A Comparative Study of Dairy Whipping Cream and Palm Oil-Based Whipping Cream in Terms of FA Composition and Foam Stability

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ABSTRACT: Nondairy creams are more stable than dairy creams, especially in hot climates. This paper considers the reasons for this stability and which FA is most suitable for producing this effect in palm oil and palm kernel oil-based whipping cream. The results show that an increase in unsaturated FA, particularly oleic acid, can produce a more stable foam in whipping cream. This study also shows that an increase in iodine value has a positive impact on the stability of foam in nondairy whipping cream as well. This study points out the advantages of a palm oil-based whipping cream over commercial dairy whipping cream, particularly when the stability of the foam is important and the product is supposed to be consumed in hot weather.

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KEY WORDS: FAC, non-dairy whipping cream, RBD palm kernel oil, RBD palm oil, stability.

Whipped toppings have become popular both for commercial and consumer use on puddings, sodas, cakes, ice cream, fruit, and pastries and for cream pie bases. Consumers and the dairy industry have certain expectations for the quality of whipped toppings with regard to taste, shelf life, and whipping characteristics such as speed of whipping, overrun, consistency, and stability (1).

The whipping process forms air cells that are stabilized by fat globules at the air–water interface (1,2). During whipping, the globules attach to air bubbles; as these air bubbles break and coalesce, the fat clumps. As whipping continues, air cells become smaller and more numerous, fat clumping continues, and the foam increases in volume and rigidity. If whipping continues still further, the fat clumps become so large that they rupture the lamellae enclosing the air cells. Air bubbles start to coalesce, overrun decreases, and churning results. Many researchers agree that fat content, cream temperature, homogenization and pasteurization conditions, and presence of stabilizers and emulsifiers influence the functional properties of whipping creams (3–7).

The fat component and its FA greatly influence the whipping properties and stability of cream. Creams for whipping contain significant proportions of fat. Butterfat is composed of ~70% saturated FA (SFA), which have high m.p. and are generally solid at ambient temperature. On the other hand, many vegetable oils contain a high percentage of unsaturated FA (UFA), which are usually liquid at room temperature (8). Nondairy whipped toppings are more functional than dairy whipping cream because manufacturers can choose to use a more desirable fat characterized by a specific solid fat index profile with complementary emulsifier systems. Creams made from palm oil (PO) and palm kernel oil (PKO) are generally more stable than dairy cream (8).

For commercial dairy creams a high amount of fat (i.e., up 30%) in the presence of emulsifiers and stabilizers increases the whippability and decreases the time necessary for optimal whipping. Generally, the fat for whipping cream should be partly solid at 5°C, solid enough at ambient temperature, and melt at <37°C (body temperature) (7). The interest in improving physical characteristics of nondairy cream has increased commercial activity in developing this product (9).

The objectives of this study were (i) to compare the foam stability of dairy whipping cream and PO-based whipping cream, and (ii) to determine the relationship between the stability of froth in nondairy whipping cream and its FA composition.

MATERIALS AND METHODS

Materials. Refined, bleached, and deodorized palm kernel oil (RBDPKO) and refined, bleached, and deodorized palm oil (RBDPO), sucrose, corn syrup solids, sodium caseinate, soybean lecithin, carboxymethyl cellulose (CMC), and MG were provided by the Malaysian Palm Oil Board (MPOB). Anchor Dairy Whipping Cream (according to the label, containing 36% fat, and 64% nonfat milk solids including emulsifiers 471 and 433 and stabilizers 412, 415, and 407) was purchased from a local shop.

Methods. The oils were kept overnight at 60°C. Then they were blended in different portions as shown in Table 1. No interesterification or hydrogenation was applied to the oils. The blended oils were combined with other ingredients according to the following formulation (ingredient, wt%): vegetable fat (blends of RBDPKO and RBDPO), 25.0; sodium caseinate, 1.0; sucrose, 10.0; corn syrup solids, 3.0; sodium CMC, 1.0; soybean lecithin, 0.3; MG, 0.05; water (distilled), 59.95.

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TABLE 1
Blends of RBDPKO and RBDPO[a]

Designation	RBDPKO	RBDPO
B1[b]	0	100
B2	10	90
B3	20	80
B4	30	70
B5	40	60
B6	50	50
B7	60	40
B8	70	30
B9	80	20
B10	90	10
B11	100	0

[a]Abbreviations: RBDPKO, refined, bleached, deodorized palm kernel oil; RBDPO, refined, bleached, deodorized palm oil.
[b]B, Blend.

(i) Preparation of emulsions. Distilled water was heated to 80°C, and all dry ingredients were added to it and mixed for 1 min at low speed, then 2 min at high speed in a commercial blender (Model 32BL80; Waring Commercial Blender, New Hartford, CT) to prevent lump formation. Then the oil was added to the liquid phase and mixed for 3 min at high speed. The mixture was heated to 71°C in a water bath for 30 min and then homogenized in a Heavy Duty Laboratory Homogenizer (Model L4RT; Silverson Machines Ltd., Waterside, Chesham, Bucks, England) at 1,656 × *g* rpm for 2 min in order to disperse the oil molecules evenly in the emulsion and reduce the risk of serum separation. The homogenized cream was immediately cooled to 5°C and aged for 24 h in the refrigerator. The finished mixes usually require 18–24 h of tempering before satisfactory whipping performance can be expected (5).

(ii) FA analysis by GC. FAME were prepared according to the direct methylation technique of Divakaran and Ostrowski (10). NaOH (10 g) was added to 500 mL methanol to make a 2% solution. Dairy cream (1 g) and RBDPO and RBDPKO blends (0.1 g) were added to this solution separately and heated to 100°C in a water bath connected to a reflux system for 10 min in order to break TAG into its components. Then 6.25 mL boron trifluoride/methanol complex (BF_3) was added to the solution. (BF_3 adds a methyl group to the FA to make it less polar.) After 3 min, 3 mL heptane was added and the solution was boiled for 1.5 min. It was then cooled in a water bath to ambient temperature (~25°C) and poured into a test tube. A saturated aqueous NaCl solution (2 mL) was added next. The upper clear layer, containing FAME, was decanted by using a pipette, and dried with 1 g anhydrous Na_2SO_4. The tube containing FAME was centrifuged for 4 min at 762 × *g* and then the upper layer was decanted by pipette.

The gas chromatograph used was a Shimadzu model GC-8A (Kyoto, Japan) equipped with an FID and a BPX-70 (SGE, Melbourne, Australia) capillary column (30 m, 0.25 mm i.d.). The oven temperature was programmed from 150 to 190°C at a ramp rate of 3°C/min after an initial isothermal period of 8 min, and was held for 15 min at 190°C. The carrier gas was helium, and the temperatures of the injector and detector were 250 and 280°C, respectively. Identification of FAME was based on comparison of the sample retention times to those of known standards and confirmed by mass spectra. The magnitude of the peaks of each chromatogram was quantified by a C-R3A Chromatopac (Shimadzu, Kyoto, Japan). FAME sample sizes were 0.1 μL ($n = 5$). The percentage of each FA was calculated from the peak area of the FA over total peak area.

Determination of consistency. The consistency of the whipped creams was measured by using a Texture Analyzer (Model TA-XT2; Stable Micro Systems Ltd., Haslemere, England) after being refrigerated for 24 h. The Texture Analyzer was set as follows: mode: measure force in compression; option: return to start; pretest speed: 1.00 mm/s; test speed: 1.00 mm/s; posttest speed: 10.00 mm/s; distance: 10 mm; trigger type: Auto, 5 g; data acquisition rate: 200 pps; accessory: 50 mm cylinder probe (p/50).

(iv) Slip melting point (SMP). The SMP of the blends were determined according to the PORIM Test Methods (11). Four capillary tubes (o.d. 1.4–1.7 mm, i.d. 1.1–1.3 mm, length 50–60 mm) were dipped in each blend so that the oil, which had been equilibrated at 60°C overnight, rose 10 mm in the tubes. Then the tubes were rolled against a piece of ice to solidify the oil. The capillary tubes were held in empty test tubes in a beaker full of ice water for 1 h in the refrigerator.

After 1 h, the capillary tubes and a thermometer were fastened to glass rods in a beaker containing 600 mL of 5°C distilled water and a magnetic stirrer. Heat was applied with a heating coil that was turned on for 10 s and off for 50 s, allowing the temperature to rise 1°C/min. The temperature at which the fat changed to oil and began to rise in the capillary tubes was noted. The mean was calculated and considered as the SMP for each tube. The experiment was carried out in duplicate.

Iodine value (Wijs method). The degree of unsaturation of the blends was determined according to the PORIM Test Method (11). A thoroughly melted sample (PO, 0.4 g; PKO, 1 g) was dissolved in 20 mL of cyclohexane, followed by addition 25 mL of Wijs solution. The sample was stored in the dark for 1 h before reacting it with potassium iodide, followed by titration with 0.1 N sodium thiosulfate solution. Results were expressed as g of iodine/100 g of oil.

(vi) Whipping test. The creams were whipped in a 600-mL beaker by a Philips commercial hand mixer (Model HR 1500; Groningen, Holland) for 1 min at speed no. 1, and 3 min at speed no. 3. Whisks and container were cooled to 5°C before whipping.

(vii) Stability test of whipped and unwhipped cream. Plastic capped bottles (3 cm diameter, 7 cm height) were filled with whipped and unwhipped cream and were immersed into water baths at 20, 25, 30, 35, and 40°C for 6 h. The contents of bottles were equal (40 g). Care was taken to ensure no void was present in the mass of cream. The top was leveled off. The separated serum was measured in millimeters.

This method was modified from that of Nesaretnam *et al.* (9). Samples of whipped and unwhipped creams were poured

into beakers of 100 mL volume (5 cm diameter) and then placed in incubators held at 20, 25, 30, 35, and 40°C. Samples were checked for leakage of serum after 4 and 20 h. The stability of cream was determined by measuring the height of serum leakage.

Statistical analysis. Collected data were analyzed using Microsoft Excel 2000 software, which was used to establish equations of regression between the data. The accuracy was assessed based on the smallest standard error (SE) and the highest coefficient of determination (R^2) (12).

RESULTS AND DISCUSSION

The percentage of UFA and its impact on the stability of whipped creams was the basis for this study. Even (carbon)-numbered, straight-chain SFA and UFA make up the greatest proportion of the FA of natural fats (13,14). According to Table 2, which shows the FA content of 11 blends of RBDPO and RBDPKO and of dairy whipping cream, the percentage of SFA increased with increasing content of RBDPKO.

Figure 1 shows that an increase in SFA content reduces the consistency of foam in the whipped creams ($R^2 = 0.90$). R^2 values higher than 0.75 are relatively adequate for prediction purposes, and the closer the R^2 value is to unity, the better the empirical model fits the actual data (15). In Table 2, the relative percentage of C16:0 decreases from B1 to B11, whereas the percentages of C12:0 and C14:0 increase. In B11 the percentage of C12:0, a medium-chain SFA, exceeds 37%; however, the stability of the foam C11, formed by whipping samples of blend B11, stands at 225.15 g force according to Table 3. C18:0 and C18:2 are not considered as determining FA in these blends since their contents are fairly constant and change only slightly (<9%). However, C18:1, which is a long-chain monounsaturated FA (MUFA), plays a dominant role in

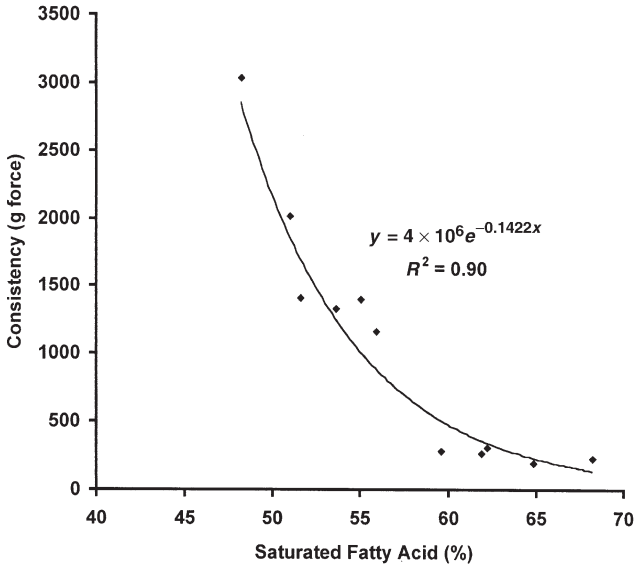

FIG. 1. Consistency vs. saturated FA content.

TABLE 2
FA Composition[a] (%) of 11 Blends[b] of RBDPKO, RBDPO, and Dairy Whipping Cream[c]

FA	DWC	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
C12:0	2.13 ± 0.04	0.5 ± 0	3.36 ± 0.09	5.68 ± 0.05	9.5 ± 0.15	12.7 ± 0.57	15.72 ± 0.23	20.95 ± 0.23	25.56 ± 1.67	27.2 ± 0.39	30.94 ± 0.45	37.86 ± 0.34
C14:0	10.12 ± 0.78	0.9 ± 0	2.11 ± 0.01	3.1 ± 0.02	4.65 ± 0.04	5.99 ± 0.1	7.32 ± 0.02	9.04 ± 0.02	10.84 ± 0.16	12 ± 0.33	14.55 ± 0.07	16.61 ± 0.09
C16:0	31.9 ± 0.2	42.96 ± 0.71	41.65 ± 0.34	39 ± 0.02	35.74 ± 0.19	32.86 ± 0.45	29.44 ± 0.4	26.32 ± 0.46	22.7 ± 0.47	19.43 ± 0.16	16.17 ± 0.12	11.3 ± 0.04
C18:0	14.05 ± 0.09	3.84 ± 0.07	3.84 ± 0	3.8 ± 0.02	3.7 ± 0.11	3.5 ± 0	3.4 ± 0.08	3.3 ± 0.14	3.17 ± 0.09	3.3 ± 0.04	3.2 ± 0.05	2.85 ± 0.04
C18:1	30.53 ± 0.17	39.81 ± 0.63	38.88 ± 0.21	38.19 ± 0.12	35.21 ± 0.18	34.5 ± 0	33.39 ± 0.2	29.22 ± 1.57	28.47 ± 0.79	28.11 ± 1.54	26.18 ± 0.32	22.65 ± 0.24
C18:2	0.94 ± 0.02	8.53 ± 0.21	7.87 ± 0.03	8.04 ± 0.14	7.33 ± 0	7.47 ± 0.29	7.01 ± 0.28	5.83 ± 0.05	5.81 ± 0.38	5.52 ± 0.05	5.1 ± 0	4.68 ± 0.12
SFA	58.2	48.2	50.96	51.58	53.59	55.05	55.88	59.61	62.27	61.93	64.86	68.22
UFA	31.47	48.34	46.75	46.23	42.54	41.97	40.4	35.05	34.28	33.63	31.28	27.33
Ratio U/S	0.54	1.00	0.91	0.89	0.79	0.76	0.72	0.58	0.55	0.54	0.48	0.4

[a]Each value represents the mean ± SD of duplicate analyses.
[b]Blends are characterized in Table 1.
[c]DWC, dairy whipping cream; SFA, saturated FA; U/S, unsaturated FA/saturated FA; UFA, unsaturated FA; for other abbreviations see Table 1.

TABLE 3
Stability, Slip Melting Point (SMP), Iodine Value (IV), and Whipping Test of Dairy Whipping Cream and Blends of RBDPO and RBDPKO[a,b]

Samples	Stability (g force)	SMP (°C)	IV	WBT (°C)	SSB (mm)	SSA (mm)
C1	3030.49 ± 540.48	37.5 ± 0.7	48.24 ± 0.79	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	No
C2	2016.79 ± 15.6	36.15 ± 1.2	45.83 ± 1.00	20	No	No
				25	No	No
				30	No	No
				35	FD	FD
				40	FD	No
C3	1410.5 ± 428.12	34 ± 1.41	40.94 ± 1.56	20	No	No
				25	No	No
				30	No	No
				35	No	No
				40	FD	FD
C4	1400.89 ± 521.19	31.5 ± 2.12	38.16 ± 0.14	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	No
C5	1394.03 ± 69.58	32.25 ± 0.35	35.58 ± 0.61	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	FD
C6	1158.15 ± 29.96	30.75 ± 2.12	32.92 ± 0.18	20	No	No
				25	No	No
				30	No	No
				35	FD	FD
				40	FD	FD
C7	278.56 ± 2.37	27.5 ± 0.7	29.16 ± 0.27	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	FD
C8	304.28 ± 29.52	26.9 ± 0.14	25.52 ± 0.5	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	No
C9	262.68 ± 24.87	26.25 ± 0.35	22.9 ± 0.99	20	No	No
				25	No	No
				30	No	No
				35	FD	No
				40	FD	No
C10	196.273 ± 14.43	26.5 ± 0.7	19.52 ± 0.24	20	No	No
				25	No	No
				30	No	No
				35	No	FD
				40	FD	FD
C11	225.15 ± 1.64	26.85 ± 1.2	16.79 ± 0.42	20	No	No
				25	No	No
				30	No	No
				35	No	No
				40	FD	FD
DWC[e]	1450.86 ± 255.45	8.14 ± 1.5	29.75 ± 0.36	20	No	No
				25	No	10 mm
				30	No	11 mm
				35	No	11 mm
				40	FD	CS

[a]Each value represents the mean ± SD (n = 2).
[b]WBT, water bath temperature; SSB, serum separation before whipping; SSA, serum separation after whipping; FD, few drops; CS, complete separation of serum. For other abbreviations see Tables 1 and 2.
[c]C1–C11, creams made from blends B1–B11.

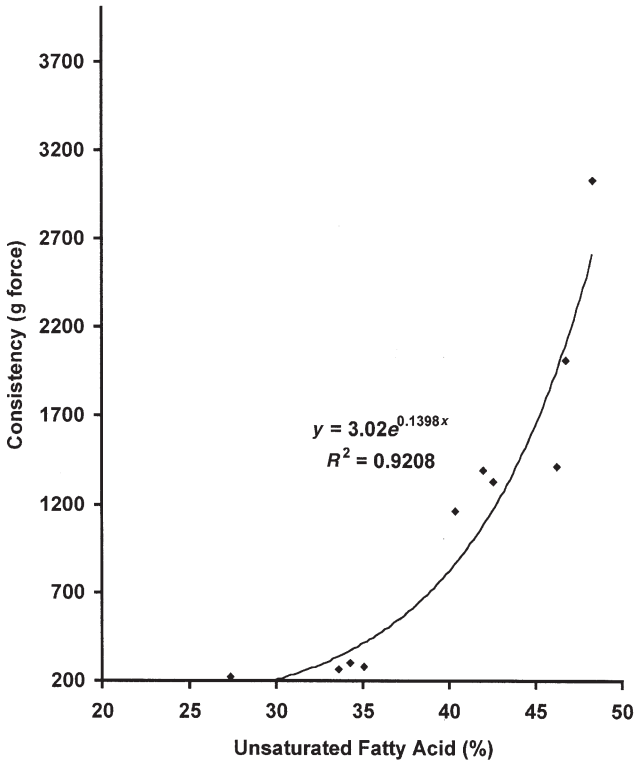

FIG. 2. Consistency vs. unsaturated FA content.

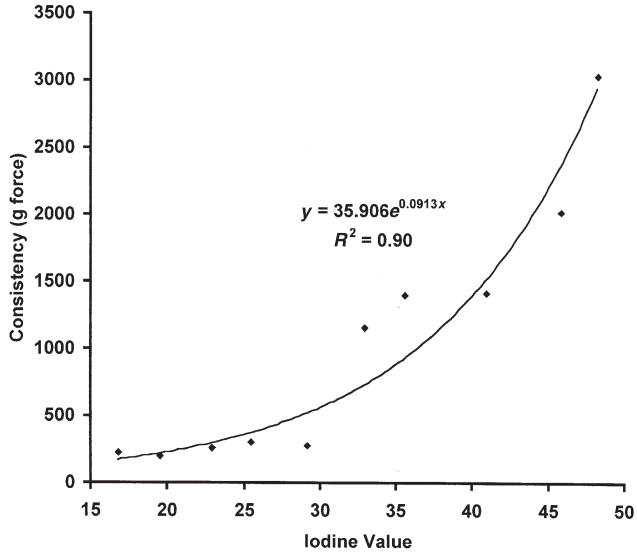

FIG. 3. Consistency vs. iodine value.

these blends to which most of the physical properties could be attributed. This MUFA has a *cis* position, which can make it more polar (16). This property can bind water and sugar together well to produce stable foam.

In B11 (22.65% C18:1) the consistency was 225.1 g force; in B1 (39.81% C18:1), the consistency was 3030, g force, i.e., 14 times greater. The UFA of 18–26 carbons can produce an excellent emulsion stability (17) (Fig. 2). Therefore, the lack of separation of serum in RBDPO- and RBDPKO-based creams can be attributed to the presence of C18:1; in dairy whipping cream (31.9% C16:0, 14.05% C18:0) at a temperature >20°C, there is a tendency for serum to separate from the foam that is enhanced by raising the temperature (Table 3). Ruminant milk fat has a complex FA composition (13,14). A considerable proportion of the fat is in the less-polar *trans* configuration (16). The presence of relatively high percentages of medium- and long-chain SFA (C14:0, C16:0, and C18:0) in dairy whipping cream intensifies this phenomenon, although it should be considered that the excellent melting point properties in the mouth, freshness, and cool feeling of a whippable oil-in-water emulsion [made from nondairy whipping cream] are derived from medium-chain FA with 8–12 carbon atoms (18).

Iodine value reflects the degree of unsaturation in oils. The relationship between the iodine value and consistency also shows that the higher the iodine value, the more consistent the foams produced from whipping the creams (Fig. 3).

Although SFA in dairy whipping cream constitute 58.2% (Table 2), the SMP (Table 3) is 8.14°C. For B1, with a SFA content of 48.2% the SMP is 37.5°C. This difference in SMP can be attributed to the presence of high amounts of C18:1 and C16:0 in B1. The higher SMP makes the whipped cream made from B1 more resistant to high temperature.

The whippable o/w emulsion prepared by using a glyceride of not less than 48 total carbon atoms has good heat resistance but has inferior melting properties in the mouth (18).

As can be seen in Table 3, in dairy whipping cream with 36% fat, serum has completely separated at temperatures ≥40°C, and the stabilizers and emulsifiers have not been effective in preventing separation. However, in the case of the other creams, only a few drops of serum separate although the fat content in these creams is 25%.

Based on the results of this study, PO-based whipping cream has a more stable foam in comparison to dairy whipping cream. The amount of UFA, particularly oleic acid, may have a considerable effect on foam stability for PO-based whipping cream. Increasing the iodine value also can enhance foam stability in nondairy whipping cream.

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REFERENCES

1. Mulder, H., and P. Walstra, The Milk Fat Globule, *Commonw. Agric. Bur., Farmham Royal*, Buckinghamshire, England, 1974, p. 81.
2. Walstra, P., and R. Jennes, *Dairy Chemistry and Physics*, John Wiley & Sons, New York, 1984, pp. 32–34.
3. Muir, D.D., J.M. Banks, A.K. Powell, and A.W.M. Sweetsur, Milk Composition—Manufacturing Properties, *Proc. Nutr. Soc. 42*:385–397 (1983).

4. Thome, K.E., and G. Eriksson, The Foaming Properties of Cream. 1. Substances in Milk Increasing the Whippability of Creams, *Milchwissenschaft 28*:502 (1973).
5. Towler, C., Measurement of Whipping Properties of Cream and the Effect of Cream Variation on Whipping, *N.Z. J. Dairy Sci. Technol. 21*:79 (1986).
6. Babcock, C.J., The Whipping Quality of Cream, Bull. No. 1075, U.S. Department of Agriculture, Washington, DC, 1922, pp. 162–163.
7. Berger, K.G., The Use of Palm and Palm Kernel Oil in Ice Cream and Whipped Cream Products, paper presented at the Palm Oil Development Conference, Kuala Lumpur, Malaysia, October 11–15, 1988.
8. Towler, C., Cream Products for the Consumer, *N.Z. Dairy Sci. Technol. 17*:191–202 (1982).
9. Nesaretnam, K., N. Robertson, Y. Basiron, and C.S. Machphie, Application of Hydrogenated Palm Kernel Oil and Palm Stearin Whipping Cream, *J. Sci. Food Agric. 61*:401–407 (1993).
10. Divakaran, S., and A.C. Ostrowski, Fatty Acid Analysis of Fish Eggs Without Solvent Extraction, *Aquaculture 80*:371–375 (1989).
11. PORIM Test Methods, Palm Oil Research Institute of Malaysia, Kuala Lumpur, Malaysia, 1995.
12. Jones, D., Use, Misuse, and Role of Multiple-Comparison Procedures in Ecological and Agricultural Entomology, *Environ. Entomol. 13*:635–649 (1984).
13. Magidman, P., Fatty Acids of Cows' Milk. Techniques Employed in Supplementing Gas–Liquid Chromatography for Identification of Fatty Acids, *J. Am. Oil Chem. Soc. 39*:137–142 (1962).
14. Herb, S.F., Fatty Acids of Cows' Milk. B. Composition by Gas–Liquid Chromatography Aided by Other Methods of Fractionation, *Ibid. 39*:142–146 (1962).
15. Henika, R.G., The Use of Response Surface Methodology in Sensory Evaluation, *Food Technol.* (November):96–101 (1982).
16. deMan, J.M., *Principles of Food Chemistry*, Aspen Publishers, New York, 1999, p. 8.
17. Ezaki, M., M. Kobayashi, and T. Izumi, Production of Sterile Composite Emulsion, U.S. Patent 4,808,334 (1989).
18. Hidaka, H., K. Inayoshi, T. Nishimoto, and S. Yabuuchi, Fat Composition and Frothing Oil-in-Water Emulsion, U.S. Patent 6,228,417 (2001).

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