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Effect of flaxseed oil towards physicochemical and sensory characteristic of reduced fat ice creams and its stability in ice creams upon storage

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Abstract: This study investigates the effect of flaxseed oil towards physicochemical and sensory properties of reduced fat ice creams and its stability in ice-creams upon storage. Three formulations, (F1, F2, F3) were developed by substituting milk fat with flaxseed oil at levels of 2.5%, 5.0% and 7.5%, (w/w) respectively. Samples were subjected to sensory evaluation and analyses such as meltdown, titratable acidity, pH, total solids, protein and fatty acids composition. Incorporation of flaxseed oil into ice-cream showed no effects on physicochemical properties of the ice-creams. However, it increased the colour of ice-cream towards yellowness, decreased the sweetness, smoothness and creaminess. Flaxseed oil incorporation also slightly ($P < 0.05$) decreased the acceptance level of aroma, flavour, texture and overall acceptability of formulated ice-creams. The most acceptable level of flaxseed oil substitution is at 2.5 %. Gas chromatography analysis showed that fatty acids slightly decreased upon storage.

Keywords: Ice-cream, flaxseed oil, fat replacer, fatty acids, stability, GC

Introduction

Flaxseed oil contains mostly of omega-3 (ALA) and partly of omega-6 (LA) fatty acids (Braun and Cohen, 2007). Human consumption of omega-3 fatty acid is proven to decrease the incidence of cardiovascular disease, reduce inflammation and prevent certain chronic diseases such as diabetes, hypertension, cancer, autoimmune diseases and arthritis (Simopoulos, 1999; Kris-Etherton *et al.,* 2003; Larsson *et al*., 2004). Clinical studies have suggested that the metabolic actions of omega-3 fatty acids may be helpful in inhibiting various medical complications from deterioration and for treatment. Omega-3 fatty acids have anti-atherogenic of coronary artery, anti-proliferative of tumor, lipid lowering and other health beneficial effects (Braun and Cohen, 2007). For hyperlipidemia patients, omega-3 fatty acids could reduce their low-density lipoprotein (LDL). However, for healthy individuals and hypertriglyceridemia patients, omega-3 fatty acids lower serum triglycerides and may slightly increase high-density lipoprotein (HDL) (Simopoulos, 1991). Thus, flaxseed oil which is rich in nutraceutical omega-3 fatty acid has been reported to be a beneficial substitute for milk fat in ice cream (Pszczola, 2002). Furthermore, the low temperature storage condition of ice cream is ideal for flaxseed oil incorporation as it stabilises the oil and preserves its original goodness (Goh *et al.* 2006). However, a complete pilot scale research is essential to evaluate the ice cream sensory properties as well as the fatty acids stability of flaxseed oil upon long-term storage. Hence, this study aims to determine the physicochemical and sensory effects of flaxseed oil formulated reduced fat ice creams, identify the optimum levels of milk fat substitution by flaxseed oil in terms of sensory properties, overall acceptability and degree of preference of the product. Apart from that, the fatty acids composition of flaxseed oil and their stability after being incorporated in each formulated ice cream were analysed under duration of 21 and 42 days of storage.

Materials and Methods

Ice cream processing

The ice cream mix consist 7.5% (w/w) fat (milk fat from Fonterra, New Zealand and flaxseed oil from Biogreen, USA), 11% (w/w) skim milk powder (Sunlac Skim, Australia), 10% (w/w) sucrose (Prai Malayan Sugar Manufacturing Co. Bhd., Malaysia), 5% (w/w) corn syrup solids (MALTRIN® M200, Grain Processing Corporation, USA), 0.3% (w/w) stabiliser/emulsifier mix (Danisco, Copenhagen,

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Denmark), 3% (w/w) carbohydrate-based fat replacer (MALTRIN® M100 Maltodextrin, Grain Processing Corporation, USA), 0.8% (w/w) vanilla essence (Nona, Malaysia) and 62.4% (w/w) water. Ice cream mix (600 g) was prepared based on the formulations in Table 1. The combination of different proportions of milk fat and flaxseed oil were given as % milk fat: % flaxseed oil with the following order; 7.5:0 (C), 5.0:2.5 (F1), 2.5:5.0 (F2) and 0:7.5 (F3). All ingredients were mixed and subjected to pasteurisation at 80°C for 15s. Homogenisation was carried out using ULTRA – TURRAX IKA® T25 digital (Werke Staufen, Germany) homogeniser with 13.8 x 1000 rpm for 5 min, followed by 3600 rpm for 5 min. The ice cream mix was cooled and stored overnight at 4°C. Vanilla essence was added into the chilled mixes. The mixes were whipped in an ice cream maker (Kenwood, Model: IM 200, UK) for 30 min. The whipped mixes were stored inside the freezer at a temperature of -18 to -25°C for 24 h.

Physicochemical analyses

Ice-cream samples were analysed in triplicate. The meltdown test for ice cream samples was carried out based on a modified method of Roland *et al.* (1999) and Goh *et al.* (2006). A hardened ice cream sample of approximately 50 g with 6 cm in diameter and 3 cm thick was placed at 25 ± 2°C on a metric test sieve. The melted ice cream was collected and weighed by electronic analytical balance at every 5 min interval up to 60 min. pH of the ice-cream sample was measured using a pH meter (Jenway, Model:3505, UK) while the titratable acidity of ice cream was determined according to a modified AOAC Official Method 947.05 (AOAC, 1990). The total solids content of ice cream was determined based on the method from AOAC Official Method 941.08 (AOAC, 2005). Protein content and fat content of ice cream was determined through AOAC Official Method 991.20, Kjeldahl method (AOAC, 2005) and AOAC Official Method 2000.18, Gerber method (AOAC, 2005) respectively.

Sensory evaluations

Ice-cream samples were organoleptically examined by twelve semi-trained panellists through Quantitative Descriptive Analysis (QDA) and consumer hedonic test methods. This sensory evaluation study includes recruiting, screening, selection, training of panellists and monitoring of panellists' performance. Each panellist was provided with a set of three ice cream samples including two reference samples for sensory evaluation. The panellist has to evaluate one sample at a time on a 15 cm anchored line scale in which the two references mark the lowest and highest ends of intensity of the particular attribute. The samples were stored overnight in refrigerator at -18°C prior to sensory testing and were served at room temperature (~25°C) under normal white fluorescent lighting. The products were assessed for yellowness, sweetness, firmness, smoothness, creaminess and mouth coating. Samples were evaluated in triplicate by panellists in three different consecutive sessions. Two best ice cream formulations out of three were chosen based on Quantitative Descriptive Analysis (QDA) results. Consumer hedonic test then used the selected formulations to carry out a further investigation on the preference of public towards the products. Untrained panellists (n=100) evaluated the two best vanilla flavoured reduced fat oil formulated ice creams and a commercial ice cream. A nine-point hedonic scale was used in which '1' indicated dislike extremely,

Table 1. Ice cream formulations of different compositions

Formulations	Ingredients in percentage (%), w/w								
	Whipping cream	Flaxseed oil	MSNF*	Sugar	CSS[φ]	S/E blend[δ]	Maltodextrin	Vanilla essence	Water
Control	7.5	0	11	10	5	0.3	3	0.8	62.4
F1	5	2.5	11	10	5	0.3	3	0.8	62.4
F2	2.5	5	11	10	5	0.3	3	0.8	62.4
F3	0	7.5	11	10	5	0.3	3	0.8	62.4

[*] MSNF – Milk Solids-Not-Fat, by SUNLAC Skim Milk Powder, Australia
[φ] CSS – Corn Syrup Solids, MALTRIN® M200, Grain Processing Corporation, USA
[δ] S/E blend – Stabiliser and Emulsifier blend, Danisco, Denmark

'5' indicated neither like nor dislike and '9' indicated like extremely. The panellists evaluated their preferences on product appearance, aroma, texture and overall acceptability.

Fatty acid analysis

The changes in fatty acids concentration of flaxseed oil incorporated in ice cream samples were determined upon a storage period of 3 and 6 weeks (21 and 42 days). The composition of fatty acids in flaxseed oil was analysed by gas chromatography (GC) with flame ionisation detector (FID). The lipids in ice cream test samples were extracted by following the method proposed by Bligh and Dyer (1959) while the FAMEs for ice cream samples were prepared by using sodium methoxide method (Qian, 2003). The gas chromatography (GC) (Perkin Elmer Instruments AutoSystem XL) with a Flame Ionisation Detector (FID) was used. The GC analysis was carried out using fused silica capillary column SP™-2380 (30 m x 0.25 mm x 0.25 μm film thickness, Supelco, Bellefonte, PA) coated with cyanopropylsilicone (0.20μm film thickness) and nitrogen as carrier gas. The initial oven temperature was set at 180°C, and was held for 20 minutes while the injector and detector temperatures were set at 250°C. The detector flow rate of air and hydrogen was set at 450 mL/min and 45 mL/min respectively. The split flow setting was at 50 mL/min. The sample injection volume was 1μL. The fatty acid methyl ester (FAME) samples were identified by comparing their retention times with a standard mixture (SUPELCO F.A.M.E Mix GLC-30) and quantified using area normalisation. Duplicate results were used in fatty acids analysis to generate mean and standard deviation for each fatty acid concentration.

Statistical analysis

MINITAB® Version 15 statistical software was used for data analysis. Mean and standard deviation were calculated from triplicate results for physicochemical analyses while duplicate results for fatty acids analysis. One-way analysis of variance (ANOVA) and Tukey's mean comparison test were applied with confidence level as $p<0.05$.

Results and Discussion

Physicochemical properties

According to Figure 1, the meltdown rates of F1, F2 and F3 samples were not significantly different ($p>0.05$) to the control (C) sample. Based on the study from Goh *et al.* (2006), ice cream made with high proportion of flaxseed oil could not effectively stabilise air cells due to minimal fat flocculation and resulted in high meltdown rate. However, in this study, all samples had similar meltdown characteristics which might be associated with the addition of maltodextrin as fat replacer. This carbohydrate-based fat replacer has surface structure similar to emulsified fat which can withstand interactions between particles within ice cream microstructure (Ohmes *et al.,* 1998). The ice cream meltdown characteristic was also studied through its half-life (Table 2). There was no significant difference ($p>0.05$) of meltdown half-life for all the samples. Flaxseed oil substitution had no significant effect on ice cream pH value and titratable acidity. In terms of pH value, Marshall *et al.* (2003) had suggested that the pH of regular fat ice cream containing full dairy fat as milk fat with 11% (w/w) milk solids-not-fat was about 6.3. Since the percentage of milk solids-not-fat used for each formulation in this study was constant, there was no significant difference ($p>0.05$) in pH value between C and the other three flaxseed oil formulated samples (F1, F2 and F3). However, according to Arbuckle (1986), the pH of dairy product like ice-cream increased when the percentage of milk solids not fat used decreased. The titratable acidity for formulated ice creams ranged from 0.20 to 0.21%, slightly higher than the value reported by Marshall *et al.* (2003), stating that ice cream mix containing 11% milk solids-not-fat possessed titratable acidity of 0.19%. The apparent acidity of ice cream mix was due to the milk proteins, mineral salts and dissolved carbon dioxide (Marshall *et al.,* 2003).

However, total solids content for ice-cream samples in this study increased slightly ($p<0.05$) from control to F3 sample, 38. 95 % to 39.9 %. These seemed to be contradictory to expected value in which total solids content should decrease from control to F3. In addition, results showed that total solids were slightly higher as compared to the standard range suggested by Hui *et al.* (2004). This could be due to the presence of maltodextrin which can increase the total solid as well (Roland *et al.,* 1999). According to Hui *et al.* (2004), economy ice cream has a minimum legal requirement for total solids content of 36% (w/w). Standard regular ice cream with 10 – 12% of fat should consist about 36 – 38% (w/w) of total solids.

Based on the data in Table 2, incorporation of flaxseed oil caused no significant effect on fat content and protein content of the formulated ice-creams. The outcome was anticipated because flaxseed oil did not contribute any additional protein value. However, a slight decrease of protein content was observed when parts of whipping cream were substituted by flaxseed

Table 2. Physicochemical attributes of ice creams

Physicochemical Attributes	Samples			
	C	F1	F2	F3
Meltdown half-life	39.83 ± 0.76[a]	38.00 ± 1.32[a]	37.83 ± 1.44[a]	37.50 ± 1.32[a]
pH value	6.42 ± 0.01[a]	6.42 ± 0.01[a]	6.42 ± 0.01[a]	6.43 ± 0.01[a]
Titratable acidity	0.21 ± 0.01[a]	0.21 ± 0.01[a]	0.21 ± 0.01[a]	0.20 ± 0.01[a]
Total solids content	38.17 ± 0.09[b]	38.95 ± 0.65[ab]	39.33 ± 0.73[ab]	39.90 ± 0.33[a]
Protein content	4.07 ± 0.18[a]	4.02 ± 0.10[a]	4.00 ± 0.05[a]	3.72 ± 0.19[a]
Fat content	7.00 ± 0.00[a]	6.83 ± 0.29[a]	6.67 ± 0.29[a]	6.50 ± 0.50[a]

Mean values ± standard deviation within the same row with different letter superscripts are significantly different at $p<0.05$. Ice-cream samples containing ratio of % flaxseed to % whipping cream are denoted as 0:7.5 (C); 2.5:5.0 (F1); 5.0:0.25 (F2) and 7.5:0 (F3).

Table 3. Attributes of ice cream perceived in QDA

Attributes	Samples			
	C	F1	F2	F3
Yellowness	32.77 ± 8.56[c]	50.11 ± 4.96[b]	62.88 ± 9.38[a]	67.68 ± 9.67[a]
Sweetness	67.06 ± 13.09[a]	61.01 ± 13.17[ab]	57.22 ± 15.72[ab]	46.44 ± 13.16[b]
Firmness	70.27 ± 9.10[a]	64.55 ± 11.03[a]	63.05 ± 9.39[a]	61.28 ± 8.72[a]
Smoothness	76.13 ± 9.70[a]	66.18 ± 12.29[ab]	58.60 ± 17.13[b]	56.33 ± 13.75[b]
Creaminess	75.28 ± 12.37[a]	58.67 ± 17.07[ab]	53.77 ± 10.89[b]	50.10 ± 18.80[b]
Mouth coating	66.10 ± 13.27[a]	63.72 ± 13.69[a]	61.38 ± 15.00[a]	57.11 ± 13.08[a]

Mean values ± standard deviation within the same row with different letter superscripts are significantly different at $p<0.05$. Ice-cream samples containing ratio of % flaxseed to % whipping cream are denoted as 0:7.5 (C); 2.5:5.0 (F1); 5.0:0.25 (F2) and 7.5:0 (F3).

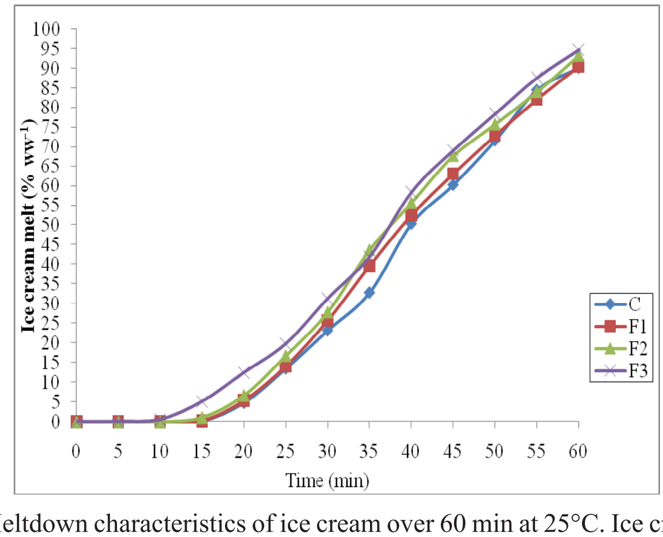

Figure 1. Meltdown characteristics of ice cream over 60 min at 25°C. Ice cream samples containing % flaxseed oil: % whipping cream are denoted as 0:7.5 (C), 2.5:5.0 (F1), 5.0:2.5 (F2) and 7.5:0 (F3).

oil since whipping cream itself provided some proteins. The main source of proteins in ice cream was from milk solids-not-fat (Alvarez *et al.,* 2005). Patel *et al.* (2006) had found that proteins are needed in forming and stabilising foams during the manufacture of ice cream. Proteins assist in emulsification, whipping and water binding capability in the development of ice cream structure (Halling, 1981; Phillips, 1981; Kinsella, 1984; Anderson *et al.,* 1987). In this study, 7.5% (w/w) fat component was set for all flaxseed oil formulated samples (F1, F2 and F3) and the control (C) in order to achieve reduced fat characteristic.

Sensory evaluation

The evaluation on ice cream colour revealed that the amount of flaxseed oil substitution was positively correlated to yellowness intensity (Table 3). As the ratio of flaxseed oil to whipping cream increased from F1 to F3 sample, the mean scores increased considerably. Flaxseed oil which displayed a strong golden-yellow colour in nature form had apparently contributed to the yellowness colour of finished ice cream. Sweetness for formulated ice-creams changed gradually ($p<0.05$) from control sample to F3 sample. This may be due to the presence of whipping cream which contributes to some sweet sensation. Thus, it can be concluded that increase in the levels of flaxseed oil substitution caused the decrease in sweetness level substantially. Research conducted by Guinard *et al*. (1997) had reported mild increase in perceived sweetness was found with higher dairy fat content in ice cream. Flaxseed oil which does not contain any sucrose is unable to exhibit sweet sensation. Furthermore, the slight nutty flavour produced by flaxseed oil could have masked the sweet perception in the sensory evaluation. It was found that smoothness and creaminess attributes were in decreasing trend when flaxseed oil substitution levels increased. All ice cream samples were perceived as moderately smooth. It was suggested that as the dairy fat content decreased, smoothness of the ice-creams decreased. Results obtained were in agreement with the findings from Aime *et al.* (2001). Hence, the smoothness of ice cream was apparently being affected by dairy fat content. In addition, Frøst and Janhoj (2007) have explained that ice cream creaminess attribute was associated with milk fat globules in dairy product. Thus, reduction of the whipping cream from control to F3 sample caused the decrease of creaminess. It can be concluded that flaxseed oil did not contribute to creaminess of the ice-cream.

Ice cream firmness and mouth coating were not significantly different ($p>0.05$) among all formulated samples. However, by reducing the amount of dairy fat, the firmness of flaxseed oil formulated ice creams was expected to decrease. Goh *et al.* (2006) found that the higher the proportion of flaxseed oil used to replace dairy fat, the lower the firmness of ice cream. Thus, similar degree of firmness for control and all formulated ice-cream in this study might be due to the presence of maltodextrin. Maltodextrin is believed to play a part in mimicking the firmness of ice cream with full dairy fat. The starch polymers in maltodextrin interact well with water and other constituents in ice cream to form gelled starch particles. These gelled particles increased the resistance of the ice cream from being deformed by tongue action (Aime *et al.,* 2001). The whipping cream which is derived from dairy fat had a large amount of saturated fats. These saturated fats formed increasing concentration of discrete small fat globules under sequential homogenisation treatments (Koxholt *et al*., 2001). Combined with the action of emulsifier, fat globules destabilised, coalesced and clustered at the air interface and within the serum phase forming a firm ice cream structure (Schmidt and Smith, 1988; Goff *et al.,* 1999; Zhang and Goff, 2005). When the amount of dairy fat in ice cream was reduced and substituted with flaxseed oil, the ice cream body began to lose its firmness. For mouth coating, similar scores were obtained for control and all formulated ice cream samples. The non-significant changes of mouth coating could possibly due to the addition of fat replacer or addition of low level of flaxseed oil. However, Stampanoni Koeferli *et al.* (1996) had reported that an increase in mouth coating was detected with increased dairy fat content in ice cream. Guinard *et al.* (1997) also reported a positive correlation between dairy fat content and mouth coating. From the Quantitative Descriptive analysis, two best formulations, F1 and F2 with higher scores of smoothness, creaminess, and acceptable level of firmness and sweetness and yellowness were chosen to undergo consumer hedonic test.

From the results shown in Table 4, the outcome of consumer hedonic test had suggested that there was no significant difference ($p>0.05$) in term of appearance preference among all ice cream samples (F1, F2 and commercial). Mean scores of above 6 points showing consumers' high acceptability towards the appearance of flaxseed oil formulated ice creams as both F1 and F2 samples were almost equally preferred compared to the commercial sample. The appearance test also included the observation on the texture of ice cream. All three ice cream samples (F1, F2 and commercial) had shown relatively smooth appearance with least surface ice crystals that made no differences under panellists' evaluation. However,

Table 4. Acceptance level for criteria in consumer hedonic test

Acceptance level of criteria	Mean scores ± Standard deviation for Formulations		
	F1	F2	commercial
Appearance	6.55 ± 1.02^{a}	6.43 ± 1.21^{a}	6.61 ± 1.47^{a}
Aroma	6.17 ± 1.39^{ab}	5.90 ± 1.31^{b}	6.47 ± 1.47^{a}
Flavour	7.07 ± 1.09^{a}	6.51 ± 1.25^{b}	7.28 ± 1.58^{a}
Texture	7.23 ± 1.11^{a}	6.61 ± 1.29^{b}	7.17 ± 1.50^{a}
Overall acceptability	7.06 ± 0.94^{a}	6.57 ± 0.94^{b}	7.26 ± 1.51^{a}

Values within the same row with different letter superscripts are significant different at $p<0.05$. The ratios of flaxseed (%) to whipping cream (%) in samples F1 and F2 are 25:50 and 50:25, respectively. Commercial samples represent Nestle Vanilla Ice cream.

the commercial sample scored 6.47 points while both F1 and F2 samples scored 6.17 and 5.90 points respectively for acceptability of aroma. F1 sample had a close resemblance to commercial sample in term of aroma liking. According to Guinard *et al.* (1997), a denser dairy fat concentration favours the release of volatile aromatic compound. F2 samples with lower content of whipping cream showed a lower score in aroma acceptability might probably due to a lesser release of volatile aromatic compound as compared to commercial sample. The degrees of flavour preference decreased with a decrease in the concentration of diary fat used. Guinard *et al.* (1997) reported that a decrease in fat content resulted in a lower flavour release in ice cream. The nutty flavour from flaxseed oil was found not commonly accepted by some panellists. Similar scores of texture acceptability were obtained for control and all formulated ice-creams in this study. These results suggested that reduced fat ice cream containing flaxseed oil could exhibit a close texture preference to the commercial ice cream. Both F1 and F2 samples scored more than 6 points which indicated panellists' high acceptability on texture quality. For overall acceptability, F1 sample appeared to be equally preferred to the commercial sample. Small amount of flaxseed oil to partly replace dairy milk fat was highly acceptable by panellists. Scores of above 6 points had depicted panellists' high acceptability on both F1 and F2 samples. It showed a potential market for reduced fat ice cream containing flaxseed oil that could bring about healthier and yet not compromise on the original preference of full dairy milk fat ice cream.

Changes of fatty acids upon storage

Table 5 and Figures 2, 3 and 4 show five types of fatty acid (palmitic, stearic, oleic, linoleic and α-linolenic acids) in flaxseed oil formulated ice cream samples (F1, F2 and F3) and their changes in concentration upon 21 and 42 days of storage. The study of fatty acids stability was focused on linoleic and α-linolenic acids in flaxseed oil as Goh *et al.* (2006) claimed that the polyunsaturated fat (linoleic and α-linolenic acids) in flaxseed oil is about 80%. Both linoleic and α-linolenic acids are known for their health beneficial effects (Pszczola, 2002). F1 and F2 samples contained partial whipping cream as the milk fat component. This whipping cream content would affect the fatty acids composition in final ice cream products. According to FDA (2008), a typical light whipping cream shall contain 30 – 36% of milk fat component. The fatty acids of milk fat are generally composed of both saturated and unsaturated forms. For saturated fatty acids, there are about 31% palmitic acid, 12% myristic acid, 11% stearic acid and 11% lower (at most 12 carbon atoms) saturated fatty acids. For unsaturated fatty acids, there are about 24% oleic acid, 4% palmitoleic acid, 3% linoleic acid and 1% linolenic acid (National Research Council, 1976). Since the whipping cream was not a good source of linoleic and linolenic acids, the incorporation of flaxseed oil in ice cream had boosted up the quantity of both fatty acids. The data in Table 5 showed high amounts of linoleic and α-linolenic acids present in the formulated ice creams. By comparing the data in Table 5, the palmitic, steric and oleic acids concentrations were highest in F1, followed by F2 and F3 samples as whipping cream consists of high palmitic, stearic and oleic acids composition (National Research Council 1976).

Table 5. Changes in fatty acids concentration in F1, F2 and F3 upon storage

Fatty acids	Concentration (mg/mL)								
	F1			F2			F3		
	Day 1	Day 21	Day 42	Day1	Day21	Day42	Day 1	Day 21	Day 42
Palmitic acid (C16:0)	15.30 ± 1.00^{a}	15.26 ± 0.76^{a}	15.02 ± 0.61^{a}	9.04 ± 0.58^{a}	9.00 ± 1.00^{a}	8.98 ± 0.74^{a}	4.87 ± 0.37^{a}	4.71 ± 0.23^{a}	4.73 ± 0.68^{a}
Stearic acid (C18:0)	5.13 ± 1.23^{a}	5.24 ± 0.07^{a}	6.06 ± 2.67^{a}	4.52 ± 1.02^{a}	4.89 ± 0.66^{a}	5.06 ± 0.24^{a}	3.02 ± 0.10^{a}	3.25 ± 0.44^{a}	4.07 ± 0.61^{a}
Oleic acid (C18:1)	19.50 ± 0.82^{a}	19.91 ± 1.25^{a}	19.82 ± 1.63^{a}	17.94 ± 0.31^{a}	18.23 ± 2.28^{a}	18.90 ± 2.65^{a}	16.31 ± 0.40^{a}	16.59 ± 1.00^{a}	17.16 ± 1.20^{a}
Linoleic acid (C18:2)	12.49 ± 1.54^{a}	11.02 ± 0.79^{a}	9.71 ± 1.15^{a}	15.33 ± 1.87^{a}	14.24 ± 2.23^{a}	12.58 ± 2.53^{a}	17.12 ± 0.47^{a}	16.09 ± 0.09^{ab}	14.65 ± 0.82^{b}
α-Linolenic acid (C18:3)	30.02 ± 1.99^{a}	29.42 ± 0.48^{a}	27.51 ± 1.97^{a}	58.39 ± 0.09^{a}	57.23 ± 0.76^{ab}	54.34 ± 1.32^{b}	80.01 ± 0.51^{a}	78.46 ± 1.46^{ab}	75.05 ± 0.23^{b}

Each value from the table represents the mean ± standard deviation of triplicate results, (n=3). Mean within each row with common superscripts are not significantly different ($p > 0.05$) and this comparison is made within various storage duration for each formulation.

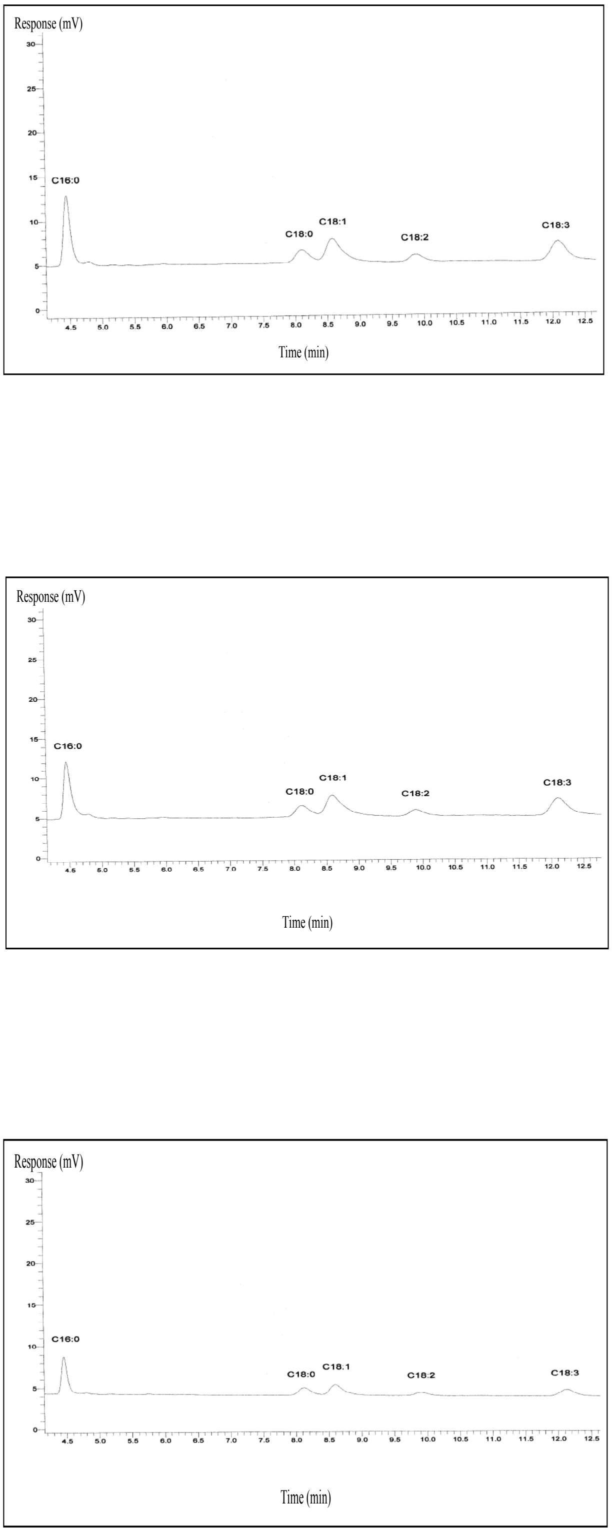

Figure 2. Chromatograms of F1 sample fatty acids profile upon storage (a) Day 1; (b) Day 21 and (c) Day 42

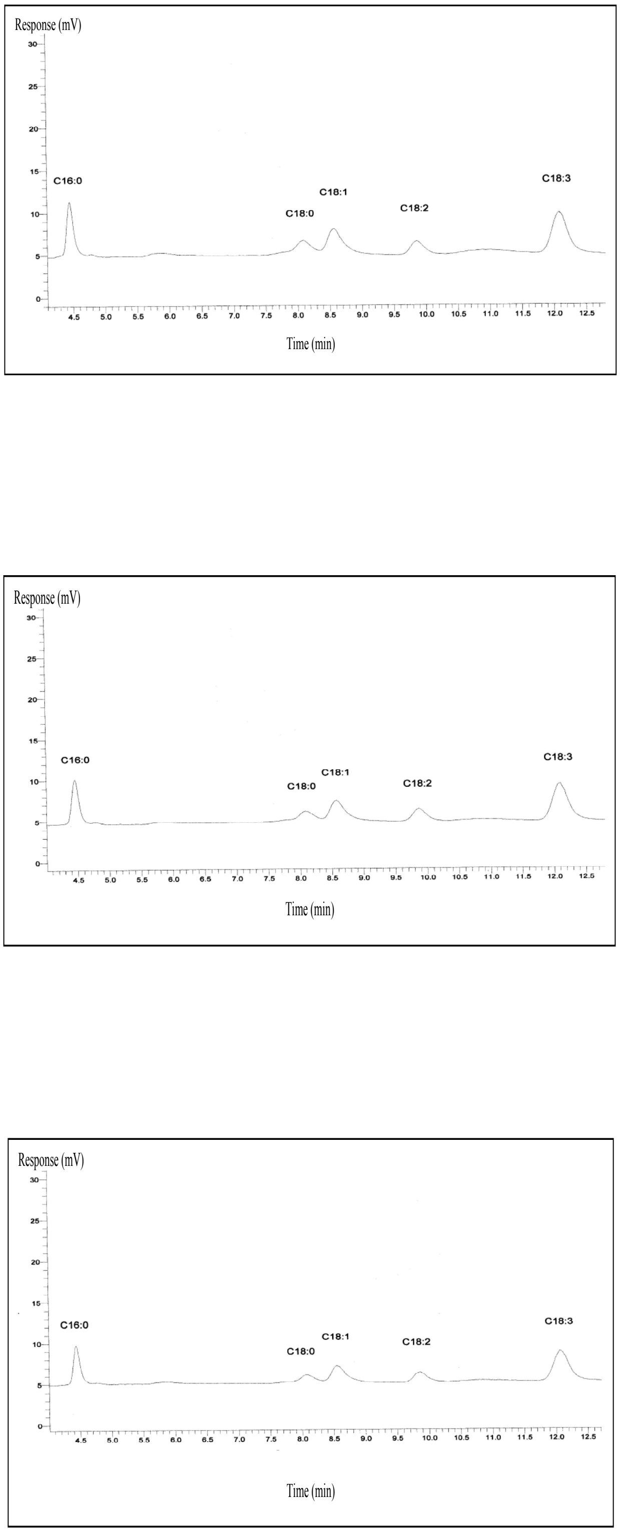

Figure 3. Chromatograms of F2 sample fatty acids profile upon storage (a) Day 1; (b) Day 21 and (c) Day 42

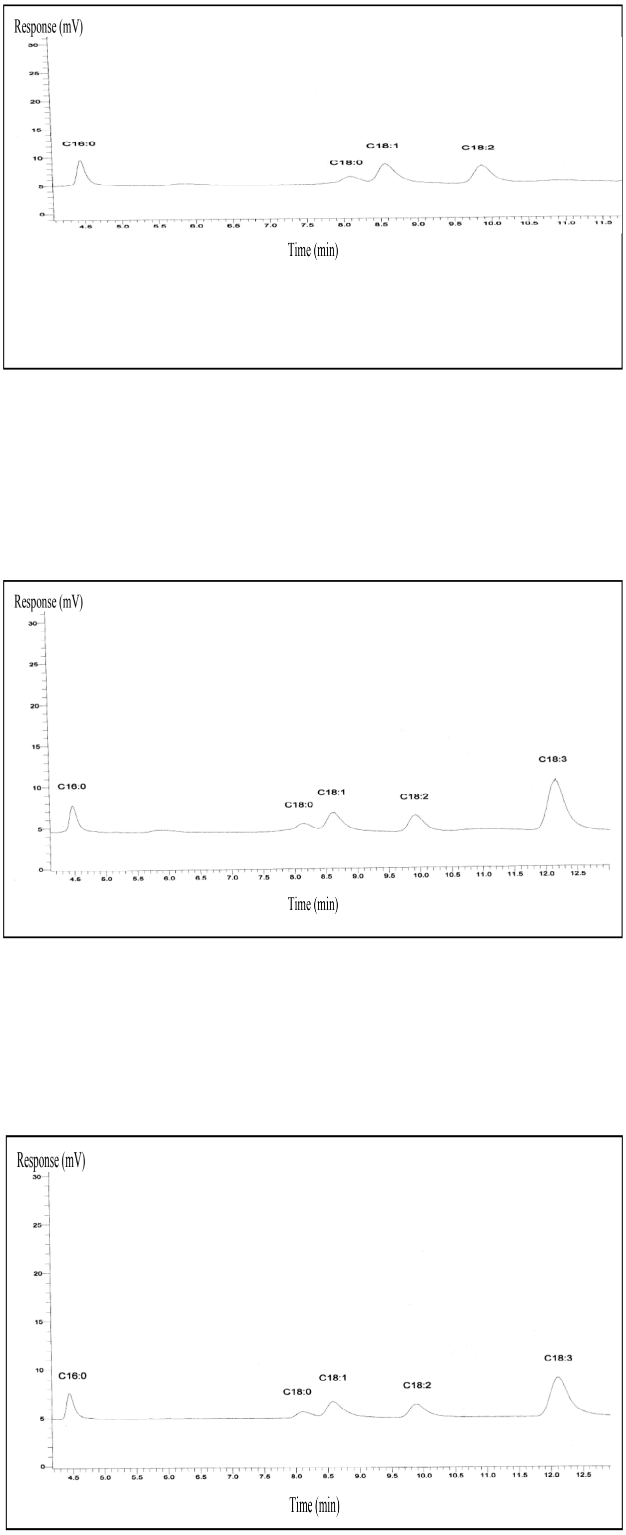

Figure 4. Chromatograms of F3 sample fatty acids profile upon storage (a) Day 1; (b) Day 21 and (c) Day 42

Upon 42 days of storage, there were no significant differences ($p>0.05$) in the concentration of palmitic, stearic and oleic acids. Flaxseed oil contained a large fraction of unsaturated fatty acids. However, both linoleic and α-linolenic acids in particular are susceptible to auto-oxidation process (Hamilton and Rossell, 1986). Rudnik *et al.* (2001) also reported that oils which contain high content of unsaturated fatty acids lead to reduced oxidative stability. This phenomenon could be ascertained by observing the trend of tabulated data in Table 5 upon 21 and 42 days of storage duration. The concentrations of linoleic acid (LA) and α-linolenic acids (ALA) had shown a slight decreasing trend with percentage losses 6.02 % for LA and 2.00% for ALA, respectively upon 21 days of storage. However, percentage losses for both LA and ALA increased to 14.4 % and 6.2% - 6.94%, respectively upon 42 days of storage. In this study, heat was not a factor affecting polyunsaturated fatty acids degradation since the ice cream was maintained at -18 to -20°C throughout 42 days of storage period. Polyunsaturated fatty acids thermal oxidation studied by Moya *et al.* (1999) had revealed that a decrease in unsaturation occurred at 150°C and above. Therefore, linoleic and linolenic acids which are polyunsaturated have high thermal stability at temperature well below 0°C. According to Goh *et al.* (2006), the low storage temperature (-18°C) of ice cream was most suitable for flaxseed oil incorporation to preserve its valuable fatty acids. In every 100mL of flaxseed oil formulated ice creams, F1, F2 and F3 samples would provide approximately 2251.5mg, 4379.3mg and 6000.8mg of omega-3 fatty acid (ALA) respectively. The Recommended Nutrient Intakes (RNI) for Malaysia 2005 has stated a minimum omega-3 fatty acids amount of 670mg a day for every individual (Ng 2006). The flaxseed oil formulated ice cream samples (F1, F2 and F3) had contributed to sufficient supply of omega-3 fatty acid that was beneficial to human health only if it was fully absorbed by the body.

Conclusion

Incorporation of flaxseed oil in ice-cream to replace milk fat could affect the physicochemical properties of ice-cream, depending on the amount of milk fat being replaced. Thus, in this study substitution of milk fat with 2.5% flaxseed oil produce ice-cream with good physicochemical properties and gives compatible overall acceptability as compared to commercial ice-cream. Besides that, both ALA and LA were found quite stable upon 42 days storage. Thus, flaxseed oil incorporation in ice cream is ideal and consumers may enjoy the health benefits of omega-3 fatty acids such as reducing coronary artery disease, tumor and lowering serum triglycerides.

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