# Influence of Soy Protein Isolate on Physical and Sensory Properties of Ice Cream

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**Abstract**

Physical and sensory properties of ice cream samples substituted for 0, 25, 50, 75 or 100% of skimmed milk powder with soy protein isolate (SPI) were investigated. An increase of SPI concentration was shown to increase viscosity and hardness of ice cream samples and also produced darker color in relation to those of control ice cream. Meltdown properties of ice cream samples demonstrated a relationship between decreased meltdown characteristics and SPI levels. Panelists rated in lower scores for smoothness, but higher scores for gumminess with increasing of SPI levels; however, no significant differences ($P>0.05$) were found for all sensory attributes between the 50% SPI substitution and control ice cream samples.

***Keywords:*** ice cream, soy protein isolate, frozen dairy products, health food

## Introduction

Soybean has been identified as inexpensive high protein resource that complement the amino acid patterns; therefore, it is recommended for dietary supplement or protein fortification in many food products, which may solve protein-malnutrition in developing countries. In 1998, U.S. Food and Drug Administration (FDA) approved soy protein for health claims, because of natural phytochemicals such as isoflavones were found to function as antioxidants to combat oxidative degradation that could lead to diseases inside the body (Conforti and Davis, 2006). Also, intake of products high in soy protein can lower total serum cholesterol, decrease risks for several cancers and coronary heart disease and inhibit bone resorption (Zind, 1998; Messina, 2001; Gallagher et al.,2000). Consequently, several researchers have been interested in incorporating soy protein into existing food products to obtain products for health such as snack, bakery, dairy and meat products (Drake et al., 2000; Yang et al., 2001). In the U.S., a food product containing 2.5% added soy protein concentrate can be qualified as a "good source" claim of soy protein, which promotes market potential for health food (Lee and Brennard, 2005).

Soy protein provides several functionalities such as water-holding, binding, and emulsifying properties (Arrese et al., 1991); therefore, its uses may affect the food quality. Beany flavor of soy protein also limit its expanded applications in food. Of all soy protein products, soy protein isolate (SPI) has the mildest flavor and higher protein content (≥ 90%); consequently, it should be used as a good soy protein source in making soy foods.

Ice cream, a popular dairy-based frozen product, has been consumed worldwide and the consumption of ice cream continues to increase. Fortification of ice cream with SPI would be an approach to provide additional health benefits in a well-accepted food (ice cream). This is a way to combine the benefits and consumer market for ice cream with the potential health benefits of soy protein. Therefore, the purpose of this study was to determine physical and sensory effects of SPI substitution for skimmed milk powder on ice cream products.

## Materials and Methods

### Materials

Konjac flour and κ-carrageenan were purchased from the Thai Food and Chemical Co., Ltd, while SPI was obtained from the Vichi Consolidate Co., Ltd. Ice cream ingredients including whole milk, whipping cream, skimmed milk powder, sugar and vanilla flavor were purchased from a local supermarket.

### Preparation of Ice Cream

Ice cream was prepared by replacing 0, 25, 50, 75 or 100% of skimmed milk powder with SPI. The control ice cream was prepared with 43 g of whole milk, 39 g of whipping cream, 4.6 g of skimmed milk powder, 13 g of sugar, 0.27 g of konjac flour, 0.03 g of κ-carrageenan and 0.1 g of vanilla flavor. Whole milk and whipping cream were mixed and heated up to 40ºC before adding dry ingredients (skimmed milk powder, sugar, konjac flour and κ-carrageenan). Ice cream mixes were pasteurized at 68.3ºC for 15 min, homogenized through a Waring blender® (Model HGBSSSP6, Torrington, Connecticut, USA) for 2 min, cooled to 4ºC and stored for processing the next day. Vanila flavor was added in aged mixes before freezing in a bench-top ice cream maker (Model GL 1l, Girmi Grangelato, Italy) for 25-30 min, and then in an air blast freezer (SK 713 TH/THS, Friga-Bohn, France) at -35ºC for 6 h. The ice cream was stored at -18ºC prior to physical and sensory analysis.

### Physical analysis

Ice cream samples were measured for pH by using a pH-meter (Model 320, Mettler-Toledo Ltd., Essex, UK). Overrun was estimated using a standard 100 ml cup, according to the equation as follows:

$$\%\text{Overrun} = \frac{\text{Volume of ice cream - Volume of mix}}{\text{Volume of mix}} \times 100$$

Melting property was analyzed at 25±2ºC. Hardened ice cream (25 g, -18ºC) was placed on a sieve (2 mm wide, square openings). The volume of the melted ice cream at the first 10-min was recorded and further measured every on 5 min interval until the time of 40 min was reached.

A Hunter Lab digital colorimeter (Model D25M, Hunter Associates Laboratory, Reston, VA) was used to measure ice cream color and CIE color scales L*a*b* values were recorded. The hue and chroma values were determined using the formula, ($\tan^{-1}$ b/a) and $(a^2+b^2)^{1/2}$, respectively.

Hardness measurement was obtained using a peretrometer (StanHope-Seta MK VI) with a needle-test cell. The time for each measurement was set up 10 sec and temperature of ice cream samples was about -9±1ºC.

Viscosity measurement of ice cream samples which filled in 180 mL containers (6 cm diameter × 9 cm height), was taken at 6±1ºC with a Brookfield viscometer (Model RTDV II, Brookfield Engineering Laboratories, Inc., MA, USA). The viscometer was operated at 20 rpm (spindle number 4).

### Sensory Evaluation

Sensory evaluation was conducted by a semitrained panel (ten judges) at University of the Thai Chamber of Commerce (UTCC). Each panelist was trained in four 30-min sessions for basic aspects and the differences concern all the attributes of the samples. Panelists developed a list of terms describing the texture attributes of ice cream using commercial samples. Definitions were developed for each of three terms chosen (smoothness, gumminess, iciness). A 13-cm unstructured line scale test (0 = none, 10 = strong) was used to rate intensity of the attributes. Samples (30g) were filled in 45-mL plastic cups with lids, labeled with three-digit codes and served at 4±2ºC. All testing sessions were held in a sensory evaluation laboratory with partitioned booth at UTCC. Distilled water was provided to rinse their palates between samples (Lawless and Heymann, 1998).

### Statistical Analysis

Ice cream production was carried out in triplicate. The statistical design for physical properties was a completely randomized design (CRD), while sensory data conducted on a randomized complete block design (RCBD). Data were analyzed statistically by analysis of variance (ANOVA) using SPSS for Window version 11.0. Means with a significant difference (P<0.05) were compared by Duncan's new multiple range test (Cochran and Cox, 1992).

## Results and Discussion

### Physical Analysis

Results illustrated that the substitution of skimmed milk powder with SPI altered physical properties of ice cream samples (Table 1). The SPI substitution from 0 to 75% did not change pH values of ice cream samples with respect to the control. When 100% SPI was incorporated, the ice cream was observed for significantly higher (P<0.05) pH value than other samples, probably due to the addition of SPI with higher pH content (6.8 -7.0). The addition of SPI to ice cream mixes significantly increased (P<0.05) viscosity values of ice cream samples, except for that with 25% SPI as compared with the control. Increasing of SPI level from 25 to 50% resulted in considerably higher viscosity, which may be explained as water binding property of SPI with liquid component to form a gel-like network to modify the rheology of the ice cream (Yao et al., 1988). Similar result was confirmed by the study of Friedeck et al. (2003) who reported that the higher viscosity achieved for the 4% SPI (by total weight) fortified ice cream was attributable to the difference of SPI (>90% protein) used to substitute for nonfat dry milk (35-36% protein and 51-52% carbohydrate); consequently, higher protein levels in added SPI samples resulted in higher viscosities. However, there were no significant differences (P>0.05) for viscosity among samples with 50 to 100% SPI, probably due to the imbalance amount of SPI with water portion in ice cream formulations, resulting in no further viscosity.

Hardness, which measured instrumentally as a penetrometer value "the shorter the penetrated distance, the higher the hardness value", of ice cream containing SPI was observed to be considerably higher than the control ice cream (Table 1). The highest hardness was observed in 50% SPI ice cream, which equal to that with 75 and 100% SPI ice cream samples. This may be attributable to the high water-holding and binding capacity of SPI, causing the formation of a gel-matrix which in turn results in a more stable product (El-Nagar et al., 2002). Yao et al. (1988) reported that the water absorbed by soy protein was physically held within a protein matrix and difficult to remove from the protein mass. As a consequence, the increased hardness observed within SPI added samples can be related to gelling property of SPI, resulting in decreased rates of ice crystallization. Muse and Hartel (2004) stated that hardness in ice cream is influenced by a number of factors including ice phase volume, ice crystal size, overrun, fat destabilization and the rheological properties of the mix.

**Table 1** Physical properties[1/] of ice cream formulations.

| Ice cream[2/] | pH | Viscosity ($\times 10^3$ cps) | Penetro-meter value (mm/10) | Overrun (%) | CIE color scale[3/] | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | L* | a* | b* | Hue | Chroma |
| Control | 6.15a | 1.20a | 336.67c | 4.23c | 85.69e | -1.16e | 15.53a | 85.73c | 15.57a |
| 25% SPI | 6.22ab | 1.64a | 183.11b | 8.51e | 83.18d | -1.98d | 16.64c | 83.2b | 16.76b |
| 50% SPI | 6.25ab | 8.20b | 50.66a | 5.97d | 81.51c | -2.52c | 16.53bc | 81.33b | 16.72b |
| 75% SPI | 6.27ab | 8.24b | 47.00a | 3.92b | 80.18b | -2.98b | 16.25bc | 79.61ab | 16.52b |
| 100% SPI | 6.34b | 8.88b | 40.89a | 2.44a | 78.96a | -4.18a | 16.86c | 76.08a | 17.37c |

[1/] a, b, c, d, e.. Means in the same column with different superscripts are different (P<0.05).

[2/] Control = no soy protein isolate added, and 25, 50, 75 and 100% are the soy protein isolate substitution levels for skimmed milk powder.

[3/] CIE color scales: L* = lightness (0 = black, 100 = white), a* = redness / greenness (+ = red, – = green), b* = yellowness / blueness (+ = yellow, – = blue).

There were significant differences (P<0.05) in overrun among ice cream samples, as evidence in Table 1. Ice cream samples with 25 and 50% SPI substitution showed higher (P<0.05) overrun than the control, while other samples were lower (P<0.05). The 25% SPI ice cream had the highest overrun, which was probably due to foaming capacity of SPI leading to enhanced air bubbles, resulting in excess volume of the frozen sample. As the SPI level increased more than 50% substitution, it caused a more viscous gel matrix, which may affect air incorporated during the freezing process, providing ice cream samples with decreased overrun.

Color differences among ice cream samples with different levels of SPI substitution were observed by instrumental analysis. The 100% SPI ice cream had a significant lower L* value (P<0.05), indicating that the sample was more dark in comparison to that of the control. The addition of SPI would increase amine compounds, which react with aldehydes via Maillard reaction to form dark pigments (melanoidins) (Alais and Linden, 1991). Values for a*, which signify red (+) and green (-) and b*, which signify yellow (+) and blue (-), were increased with increasing levels of SPI substitution, demonstrating added SPI samples were more green and yellow color. This could be attributable to the color difference between skimmed milk powder (white color) and SPI (light brown color). Hue values also revealed that ice cream color would become more brownish green with increased SPI. The increase in chroma values of added SPI ice cream samples could be mainly due to the increase in green color (-a* values).

When considering melting property, the increment in viscosity appeared to be related to meltdown properties of ice cream samples containing SPI (Figure 1). The control ice cream was observed to be the fastest melting ice cream while the 100% SPI substitution ice cream was the lowest. This result indicated that increased addition of SPI reduced melting rates of ice cream samples, probably due to the liquid binding property of SPI to form a stable gel network, which immobilized the water molecules to move freely among other molecules of the mix. This was in agreement of the work of El-Nagar et al. (2002) who reported that inulin may act as a stabilizer because of its water-binding capacity to reduce the freedom of movement of water molecules, resulting in the reduction of melting characteristics of ice cream products. Kaya and Tekin (2001) reported that the increase in viscosity values increased the resistance of the ice cream to melting.

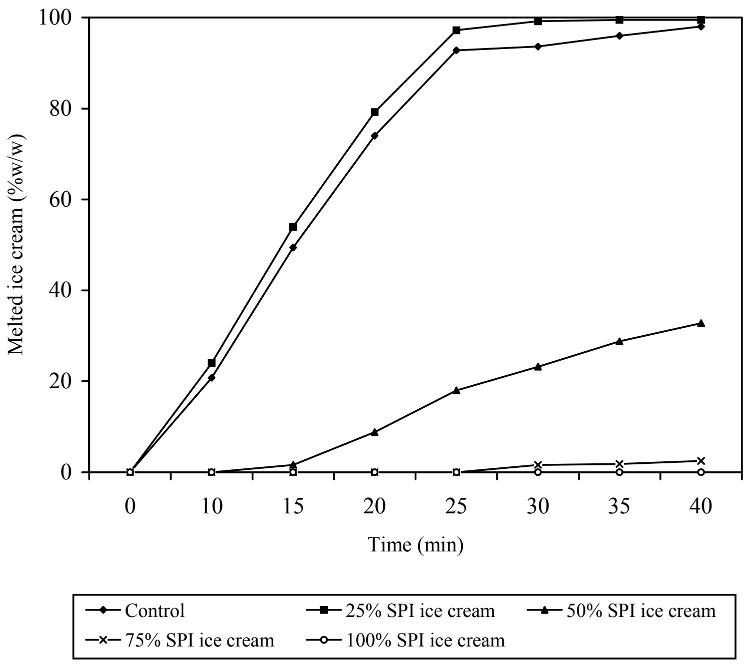


**Figure 1** Melting properties of soy added ice cream samples. (Control = no soy protein isolate (SPI) added; Sample 1-4 represent 25, 50, 75 and 100% added SPI, respectively).

**Sensory Evaluation**

Sensory results of low-fat ice cream samples with different levels of SPI presented in Table 2 shows significant differences ($P<0.05$) for smoothness and gumminess among all samples. When the SPI substitution was increased, the samples were significantly rated in lower ($P<0.05$) scores for smoothness, but higher ($P<0.05$) scores for gumminess. Thus, sensory descriptions of these added SPI ice cream samples were coarse and thick, while the control ice cream was perceived more positively, with a smoother and thinner texture. However, panelists could not determine any differences between control and samples with 50% SPI or less in terms of smoothness and gumminess. Correlation coefficients between the sensory and physical parameters shown in Table 3 presents that sensory smoothness and gumminess highly correlated ($P<0.01$) with objective viscosity and penetrometer value parameters. The maximum level of 50% SPI substitution can be used in ice cream production without any body and texture defect. Based on nutritional benefit, this product contained SPI about 2.3 g 100 $g^{-1}$, showing that it can be claimed as "a good source" of soy protein.

## Conclusions

The substitution of skimmed milk powder with SPI has significant effects on viscosity, texture, meltdown and sensory properties of ice cream samples. An increase in SPI concentration appeared to produce more hard, viscous and resistant to meltdown ice cream samples. For practical application, 50% SPI substitution seems to produce an ice cream demonstrating sensory attributes similar to the control. Further work is needed to better understand how's about SPI mechanism in ice cream systems. The addition of ice cream with SPI may provide an acceptable way to introduce additional soy protein to consumers.

**Table 2** Sensory scores of ice cream formulations.

| Ice cream[1/] | Sensory score[2/] | | |
|---|---|---|---|
| | Smoothness | Gumminess | Iciness |
| Control | 5.87[3/] | 3.97a | 3.99 |
| 25% SPI | 5.82b | 4.45a | 3.14 |
| 50% SPI | 5.47ab | 5.08ab | 3.41 |
| 75% SPI | 4.14a | 5.41b | 3.66 |
| 100% SPI | 4.01a | 6.47b | 3.64 |

[1/] Based on a 13-cm unstructured line scale test (0 = none, 10 = strong).
[2/] Control = no soy protein isolate added, and 25, 50, 75 and 100% are the soy protein isolate substitution levels for skimmed milk powder.
[3/] a, b, c, d, e.. Means in the same column with different superscripts are different ($P<0.05$).

**Table 3** Pearson correlation coefficient of sensory attributes and physical analyses of ice cream samples with different levels of SPI substitution.

| Physical parameter | Sensory attribute | |
|---|---|---|
| | Smoothness | Gumminess |
| Viscosity | -0.803** | 0.866** |
| Penetrometer value | 0.731** | -0.838** |

**Correlation is significant at the 0.01 level (2-tailed).

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