ARTICLE

Studies on Physical and Sensory Properties of Premium Vanilla Ice Cream Distributed in Korean Market

Mi-Jung Choi[1] and Kwang-Soon Shin*

Department of Food Science and Biotechnology, Kyonggi University, Suwon 443-760, Korea
[1]Department of Bioresrouces and Food Science, Konkuk University, Seoul 143-701, Korea

Abstract

The object of this study was to investigate the difference in physical and sensory properties of various premium ice creams. The physical properties of the various ice creams were compared by manufacturing brand. The water contents of the samples differed, with BR having the highest value at 60.5%, followed by NT and CS at 57.8% and 56.9%, respectively. The higher the water content, the lower Brix and milk fat contents in all samples. The density of the samples showed almost similar values in all samples ($p>0.05$). The viscosity of each ice cream had no effect on the water content in any of the brands. Before melting of the ice cream, the total color difference was dependent on the lightness, especially in the vanilla ice cream, owing to the reflection of light on the surface of the ice crystals. The CS product melted the fastest. In the sensory test, CS obtained a significantly higher sweetness intensity score but a lower score for color intensity, probably due to the smaller difference in total color, by which consumers might consider the color of CS as less intense. From this study, the cold chain system for ice cream distribution might be important to decide the physical properties although the concentration of milk fat is key factor in premium ice cream.

Keywords: physical properties, premium ice cream, sensory test

Introduction

Ice cream can be defined as a smooth, sweet, cold dessert food prepared from a frozen mixture of milk products and flavorings, containing a minimum of 10% milk fat (Karaman *et al*., 2014). The mixture is homogenized after pasteurization and aged to improve the physical properties before the freezing process. Ice cream is a representative frozen dairy product enjoyed by people of all ages due to its cooling effect in the mouth. Nowadays, manufacturers continue to develop formulations of ice cream mixtures according to consumer demands, resulting in the creation of various brand names (Sun-Waterhouse *et al*., 2013).

In the Korean ice cream market, there are a number of ice cream names depending on the ice cream company, each of which has their formulations as well. Many studies are present in the journal literature about the creation of new ice cream formulations (Dervisoglu, 2006; Dervisoglu and Yazici, 2006; Karaman and Kayacier, 2012). Nevertheless, vanilla ice cream has been the most representative of the consumer's preference for a long time (Bodyfelt *et al*., 1988; Buck *et al*., 1986).

The grade of ice cream depends on the amount of milk fat content. Generally, ice creams containing more than 12% are recognized as premium level. Milk fat is of importance in qualifying ice cream because it is closely related with the flavor and texture of the ice cream (Li *et al*., 1997). Milk fat acts as a thermal insulator which affects the melting process of ice cream. In general, ice cream containing high milk fat content could take a longer time to melt, so it has potential advantages in handling during high storage temperature.

Ice crystals also play a key role in the sensorial properties of ice cream. Ice creams with small ice crystals have softer texture, also minimizing the recrystallization during frozen storage (Arbuckle, 1966; Flores and Goff, 1999). The formation of ice crystals is dependent not only on the compositions of the ice cream, but also on the freezing temperature (Arbuckle, 1977; Trgo *et al*., 1999).

In order to evaluate the quality of frozen food, the qual-

*Corresponding author: Kwang-Soon Shin, Department of Food Science and Biotechnology, College of Natural Sciences, Kyonggi University, Suwon 443-760, Korea. Tel: +82-31-249-9655, Fax: +82-31-249-9655, E-mail: ksshin@kyonggi.ac.kr

ity is evaluated after the thawing and cooking process to analyze the physical properties. For that reason, it is hard to evaluate the actual quality of food in the frozen state. In general, ice cream, which contains milk fat, MSNF (milk solids not fat), sugars, emulsifier and stabilizer, is consumed in the frozen state, and the quality is strongly related to the physical properties (Arbuckle, 1986). According to Glickman (1991), hydrophilic gums as a stabilizer bind water molecules directly or entrap them inside the gel matrix, which reduces the amount of free water. Therefore, they provide soft texture and resistance against heat shock, and contribute to maintaining the body while delaying melting.

Owing to technological development, many premium level ice creams are now being commercially produced. Physical and rheological properties are crucial factors for consumers to evaluate the quality of ice cream. Therefore, this study was conducted to evaluate the physical and sensory properties of premium vanilla ice creams produced by specific brands in Korea, and to provide baseline data for improving the crucial factors of the ice cream related to physical and rheological properties.

Materials and Methods

Materials

In this study, premium level vanilla ice cream was purchased from CS, BR, and NT companies, respectively. Each selected ice cream was manufactured on different dates. The order of preparation was CS, NT, and BR. Each sample was formed for experimental purposes and kept at -70ºC. The experimental analysis was performed on the same day for all the samples although the manufacturing dates were different. All experiments were repeated on the 3 different days for determination (n=3).

Methods

Water content

The water content was determined by the method of AOAC (1995). Two gram aliquots of the samples were put into a bottle and dried for 24 h at 105ºC. Water content was calculated as the difference of water weight before and after drying.

Brix

Brix of molten ice cream was determined via refractometer (Portable refractometer C-2 REF-104, SPECTRO-LAB, England) at room temperature.

Milk fat content

The milk fat content was determined by the method of Soxhlet extract (Soxhlet extractor Ser148, VELP, Italy).

Density

In order to estimate the overrun, the weight of 30 mL of molten ice cream was determined at 25ºC under atmospheric pressure and the density of milk was calculated.

Viscosity

The viscosity of molten ice cream was determined by a rotational viscometer (Visco star-L, J. P. SELECTA, Spain) using Spindle L2. The temperature of the sample was fixed at 4ºC and spindle 1 rotated at 200 rpm.

Color

The color of the frozen ice cream was measured using a spectrocolorimeter (CR 400, Minolta Co., Japan) calibrated with a white plate and light trap supplied by the manufacturer. Color was expressed using the CIE L*, a*, b* color system (CIE, 1976). The total color difference was calculated using the equation below.

$$\text{Total color difference} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

Melting time

The heat shock resistance of the ice cream was determined by using a self-manufactured system (Fig. 1). The melting time of one hundred grams of ice cream kept at 20ºC to melt completely in the chamber was measured. Here, the initial temperature of the ice cream was set to be -70ºC. The onset melting time of ice cream was initiated at the point of weight change. During the melting process, the weight of the ice cream was determined every 1 min.
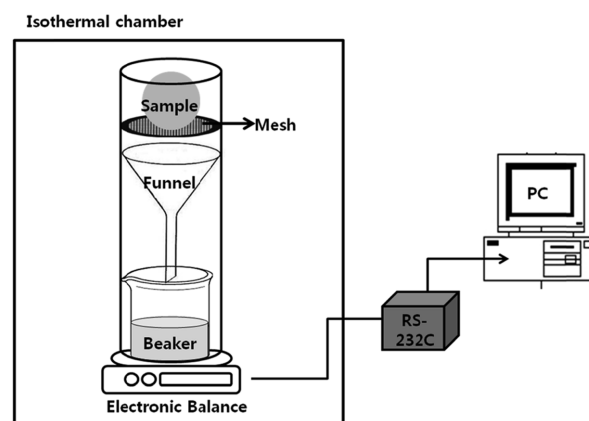

Fig. 1. The lab-manufactured apparatus for the determination of melting time of ice cream.

Sensory test

The samples were served to 10 experienced panel members. The determination was carried out in duplicate by the sensory panelists. The color, aroma, ice crystal size, retention of air bubbles, hardness and sweetness (1=extremely undesirable, 5=extremely desirable) were evaluated using a 5-point descriptive scale. The panelists were required to cleanse their palate between samples with water.

Statistical analysis

Analysis of variance was performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package (1999). The Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

Results and Discussion

Water content

The water content of each sample is shown in Fig. 2. The water contents of the ice cream from CS, BR, and NT were 56.9, 60.5, and 57.9%, respectively. The ice creams contained water contents approximately around 55-60%. The water content of the BR ice cream was the highest among the samples ($p<0.05$). In general, ice cream mix containing a low amount of total solids (high water content) has proportionately more water to freeze than that containing a higher amount of total solids (low water content) when hardened at the same storage temperature (El Owni and Zeinab, 2009).

Brix

The Brix of each sample is shown in Fig. 3. The highest content of sugar was found in the CS company brand, at
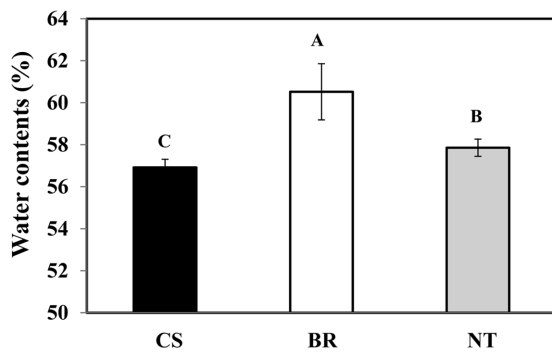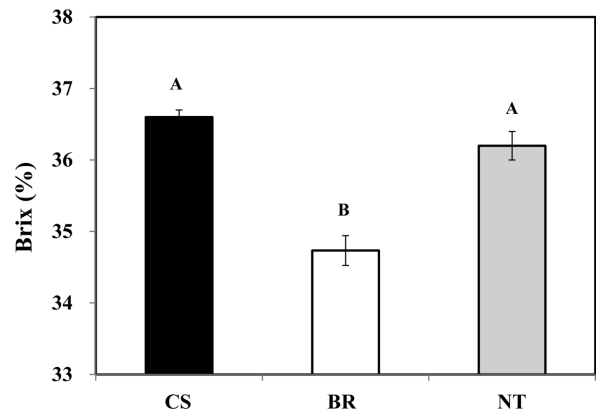

Fig. 3. Brix of various premium vanilla ice creams. Different letters indicate significant differences between samples.

36.6%. The Brix of NT and BR ice cream was 36.2% and 34.7%, respectively ($p<0.05$). However, there were no significant differences between the CS and NT ice creams ($p>0.05$). It was supposed that Brix decreased as the water contents increased. According to the authors, a greater extent of total solid contents increases the resistance to flow of the serum phase as ice melted, which leads to slower meltdown. On the other hand, ice creams with low levels of total solid content (up to 30%) melted quickly (Silva Junior and Silva Lannes, 2011).

Milk fat content

The milk fat content is presented in Fig. 4. The milk fat content of CS, BR, and NT ice cream was 13.6, 12.7 and 13.54%, respectively. The three samples contained approximately 12-14% milk fat. Among the samples, BR contained the lowest value ($p<0.05$). From these results, it could be seen that as the water content rose, the milk fat content lowered.
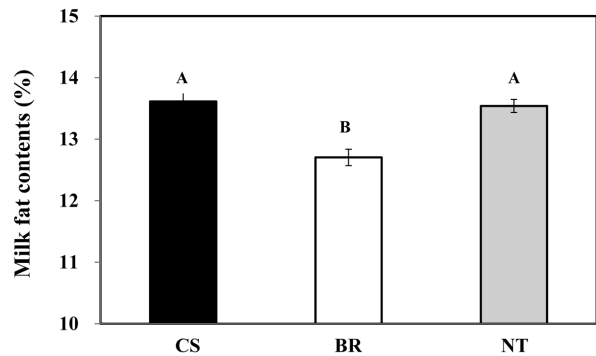

Fig. 2. Water contents of various premium vanilla ice creams. Different letters indicate significant differences between samples.

Fig. 4. Milk fat contents of various premium vanilla ice creams. Different letters indicate significant differences between samples.

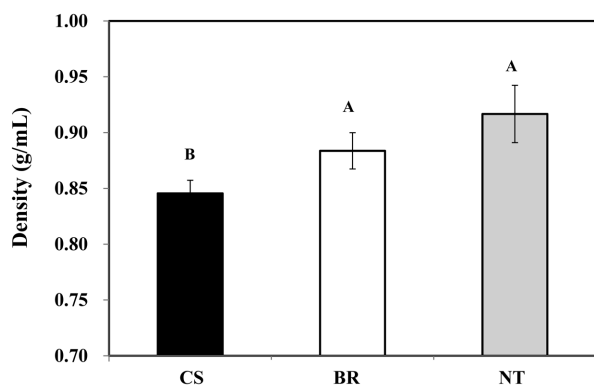**Fig. 5. Density of various premium vanilla ice creams.** Different letters indicate significant differences between samples.
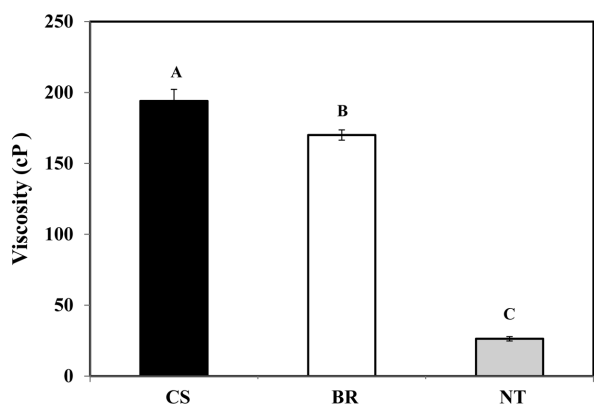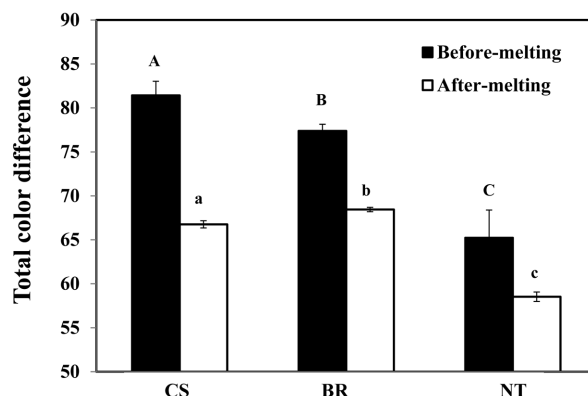

Fig. 7. Total color difference of various premium vanilla ice creams. Different letters within the same bar indicate significant differences between samples.

Fig. 6. Viscosity of various premium vanilla ice creams. Different letters indicate significant differences between samples.

Density

The densities of the samples are shown in Fig. 5. The densities of CS, BR, and NT ice creams were 0.846 g/mL, 0.884 g/mL, and 0.917 g/mL, respectively. The density of CR ice cream was significantly lower than the other samples ($p<0.05$). However, there were no significant differences between BR and NT ($p>0.05$). Therefore, it was assumed that the density of ice cream depends on the water content. In addition, the overrun time of CS was thought to be higher than the others, causing higher contents of air cells by air injection time. Normally, the dispersed air cells in the ice cream significantly affect the qualities of ice cream such as the soft mouthfeel of the product (Park *et al.*, 2006).

Viscosity

The viscosities of the samples are displayed at Fig. 6.

The viscosities of CS and BR ice cream were 198 cP and 170 cP. Exceptionally, the viscosity of NT ice cream was 26.3 cP. These values presented significantly differences among the samples ($p<0.05$). As considered in the previous results, it was supposed that the viscosity of ice cream could be dependent not on water content, but on the addition of a thickening agent or other stabilizer.

Total color difference

Based on the measurement of lightness, redness and yellowness, the total color differences were calculated and shown in Fig. 7. The total color difference of CS ice cream was 81.4 at the highest value before melting, followed by BR and NT ice cream at 77.3 and 65.2. Similarly, the total color differences of CS, BR, and NT samples were 66.7, 68.4 and 58.5 after melting. The main factor determining the color properties of vanilla ice cream is the lightness value, as compared to redness or yellowness. Furthermore, the value of lightness presented the highest value since light reflects on the surface of ice crystals before melting of the ice cream. In general, the color of the ice cream increased in whiteness as the fat content increased (Roland *et al.*, 1999), namely, by the different brand names. However, a relationship between the fat content and whiteness intensity in the ice cream was not observed herein due to the different water contents.

Melting time

The melting ratio as a function of time is shown in Fig. 8, and the parameters estimated in the melting curve are depicted in Fig. 9. The onset point of melting was found at 67.3 min for BR, which was significantly longer than
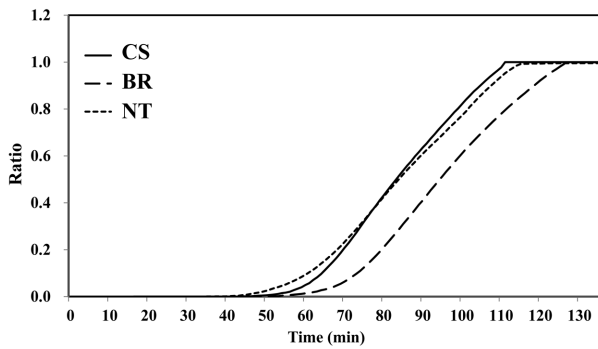
Fig. 8. Melting ratio of various premium vanilla ice creams as a function of time; (y: Molten ice cream weight (g) per total ice cream weight (g), x: melting time (min)).
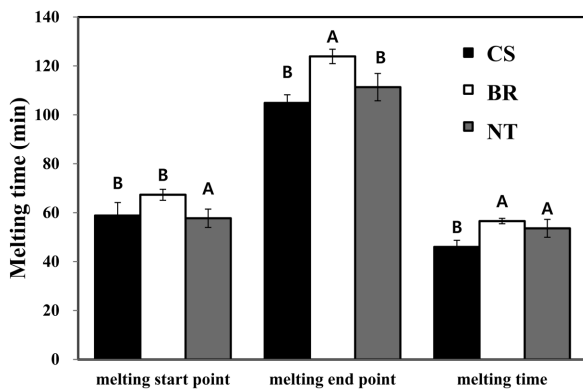

Fig. 9. Comparisons of melting profiles of premium vanilla ice creams. Different letters within the same bar indicate significant differences between samples.

the 58.8 min for CS and 57.7 min for NT ($p<0.05$). Furthermore, the end point of BR melting was estimated at 121.5 min, which was also significantly later compared to the 104.9 min of CS and 111.3 min of NT ($p<0.05$). The CS product had a significantly shorter overall melting time than the BR and NT products.

Based on the statistical analysis, the overall melting time of BR and NT did not differ from each other, though BR took more time to begin melting comparing to the NT product. Consequently, melting was delayed in the order of BS, NT and then CS products. This order of melting was reversely proportional to the contents of milk fat.

A possible explanation was suggested in that more time was required to begin melting when the ice cream contained more water content. Based on the fact that the melting point of milk fat is relatively low, it is possible that NT and CS, which contained higher amounts of milk fat, began melting more quickly than BR. Another explanation is that the NT product had a relatively low viscos-

ity, which is evidence that it likely contained lower amounts of stabilizer. This would result in the short starting point of melting. However, while NT began to melt earlier than CS, it had a similar end point, reflecting that the water content of CS was lower than NT. Consequently, these factors would lead to the quick melt of the CS product.

In general, the melting properties of ice cream are known to be influenced by the fat content. According to Roland *et al.* (1999), increase of the fat content of ice cream from 7 to 10% caused an increase in the half-life of the ice cream. They noted that the melting results corresponded to the hardness determinations, i.e., while there were no changes for the 0.1, 3, or 7% samples, significant difference occurred when the percentage of fat was increased from 7 to 10% milk fat. Although the melting time and sample hardness were not significantly different among the 0.1, 3, and 7% fat samples of ice cream in that study, the characteristics of the lower fat ice creams differed from those of the 10% fat samples. In our study, although there were no significant differences in the melting time due to fat contents, the onset temperature of melting of the BR ice cream, containing relatively lower fat content, appeared earlier than the others. Based on these analyses, the BR ice cream contained higher water content and lower Brix, resulting in the earlier starting time of ice cream melting. It appears from these results that the onset of melting of BR ice cream, which contains lower fat, was later than the other ice creams. This seems to be opposite to the results obtained by Roland *et al.* (1999). In general, the quality of ice cream is characterized by hardness, melting properties, air entrapment, and ice content (Roland *et al.*, 1999). However, no significant relationship between fat content and the physical properties of ice cream was found in this study.

Sensorial properties of premium ice cream

The sensorial properties of the premium ice creams are given in Fig. 10. For color intensity, both BR and NT measured 3.3 and 3.8, which was significantly higher intensity compared to the 2.4 of CS ($p<0.05$). The vanilla flavor intensities of all products were from 2.7 to 3.4, whereas the intensities did not significantly differ with one another. Ice crystal content tended to be high in NT and low in CS, although the difference was not significant. Overrun intensities (texture) and hardnesses were similar for all products. For sweetness, CS scored higher than BR and NT ($p<0.05$), while no difference in sweetness between BR and NT was obtained.
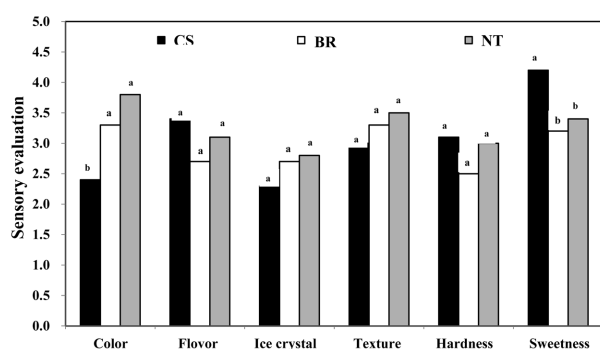
Fig. 10. Sensory evaluation of various premium vanilla ice creams (5-point scoring method). Different letters within the same bar indicate significant differences between samples.

In the present study, CS obtained a significantly higher sweetness intensity score but a lower score for color intensity, probably due to the smaller difference in total color, by which consumers might consider the color of CS as less intense. The main factor deciding the mouthfeel taste of ice cream is the content of milk fat. Unfortunately, a significant relationship between the ice cream quality measured by sensory test and the fat content among the samples of different brands of ice cream could not be measured. However, based on the analysis of physical properties, the quality of ice cream could be different because of the storage conditions, although we did not trace the cold chain system of each company. For further research, the effect of storage temperature on the recrystallization of different commercial ice creams should be performed to evaluate the mouthfeel taste.

Acknowledgements

References

1. AOAC (1995) Official methods of analysis. 16th ed. Association of Official Analytical Chemists, Washington, USA., p. 1141.

2. Arbuckle, W. S. (1966) Relation of freezing and gardening to the body and texture of ice cream. *Ice Cream Field Trade J.* **148**, 34.

3. Arbuckle, W. S. (1977) Ice cream, 3rd ed. AVI Publ. Co. Westport, CT.

4. Arbuckle, W. S. (1986) Ice cream, 4th ed. Van Nostrand Reinhole, New York.

5. Bodyfelt, F. W., Tobias, J., and Trout, G. M. (1988) Sensory evaluation of ice cream and related products, F. W. Bodyfelt, J. Tobias, G. M. Trout (ed), The sensory evaluation of dairy products, Van Nostrand Reinhold, NY, pp. 166-226.

6. Buck, J. S., Walker, C. E., and Poerce, M. M. (1986) Evaluation of sucrose esters in ice cream. *J. Food Sci.* **51**, 489.

7. CIE (1976) Official recommendations on uniform color spaces color difference equations and metric color terms, Suppl. No. 2. CIE (Commission International de l'Éclairage) Publication No. 15 Colorimetry, Paris, France.

8. Dervisoglu, M. (2006) Influence of hazelnut flour and skin addition on the physical, chemical and sensory properties of vanilla ice cream. *Int. J. Food Sci. Technol.* **41**, 657-661.

9. Dervisoglu, M. and Yazici. F. (2006) The effect of citrus fibre on the physical, chemical and sensory properties of ice cream. *Food Sci. Technol. Int.* **12**, 159-164.

10. El Owni, O. A. O. and Zeinab, K. O. K. (2009) Chemical composition of ice cream produced in Khartoum state, Sudan. *Pakistan J. Nutr.* **8**, 158-160.

11. Flores, A. A. and Goff, H. D. (1999) Ice crystal size distributions in dynamically frozen model solutions and ice as affected by stabilizers. *J. Dairy Sci.* **82**, 1399-1407.

12. Glickman (1991) The special problems of freezing ice cream. In "Food Freezing: Today and Tomorrow". Bald, W.B.(Ed.) Springer-Verlag. London. Berlin. Heidelberg, NY, USA.

13. Karaman, S. and Kayacier. A. (2012) Rheology of ice cream mix flavored with black tea or herbal teas and effect of flavoring on the sensory properties of ice cream. *Food Bioprocess Technol.* **5**, 3159-3169.

14. Karaman, S., Toker, Ö. S., Yüksel, F., Çam, M., Kayacier, A., and Dogan, M. (2014) Physicochemical, bioactive, and sensory properties of persimmon-based ice cream: Technique for order preference by similarity to ideal solution to determine optimum concentration. *J. Dairy Sci.* **97**, 97-110.

15. Li, Z., Marshall, R., H., and Fernando, H. L. (1997) Effect of milk fat content on flavor perception of vanilla ice cream. *J. Dairy Sci.* **80**, 3133-3141.

16. Park, S. H., Hong, G. P., Kim, J. Y., Choi, M. J., and Min, S. G. (2006) The influence of food hydrocolloids on changes in the physical properties of ice cream. *Food Sci. Biotechnol.* **15**, 721-727.

17. Roland, A. M., Phillips, L. G., and Boor, K. J. (1999) Effects of fat content on the sensory properties, melting, color and hardness of ice cream. *J. Dairy Sci.* **82**, 32-38.

18. SAS (1999) SAS/STAT Software for PC. Release 6.11, SAS Institute, Cary, NC, USA

19. Silva Jr., E. and Silva Lannes, S. (2011) Effect of different sweetener blends and fat types on ice cream properties. *Ciênc. Technol. Aliment.* **31**, 217-220.

20. Sun-Waterhouse, D., Edmonds, L., Wadhwa, S. S., and Wibisono, R. (2013) Producing ice cream using a substantial amount of juice from kiwifruit with green, gold or red flesh. *Food Res. Int.* **50**, 647-656.

21. Trgo, C., Koxholt, M., and Kessler, H. G. (1999) Effect of freezing point and texture regulating parameters on the initial ice crystal growth in ice cream. *J. Dairy Sci.* **82**, 460-465.