J. Food Sci. Nutr.
Vol. 4, No. 4, p. 226~230 (1999)

A Study of Frozen Dessert Containing Canola and Soybean Oils as a Replacement for Milk Fat

Ji-Soon Im

Department of Food Science and Technology, Konyang University, Nonsan 320-711, Korea

Abstract

This study was done to determine how added vegetable oils affect the physical, chemical and microbial properties of experimental frozen desserts. There were no differences in the percentages of total fat and total solids in the seven frozen desserts. Freezing points did not differ among treatments. There were significant differences in viscosity among the frozen desserts containing up to 80% of vegetable oils. Oil substitution at 30% or higher significantly decreased viscosity when compared to the milk fat control. The hardness of frozen desserts decreased significantly with increasing addition of oils. Oil substitution at 20% or higher significantly decreased hardness. Substitution of canola and soybean oils for milk fat increased melting rate. Initiation of fluid release in the control was slower than in frozen products with added oils. The SPC values and coliform counts of all frozen products were not significantly changed. Cholesterol content decreased significantly in the products as the vegetable oil content was raised. Frozen desserts containing 10%, 30% or 60% of vegetable oils in the total fat contained 91.8%, 73.5% or 32.5%, respectively, of the cholesterol in the control.

Key words: frozen desserts, vegetable oils, milk fat, substitution, cholesterol

INTRODUCTION

Fats in food have attracted much concern from consumers as components that are undesirable to health. Thus the pressure to remove fat from food items is enormous. Unfortunately, it has not been considered by most consumers that essential fat and a healthy balance of different types of fat could be much more nutritious than no fat at all (1). In addition, fat contributes to the palatability of food and is thus important in food processing (2). Therefore, the composition of fat in the diet is becoming increasingly important. FAO and WHO are concerned about the implications of dietary fats in human nutrition because of the positive contribution to health, and because of the possible adverse effect of certain fats on atherosclerosis and on obesity and its complications. During the last decade there have been significant advances in knowledge of the nutritional value and physiological effects of different fats (3,4). There are two general considerations: first, the importance of fats in food and, second, the safety aspects. Dietary fat is important for at least three reasons: as a source of energy, as a source of essential fatty acids for cell structure and prostaglandin synthesis, and as a vehicle for fat-soluble vitamins (1,4). In considering the safety of fats, a major issue that remains to be resolved is that of the health implications. Today, consumer demands for convenience, safety, good nutrition and sensory satisfaction are the driving forces behind new food product development. Consumer interest in the relationship of food to good health opens new marketing opportunities.

Common fats and oils are composed of triglycerides that may have various saturates, monounsaturates and polyunsaturates (5). For instance, canola oil is composed of 57.4% oleic acid and is considered to be a monounsaturated oil. Similarly, soybean oil contains 63.7% polyunsaturated fatty acids and is considered to be polyunsaturated oil (6-8). Milk fat is frequently described as being a saturated fat because of the high levels of those types of acids present (9,10). Milk fat is popularly regarded as a high cholesterol food (9). The real issue in educating the public is the need for limitation of excessive caloric intake and the restriction of saturated fat intake. It is generally acknowledged that reducing the intake of saturated fat exerts approximately twice the beneficial impact on circulating cholesterol as does an equivalent increase in polyunsaturates (11). Milk fat is the only fat commonly consumed other than coconut oil that markedly elevates the cholesterol concentration in humans and other mammals. Yet, reducing fat in the diet is difficult since consumers prefer products that have the taste and texture of high-fat foods. Therefore, this study was done to determine how added vegetable oils instead of milk fat affect the physical, chemical and microbial properties of the experimental frozen desserts.

MATERIALS AND METHODS

Ingredients and mix composition

Heavy whipping cream (Prairie Farms Dairy, Inc., Carlinville, IL, USA), canola oil, soybean oil, skim milk, nonfat dry milk (NDM), granulated sucrose, 36/43 DE corn syrup solids, and stabilizer/emulsifier (Aristocrat IC, Bunge Foods, Atlanta, GA, USA) were used as ingredients. Each mix con-

E-mail: imjst@kytis.konyang.ac.kr
Phone: 82-461-730-5156, Fax: 82-461-736-4078

sisted of 12% fat, 10% nonfat milk solids, 10% sucrose, 5% corn syrup solids, and 0.3% stabilizer/emulsifier.

Processing

Mixes were made in 60 L processing vats. Mixes were pasteurized at 68°C for 30 min and homogenized at 175 kg/cm^2 in a two-stage APV-Gaulin homogenizer. Mixes were then cooled and aged at 4°C. The continuous freezer (Technogel, Model 80, Bergamo, Italy) was employed to produce frozen products.

Total fat and total solids

The total fat of mixes was determined using the Mojonnier fat test (12). The total solids were measured by the oven method (13).

Freezing point

Freezing points of mixes were measured with a Fiske milk cryoscope (Model J, Fiske Assoc., Inc., Bethel, CT, USA). One part of the sample was diluted with 3 parts of distilled water to bring freezing points within the range of 7% and 10% solutions of sucrose. Subsequently, freezing points were corrected by multiplying observed values by 4.

Viscosity of mix and hardness of frozen product

Mixes were kept at 5°C and measured for viscosity within 48 hours after production. Viscosity was measured at 5°C with a Haake Rotovisco II Viscometer (Haake-Buchler, Saddlebrook, NJ, USA) fitted with an MV II sensor system and a size 50 head. A Haake 86A refrigerated water bath was used to maintain temperatures and a Hewlett Packard plotter (Model 1040A) was used to record viscosity readings.

Hardness was determined with an Instron Universal Testing machine (Model 1132, Instron Corp., Canton, MA, USA) equipped with a 4.8 kg load cell and a probe of 3.12 mm diameter. Samples were prepared by filling frozen desserts into 130 ml Styrofoam cups. They were covered with aluminum foil after the frozen products were leveled to the container rim. After 48 hours storage at -22°C, the samples were analyzed by a cycle compression test in which samples were compressed to 50% of their original height.

Melting rate

Melting rate was measured by modifying the method described by Arbuckle (14). Each sample in a 130 ml Styrofoam cup was tempered overnight at -22°C. The Styrofoam cups were cut and peeled from the products, and the contents were placed on a metal gauze (15 mesh) at 30°C in an incubator (GCA Precision Scientific, Chicago, IL, USA). The volume of melted liquid collected in a graduated cylinder was recorded every 10 min.

Thermal properties by differential scanning calorimetry

Thermal properties of the fat in each frozen dessert were studied by differential scanning calorimetry (Model 7, Perkin-Elmer, Norwalk, CT, USA). Samples (5 mg) were weighed into aluminium pans to which lids were sealed with a crimper. An empty pan was used as reference. Heating rate was controlled at 6°C/min by a microcomputer over the range of -30°C to 60°C. Peak areas of samples were determined from the recorded melting thermograms.

Microbial analyses

Microbial analyses were based on procedures outlined in Standard Methods for the Examination of Dairy Products (12). Total bacteria counts were performed using plate count agar, and coliform counts were made using violet red bile agar.

Cholesterol assay

Cholesterol content was determined according to Bailey (15). Three ml of internal standard [1.0 mg stigmasterol (Sigma, St. Louis, MO)/ml acetone] were transferred to a screw cap saponification tube. The solvent was evaporated under a stream of nitrogen. Frozen dessert (5 g) was then weighed into the same saponification tube and 15 ml of 12% KOH solution in 90% ethanol were added. The samples were saponified for 30 min in a water bath at 80°C. The tube was cooled, and 5 ml of distilled water was added. The non-saponifiables were extracted with 2×5 ml portions of hexane with shaking for 1 min. The two portions of extract were combined and mixed. Cholesterol content in 2 μl of the extract was measured with a sigma 8500 gas chromatograph (Perkin Elmer, Norwalk, CT, USA) equipped with SE-30 capillary column. Carrier gas (helium) was delivered at 50 ml/min. Oven temperature was programmed isothermally at 275°C for 5 min. The injection port was 275°C and the detector was 290°C.

Statistical analyses

All collected data was analyzed statistically using the Statistical Analysis System (16). A Least Significant Difference (LSD) test with a 5% level of significance after general linear model test was used to analyze the differences among samples.

RESULTS AND DISCUSSION

Proximate compositions

Total fat and total solids in the frozen products are shown

Table 1. Average proximate compositions and freezing points of frozen desserts containing up to 80% of oils as a replacement for milk fat

Sample	Total fat (%)	Total solids (%)	Freezing point (°C)
Control[1)]	11.82^{ns} (0.42)[3)]	37.40^{ns} (1.20)	-1.903^{ns} (0.050)
10%[2)]	11.99^{ns} (0.19)	37.27^{ns} (0.09)	-1.873^{ns} (0.048)
20%	12.23^{ns} (0.49)	37.57^{ns} (1.40)	-1.869^{ns} (0.042)
30%	12.07^{ns} (0.24)	37.77^{ns} (0.61)	-1.909^{ns} (0.056)
40%	12.19^{ns} (0.24)	37.50^{ns} (1.11)	-1.867^{ns} (0.036)
60%	12.20^{ns} (0.31)	37.43^{ns} (0.83)	-1.909^{ns} (0.072)
80%	11.92^{ns} (0.14)	37.67^{ns} (1.30)	-1.886^{ns} (0.051)

[1)]Ice cream with 12% milk fat.
[2)]Canola oil and soybean oil, 1:1, substituted for milk fat at rates shown.
[3)]Standard deviation in parentheses (n=3).
^{ns}Not significantly different.

in Table 1. There were no differences in the percentages of total fat in the seven frozen desserts ($p>0.05$). Average percentages ranged from 11.82% to 12.23%. Replication was not a significant variable. There were also no differences in the total solids contents of the seven frozen desserts (Table 1). Average total solids ranged from 37.27% to 37.77%. Replication was not a significant factor. The total fat and solid levels were initially calculated at 12% and 37.3%, respectively.

Freezing point

Freezing points did not differ among treatments (Table 1). The freezing point of ice cream is dependent on the soluble constituents and varies with composition. Solutes dissolved in an aqueous solvent generally lower the freezing point. Since oil is not dissolved in aqueous solvent and the other ingredients were the same, the freezing point was expected to be unchanged.

Viscosity of mix

There were significant differences in viscosity among the frozen desserts containing up to 80% of vegetable oils ($p< 0.05$). Replication effect was also significant. As more oils were added, viscosity appeared to decrease (Fig. 1). Oil substitution at 30% or higher significantly decreased viscosity when compared to the milk fat control. Replacements of 30% and 60% of the milk fat with oils decreased the viscosity by 4% and 9%, respectively, compared to the milk fat control. This result was explained by a change in size and distribution or melting point of the fat globules or both.

Hardness of frozen product

The hardness of frozen desserts decreased significantly with increasing addition of oils (Fig. 2). Oil substitution at 20% or higher significantly decreased hardness ($p<0.05$). No replication effect was observed for hardness. Differences in frozen dessert hardness could be explained by the effect of substituted oils on the melting profile in the frozen desserts. Or it was because of different size and distribution of fat globules or a difference in the membranes of the globules. The possibility that a relationship existed between viscosity and hardness was indicated by the very high r^2 of 0.942.

Melting rate and thermal properties

Substitution of canola and soybean oils for milk fat increased melting rate compared to the control (Fig. 3). Initiation of fluid release in the control was slower than in frozen products with added oils. Compared to the control, more than 30% oil had to be substituted to significantly affect the melting rate of the frozen products. This may be explained by the fact that melting points of fatty acids differ. Results of differential scanning calorimetry confirmed this. Each sample produced a thermal curve with three different transitions (Table 2). As more oils were added, thermal transition started at lower temperatures (T_{onset}). Total enthalpy required to induce transition of fat in the control mix was significantly higher than that necessary for the others ($p<0.05$). The high enthalpy of the control mix for transition could be explained by the melting properties of individual fatty acids. Saturated and long chain fatty acids are difficult to melt (17). As more oils were added, unsaturated fatty acids increased while saturated fatty acids decreased.

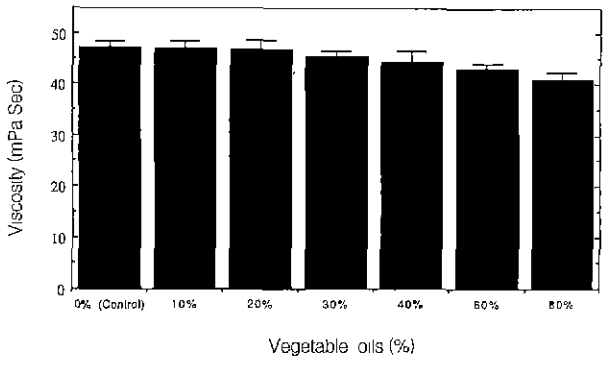

Fig. 1. Viscosity of frozen dessert mixes as a function of percent of vegetable oils in the total fat of the mix.

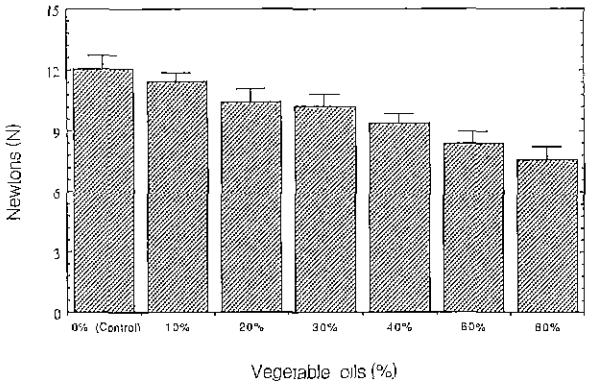

Fig. 2. Hardness of frozen desserts as a function of percent of vegetable oils in the total fat of the mix.

Microbial analyses

The frozen desserts containing up to 80% of vegetable oils as a replacement for milk fat were subjected to standard plate counts (SPC) and coliform counts to determine the effects of added oils on bacterial survival. The log SPC values and coliform counts are shown in Table 3. No significant differences were detected among treatments at 1 day of storage. More-

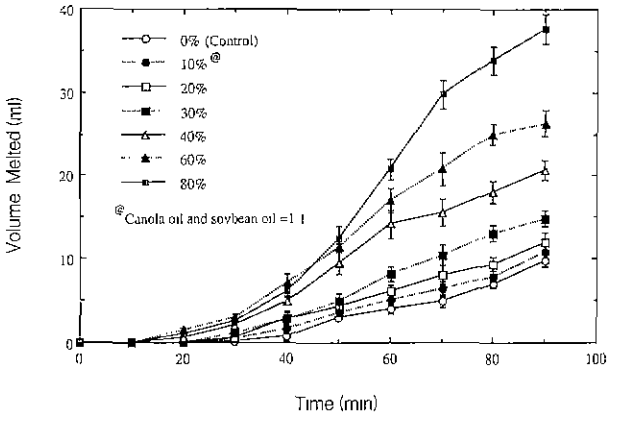

Fig. 3. Melting curves of frozen desserts containing up to 80% of oils as a replacement for milk fat.

Table 2. Thermal properties of frozen desserts containing up to 80% of vegetable oils as a replacement for milk fat

Sample	T_{onset} (°C)	T_{max1} (°C)	T_{max2} (°C)	T_{max3} (°C)
Control[1)]	1.50[a]	4.91	13.97	30.31
	(0.28)[3)]	(0.30)	(0.11)	(0.31)
30%[2)]	-3.34[b4)]	0.47	11.34	29.11
	(0.29)	(0.37)	(0.26)	(0.99)
60%	-8.83[c]	-5.54	7.41	29.87
	(0.01)	(0.85)	(0.45)	(0.31)
80%	-9 04[c]	-2.88	3.19	25.85
	(0.23)	(0.08)	(0.37)	(0.45)
Sample	ΔH_1 (J/g)	ΔH_2 (J/g)	ΔH_3 (J/g)	ΔH_{total} (J/g)
Control[1)]	3.29	11.33	14.17	28.78[a]
	(0.86)[3)]	(0.99)	(0.39)	(1.47)
30%[2)]	0.88	9.33	10.62	20.82[b]
	(0.06)	(0.33)	(0.63)	(0.89)
60%	0.43	3.36	4.25	8.04[c]
	(0.12)	(0.42)	(0.78)	(1.08)
80%	2.34	0.71	1.42	4.28[d]
	(0.42)	(0.35)	(0.52)	(0.19)

[1)]Ice cream with 12% milk fat.
[2)]Canola oil and soybean oil, 1:1, substituted for milk fat at rates shown.
[3)]Standard deviation in parentheses (n=2).
[4)]Means in a column which are not followed by the same letter are significantly different ($p<0.05$).

Table 3. Total bacterial counts and coliform counts of frozen desserts containing up to 80% of vegetable oils as a replacement for milk fat at 1 day and 30 days storage

Substituent (%)	Standard plate count		Violet red bile agar	
	1 day	30 days	1 day	30 days
	——log CFU/ml——		——CFU/ml——	
0% (Control)	2.84[ns]	2.83[ns]	1.0	0.67
	(0.05)[2)]	(0.03)		
10%[1)]	2.88[ns]	2.89[ns]	1.0	1.33
	(0.09)	(0.01)		
20%	2.84[ns]	2.82[ns]	1.0	0.67
	(0 07)	(0.09)		
30%	2.90[ns]	2.87[ns]	1.33	1.0
	(0.05)	(0.06)		
40%	2.84[ns]	2.81[ns]	1.0	1.0
	(0.07)	(0.03)		
60%	2.80[ns]	2.81[ns]	0.67	0.67
	(0.06)	(0.02)		
80%	2.82[ns]	2.84[ns]	1.0	0.67
	(0.04)	(0.04)		

[1)]Canola oil and soybean oil, 1:1, substituted for milk fat at rates shown.
[2)]Standard deviation in parentheses (n=3).
[ns]Not significantly different.

over, after 30 days of storage, the SPC values and coliform counts of all frozen products were not significantly changed. This suggests that amount of oils added did not affect the microbiological quality of these frozen desserts.

Cholesterol assay

The nutritional emphasis, fueled by consumer awareness, has turned to replace saturated fatty acids from milk fat with vegetable oils as well as to partially remove cholesterol. This

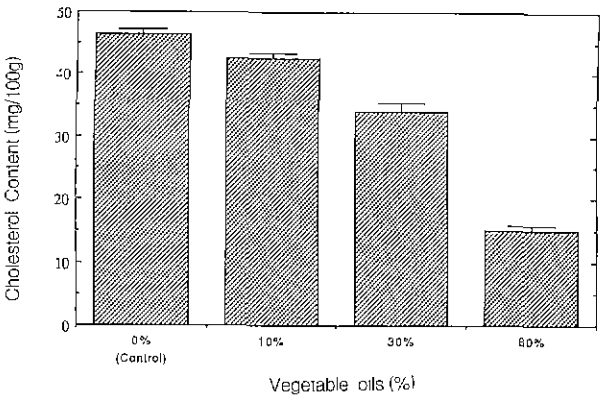

Fig. 4. Cholesterol content in frozen desserts containing vegetable oils as a replacement for milk fat.

was achieved in the present experiments by replacement of some milk fat with canola and soybean oils. These oils are all low in saturated fat, contain no cholesterol, and are rich in unsaturated fat. Stigmasterol (0.6 mg/g frozen product) was used as an internal standard for quantification of cholesterol. The retention times of cholesterol and stigmasterol were detected with a flame ionization detector. Cholesterol content decreased significantly ($p<0.05$) in the products as the vegetable oil content was raised from 0% to 10% to 30% and to 60% (Fig. 4). Frozen desserts containing 10%, 30% or 60% of vegetable oils in the total fat contained 91.8%, 73.5% or 32.5%, respectively, of the cholesterol in the control. The cholesterol value (46.3 mg/100 g) shown in Fig. 4 for the control (12% ice cream) was similar to the value reported by Arbuckle (14) for ice cream.

REFERENCES

1 Anonymous : *Dietary fats and oils in human nutrition.* Food and Agriculture Organization of the United Nations, Rome, Italy, p.21 (1980)
2. Welch, V. A. and Borlakoglu, J. T. . Absorption and transport of dietary lipid: effect on some lipid-related health probrems. In "*Fatty acids in foods and their health implications*" Chow, C. K. (ed.), Marcell Dekker, Inc., New York, p.559 (1992)
3. Dreon, D. M., Vranizan, K. M., Krauss, R. M., Austin, M. A. and Wood, P. D. : The effects of polyunsaturated fat vs monounsaturated fat on plasma lipoproteins. *J. Am. Med. Assoc.*, **263**, 2462 (1990)
4. Mead, J. F., Alfin-Slater, R. B., Howton, D. R. and Popjak, G. : *Nutritional value of lipids.* Plenum Press, New York, p.459 (1986)
5. Babayan, V. K. : *Sense and nonsense about fats in the diet.* Food Tech. Jan., p.90, 91, 207 (1989)
6. White, P. J. : Fatty acids in oilseeds (vegetable oils). In "*Fatty acids in foods and their health implications*" Chow, C. K. (ed.), Marcell Dekker, Inc., New York, p.237 (1992)
7. Spiller, G. A. : Physiological effects of monounsaturated oils. In "*The mediterranean diets in health and disease*" Van Nostrand Reinhold Co. Inc., New York, p.182 (1991)
8. Yodice, R. : *Nutritional and stability characteristics of high oleic sunflower seed oil.* SVO Enterprises, Eastlake, Ohio, p.1 (1990)
9. Gurr, M. I. : Dairy fat: Nutritional nasties or dietary delights? In "*Fats for the future*" Cambie, R. C. (ed.), Ellis Horwood Lim-

ited, West Sussex, England, p.41 (1989)
10. Jensen, R. G. : Fatty acids in milk and dairy products. In "*Fatty acids in foods and their health implications*" Chow, C. K. (ed.), Marcell Dekker, Inc., New York, p.95 (1992)
11. Keys, A., Anderson, J. T. and Grande, F. : Serum cholesterol response to changes in the diet. IV. Particular saturated fatty acids in the diet. *Metabolism*, **14**, 776 (1965)
12. Marshall, R. T. : *Standard methods for the examination of dairy products*. American Public Health Association, Washington, DC, USA (1993)
13. AOAC : *Official methods of analysis*. 16th ed., Association of Official Analytical Chemists, Washington, D.C., 33.2.44 (1995)
14. Arbuckle, W. S. : *Ice cream*. Van Nostrand Reinhold Co., Inc., New York, p.352 (1986)
15. Bailey, M. E. : Food cholesterol content. Manual of Food Analysis, University of Missouri, Columbia, Missouri (1992)
16. SAS Institute, Inc. : *SAS user's guide*. Statistical Analysis Systems Institute, Cary, North Carolina (1993)
17. deMan, J. M. : Chemical and physical properties of fatty acids. In "*Fatty acids in foods and their health implications*" Chow, C. K. (ed.), Marcell Dekker, Inc., New York, p.17 (1992)

(Received September 20, 1999)