-1 and sn-3).	The sn-2 palmitic acid-fed piglets have higher total cholesterol and HDL-cholesterol compared to sn-2 oleic acid-fed piglets.	Innis <i>et al.</i> (1993)
	Palmitic acid vs. stearic acid at sn-2 position.	Sn-2 palmitic acid is more atherogenic than stearic acid at sn-2 position.	Kritchevsky <i>et al.</i> (1997)
	Stearic acid at sn-2, sn-1 and sn-3 positions.	Stearic acid at sn-1 and sn-3 positions resulted in increased loss of fats and calcium in the feces due to formation of insoluble calcium soaps compared to stearic acid at sn-2 position in rats.	Apgar <i>et al.</i> (1987), Brink <i>et al.</i> (1995)
	Seal oil vs. fish oil (DHA at sn-1 and sn-3 vs. DHA at sn-2 positions, respectively).	DHA content was similar in both seal and fish oil-fed rats.	Jensen <i>et al.</i> (1996)
	n-3 PUFA at sn-1 and sn-3 positions vs. n-3 PUFA at sn-2 position.	There was no difference in the absorption profiles and <i>in vitro</i> rate of lipase activity in rats.	Porsgaard <i>et al.</i> (2005)
EPA and DHA at sn-1, sn-3 and sn-2 positions.	EPA and DHA predominantly at the sn-2 position were more readily absorbed than at the sn-1 and sn-3 positions in rats.	Christensen <i>et al.</i> (1995)	

allows good and rapid absorption of TAG by infants (Filter *et al.*, 1969; Bracco *et al.*, 1994; Innis *et al.*, 1994). If the infant formulation contains long chain SFA at the sn-1 and sn-3 positions, absorption will be delayed as the milk lipase may only act on 2-MAG formed in the intestine before new TAG is resynthesized. Hence, the tendency to form long chain calcium soap causes hard stools or constipation, and less calcium absorption in infants. The TAG structure of human milk is unique as it leads to optimize absorption of palmitic acid. That is why sn-2 palmitic acid is preferred in infants over sn-1 and sn-3 palmitic acid. Thus, an improved infant formulation that mimics the TAG positional distribution of human milk is required. Betapol is one example of such an infant formulation.

#### EFFECTS OF STEREOSPECIFIC FATS ON LIPID PROFILE

Clinical trials on humans and animal testing have been carried out to determine the effects of stereospecific fats on lipid profile. Table 2 summarizes the outcome of these trials. The position of SFA at TAG may exert two effects on plasma cholesterol. If the long chain SFA occur at the sn-1 and sn-3 positions, they are either neutral or tend to lower cholesterol levels. If the long chain SFA occur at the sn-2 position, they generally tend to increase the cholesterol level.

#### SN-2 HYPOTHESIS AND PALM OIL

In palm oil, the long chain SFA (palmitic acid) is predominantly situated at the sn-1 and sn-3

positions, and is mainly excreted through the formation of calcium soaps (evidence shown in human infant and animals, no evidence of this in human adults yet). The other main fatty acid in palm oil, oleic acid, is situated at the sn-2 position, and at this position, it will be absorbed into the body and does not alter the blood lipid profile as shown in studies with olive oil (~ 80% oleic acid at sn-2) (Ng *et al.*, 1992; Choudhury *et al.*, 1995). Hence, it is wrong to group palm oil with the traditional sources of saturated fats. In addition, plasma lipid response to a palm oil-rich diet was found to be mild in intensity, and appeared to be more dependent on age, gender, increased body mass index (BMI), daily cholesterol ingestion and the synthetic nature of the oils. More scientific evidence with adequate and well controlled study designs are required to clear the misconception of palm oil and its nutritional implications especially on human adults. This is currently the focus of research at MPOB.

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cream contains a high amount of fat (25%-40%) in the presence of emulsifiers and stabilizers. Creams made from palm oil (PO), palm kernel oil (PKO), hydrogenated palm kernel oil (HPKO): POs blends and hydrogenated coconut oil (HCO) are more stable than dairy cream (Barfod and Krog, 1987; Nesaretnam *et al.*, 1993; Berger, 1994; Shamsi *et al.*, 2002). The objective of this study was to investigate the feasibility of using blends of palm stearin and palm olein to produce whipped toppings.

## METHODOLOGY

### Materials

Palm stearin (POs IV 40-42) and double-fractionated palm olein (POo) were obtained from a local company. Skimmed milk powder was purchased from the New Zealand Dairy Board, Wellington, New Zealand. The emulsifier-stabilizer was obtained from Danisco (Denmark) while sucrose and glucose syrup were purchased from a local supermarket.

### Preparation of the Emulsion

Whipped topping emulsion was prepared using the formulation shown in *Table 1*. The ingredients were reconstituted with water and mixed in a jacketed vessel (Armfield Ltd, U.K) at 40°C. The mixture was heated to 72°C while being agitated before it was homogenized [homogenizer model: APV 1000, APV Hill & Mills (M) Sdn Bhd]. The mixture was then pasteurized at 72°C for 30 min, and then immediately cooled to 5°C and stored overnight in a refrigerator before whipping.

TABLE 1. TYPICAL FORMULATION FOR A WHIPPED TOPPING

Ingredient	Formulation (%)
Fat	25 - 40
Milk powder/protein	1 - 4
Sucrose	10 - 12
Glucose syrup	3 - 5
Emulsifier-stabilizer	0.3 - 1.6
Water	60 - 80
Flavour/colour	small amount

Note: Control = dairy cream.

### Determination of Characteristics

**Slip melting point.** Slip melting point (SMP) was determined according to the MPOB Test Method, p. 4.2 (MPOB, 2005).

**Solid fat content.** Solid fat content (SFC) was determined by pulse nuclear magnetic resonance (PNMR) using a Bruker NMS 120 Mini Spec NMR analyser (Karlsruhe, Germany) according to the MPOB Test Method, p. 4.9 (MPOB, 2005).

**Triacylglycerol composition.** Triacylglycerol composition (TAG) was determined according to the MPOB Test Method, p. 3.3 (MPOB, 2005).

**Fatty acid composition.** Fatty acid composition (FAC) was determined according to the MPOB Test Method, p. 3.5 (MPOB, 2005).

**Thermal analysis by differential scanning calorimetry.** Thermal analysis by differential scanning calorimetry (DSC) was carried out using a model DSC-7 calorimeter (Perkin-Elmer, Norwalk, Connecticut, USA), which was attached to a

data processing unit (Perkin-Elmer Thermal Data Station). The instrument was equipped with a dry box with nitrogen purging and an external cooling source (Intra-cooler). Calibrations were carried out using the Indium standard. A sample of 3-5 mg fat was placed in the DSC pan and melted at 70°C for 30 min before cooling to 0°C, after which it was held for 90 min before transferring to the DSC head. The pan was held at -50°C for 5 min prior to measurement. The DSC melting and crystallization curves were recorded at a heating rate of 5°C per min from -50°C to 60°C.

**Viscosity.** Viscosity was measured using a viscometer (Brookfield Digital Model DV- II, Brookfield Engineering Laboratories, Inc., USA). A constant shear rate (50 r.p.m) was maintained for 25 s, and viscosity was recorded in mPa s.

**Whipping performance.** Evaluation of whipping performance was carried out in a 5-litre Kenwood Chef Mixer (Model: Kenwood 2000). The samples and utensils were cooled overnight at 5°C prior to use. Medium speed was em-

ployed until the whisk cut through the cream after 3 min.

Whipping performance was calculated using the following equation:

$$\text{Whipping performance (\%)} = \frac{W_1 - W_2}{W_2} \times 100$$

where  $W_1$  is the weight of unit volume of the mix, and  $W_2$  is the weight of unit volume of the whipped topping.

**Emulsion stability (ES).** A 100-ml sample of whipped cream was poured into a 100-ml measuring cylinder of 5 cm (2.0-inch) diameter. Samples were placed separately in 5°C and 20°C incubators, and were observed visually for syneresis of serum after an overnight stand, and weekly observations were conducted over a month. The serum was measured in ml, as indicated on the measuring cylinder (0-100 ml).

$$\text{ES} = \frac{\text{ml of water in formulation} - \text{ml of water separated}}{\text{ml of water in formulation}} \times 100$$

### Sensory Evaluation

A sensory evaluation of the whipped topping was conducted using a multiple comparison test. Ten MPOB staff members were trained as panellists. Samples were coded using three-digit random numbers, and were stored in a refrigerator. They were taken out and presented to the panellists just before evaluation. Data were analysed by the analysis of variance (ANOVA) using Microsoft Excel 2000 software. The significance level was set at 95%.

## RESULTS AND DISCUSSION

### Slip Melting Point and Solid Fat Content

Table 2 shows SMP and SFC of POs, POo and their respective blends of different ratios. The SMP and SFC were the criteria chosen for the selection of oils. A higher SMP makes the whipped topping more resistant

**TABLE 2. SLIP MELTING POINTS (°C) OF PALM STEARIN (POs), PALM OLEIN (POo), DAIRY FAT AND POo:POs BLENDS OF DIFFERENT RATIOS**

Oil/fat	Slip melting point (°C)
POs	51.3
POo	18.5
POo:POs 85:15	31.4
POo:POs 75:25	33.9
POo:POs 65:35	39.3
Dairy fat	32.0

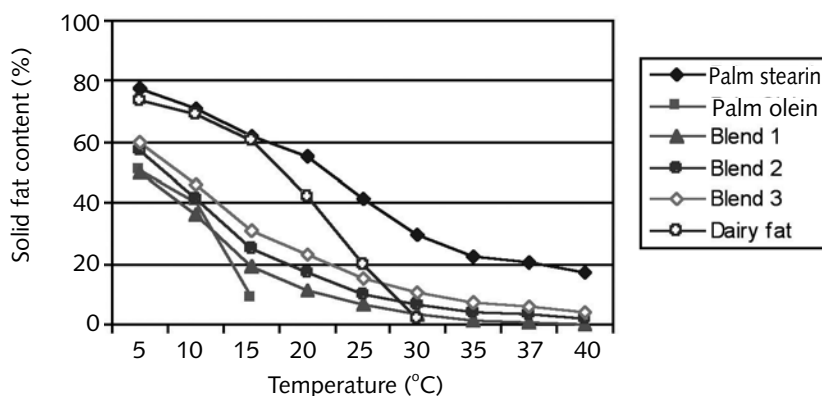
to high temperature. The aerated structure of whipped topping owes its stability to a high SFC at ambient temperature. At body temperature (37°C), however, it should be completely melted so that no waxy after-taste remains. Satisfying the requirement of fat for whipping cream, a steep SFC profile (Figure 1) is required (Berger, 1994). Palm stearin, with SFC of 15% to 35%, were selected as the most promising fats for topping preparations.

### Fatty Acid Composition

The FAC results (Table 3) showed a predominance of C16:0 and C18:1 fatty acids in all the samples. Increasing the amount of POo in the POo:POs blends decreased the amount of palmitic acids (C16:0) but increased the oleic acid (C18:1) content. However, the saturated fatty acids (SAFA) were dominant in this particular blend. Increasing SAFA content would reduce the consistency of foam in the whipped cream (Shamsi *et al.*, 2002). The dairy fat used was rich in C14:0 (10%), C16:0 (31.9%), C18:0 (14.1%) and C18:1 (30.5%) acids. However, lower amounts of C16:0, C18:1 and C18:2 fatty acids and a higher amount of C18:0 were found in the dairy fat than in POs.

### Triacylglycerols Composition

Table 4 shows the triacylglycerol (TAG) composition of oils and fats used in the whipped toppings. The TAG composition determines the physical characteristics of fats and oils and can affect their crystallization behaviour. POs contained higher oleodipalmitin (POP, 30.7%) and tripalmitin (PPP, 20.7%) whereas dairy fat was higher in oleodistearin (SOS, 37.9%) and oleopalmitostearin (POS, 36.1%). The high



Note: Blend 1= POo:POs 85:15; Blend 2= POo:POs 75:25; Blend 3= POo:POs 65:35.

Figure 1. Solid fat content (SFC) of palm stearin (POs), palm olein (POo), dairy fat and POo:POs blends of different ratios.

amounts of palmitic and oleic acids in palm stearin were consistent with the high contents of palmitodiolein (POO, 17.2%), POP (30.7%) and PPP (20.7%).

### Thermal Behaviour

The melting and cooling thermographs of POo, POs and their blends are shown in Figures 2 and 3, respectively. The melting profile shows endothermic heat flow over a wide range of temperatures during scanning from -30°C to 40°C, indicating the presence of low melting (<0°C), middle melting (5°C) and high melting (>20°C) fractions. POs and their blends had multiple peaks of melting and crystallization profiles, while POo had a single melting and crystallization peak. The heating curve from the DSC analysis showed that the blended oils of all ratios melted between the -10°C and 40°C region. These data are consistent with the SMP values given in Table 2.

### Emulsion Stability

The emulsion stability of palm-based whipped toppings are shown in Table 5. At 5°C all samples were stable. POs showed complete separation at 20°C. Other blends showed different percentages of separation. After whipping, only a few blends showed a whipping performance up to 60%-70%. However, POo:POs 85:15 showed comparable performance to dairy cream.

### Storage Stability

Table 6 shows the storage stability of whipped toppings prepared from PO-based fat (PC) compared to commercial cream (CC). PO-based whipped toppings were stable up until three weeks' storage at 5°C compared to the commercial samples. A 50% serum separation appeared at 5°C, and completely denatured at 20°C after a month's storage. The commercial samples remained stable for a month. The separation of serum in the PO-based whipped toppings could be attributed to the presence of a high content of C18:1 (43%) compared to dairy fat (30.5%). The presence of relatively high percentages of medium and long chain SAFA (C14:0, C16:0 and C18:0) in dairy cream may have enhanced the storage stability phenomenon.

### Viscosity and Whipping Performance

The viscosity and whipping performance of whipped toppings prepared from fat blends POo:POs; 85:15, 75: 25 and 65:35 and those

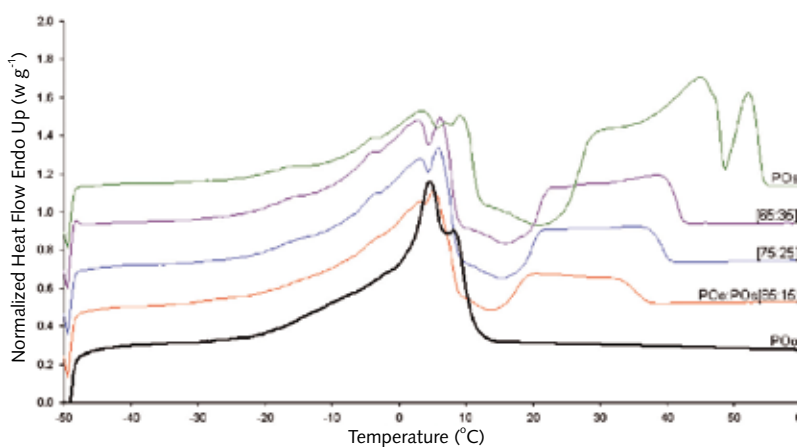


Figure 2. Heating thermograms of palm stearin (POs), palm olein (POo) and their blends of different ratios.

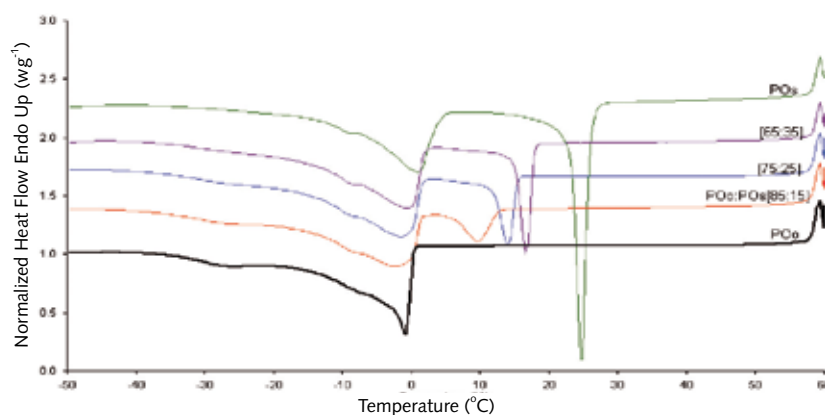


Figure 3. Cooling thermograms of of palm stearin (POs), palm olein (POo) and their blends of different ratios.

**TABLE 3. FATTY ACID COMPOSITION BY CARBON NUMBER OF PALM STEARIN (POs), PALM OLEIN (POo), DAIRY FAT AND POo:POs BLENDS OF DIFFERENT RATIOS**

Oil/fat	Fatty acid composition (%)							
	12:0	14:0	16:0	18:0	18:1	18:2	18:3	20:0
POs	0.6	1.3	56.5	4.5	29.9	6.5	0.1	0.4
POo	0.2	0.9	40.7	3.8	42.8	10.8	0.3	0.3
POo:POs (85:15)	0.5	1.2	39.8	4.2	42.4	11.6	0.3	0.4
POo:POs (75:25)	0.3	1.1	40.8	4.2	40.7	11.5	0.3	0.4
POo:POs (65:35)	0.2	1.1	43.7	4.4	39.4	11.1	0.3	0.4
Dairy fat	2.1	10.1	31.9	14.1	30.5	0.9	-	-

**TABLE 4. TRIACYLGLYCEROL (TAG) COMPOSITION (%) OF PALM STEARIN (POs), DAIRY FAT AND POo:POs BLENDS OF DIFFERENT RATIOS**

TAG* (%)	Oil/fat				
	POs	POo:POs (85:15)	POo:POs (75:25)	POo:POs (65:35)	Dairy Fat
OLL	0.2	0.4	0.4	0.4	17.6
PLL	1.4	2.6	2.6	2.5	-
OOL	0.9	1.7	1.7	1.6	21.9
POL	6.7	12.5	12.4	11.7	-
PPL	8.7	11.1	10.9	10.8	-
MPP	1.1	0.2	0.3	0.4	26.2
OOO	2.3	4.3	4.2	4.1	-
POO	17.2	31.0	29.5	27.4	28.4
POP	30.7	25.8	25.9	26.3	29.9
PPP	20.7	2.9	4.5	6.7	31.5
SOO	1.6	2.7	2.6	2.5	-
POS	4.3	3.7	3.7	3.9	36.1
PPS	3.3	0.4	0.6	0.9	-
SOS	0.3	0.3	0.2	0.3	37.9

\*Notes: P, palmitic acid; L, lauric acid; M, myristic acid; O, oleic acid; S, stearic acid; POo, palm olein.

**TABLE 5. EMULSION STABILITY OF PALM-BASED WHIPPED TOPPINGS**

Stability (%SS*) 5°C	Stability (%SS*) 20°C
Good	CS
Good	5
Good	FD
Good	10
Good	15
Good	FD

Notes: SS\*= serum separation after 24 hr; FD= few drops; CS= complete separation.

**TABLE 6. STORAGE STABILITY OF WHIPPED TOPPINGS PREPARED FROM PO-BASED FAT (PC) COMPARED TO COMMERCIAL CREAM (CC)**

Serum separation at 5 °C				
Sample	Week 1	Week 2	Week 3	Week 4
PB	No separation	No separation	No separation	50%
CC1	No separation	No separation	No separation	No separation
CC2	No separation	No separation	No separation	No separation
Serum separation at 20 °C				
Sample	Week 1	Week 2	Week 3	Week 4
PB	No separation	No separation	No separation	100%
CC1	No separation	No separation	No separation	No separation
CC2	No separation	No separation	No separation	No separation

Notes: PC - palm-based whipped topping (POo:POs 85:15).  
 CC1 - dairy-based whipped cream.  
 CC2 - vegetable-based whipped cream.

of dairy cream are shown in *Figures 4 and 5*, respectively. The whipping performance of PO-based whipped toppings was similar for all the samples, and the values were lower compared to dairy cream. Whipped topping prepared from POo:POs 75:25 had a lower viscosity as compared to dairy cream and the other samples. The viscosity of the mixture was affected by the chain length of the unsaturated fatty acids (UFA) and their solid content at 5°C.

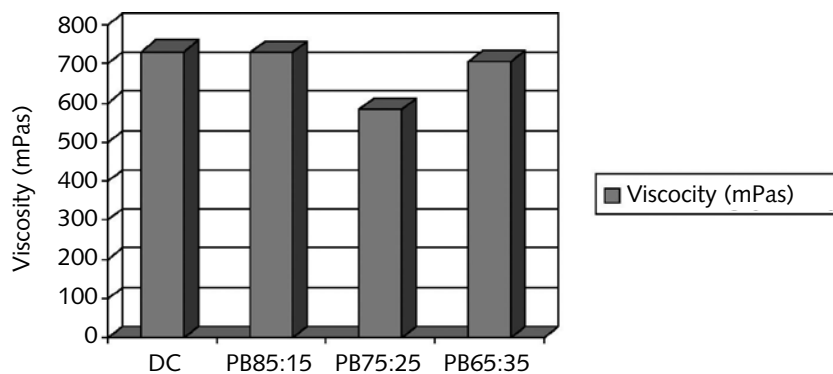


Figure 4. Viscosity of whipped toppings prepared from palm-based blends (PB) and dairy cream (DC).

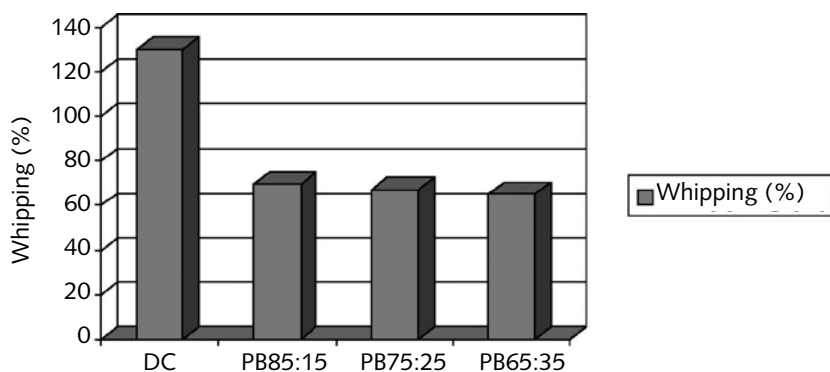
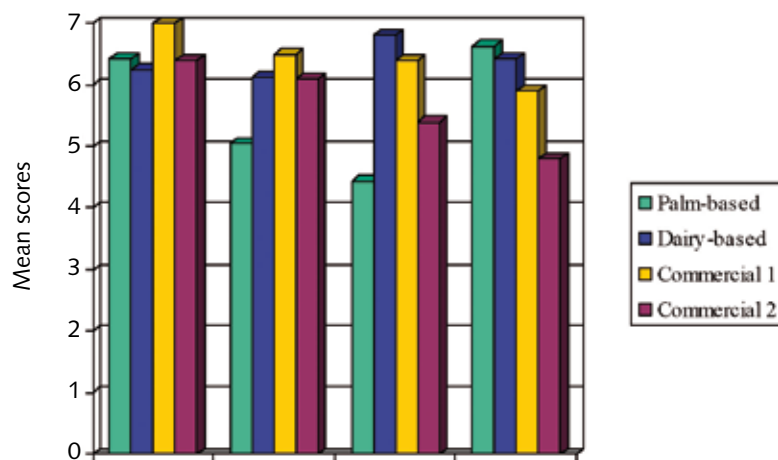


Figure 5. Whipping performance of whipped toppings prepared from palm-based blends (PB) and dairy cream (DC).



Notes: Palm-based - POo:POs 85:15.  
 Dairy-based - Dairy cream.  
 Commercial 1 - HPKO 36.  
 Commercial 2 - HPKO 38.

Figure 6. Sensory evaluation of whipped toppings prepared from palm-based fat, dairy cream and commercial fats.

### Sensory Evaluation

Sensory evaluation of the whipped toppings prepared from palm-based whipped toppings, dairy cream and commercial fats are shown in Figure 6. Results show that the PO-based fat had a higher score (6.6) in creamy properties compared to dairy cream (6.4) and Commercial 1 (5.9). However, Commercial 1 had a higher score for appearance and taste. The taste and odour scores of the PO-based product were 5.1 and 4.4 while those of the dairy-based were 6.1 and 6.8, respectively. The lowest scores for taste and odour properties of the PO-based product were due to the high palmitic acid content in the oil blends.

### CONCLUSION

The addition of POs to POo was acceptable for the whipped topping formulation. Blending of POs: POo also helped to eliminate the hydrogenation process to produce whipped toppings which are free from *trans* fatty acid.

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