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Influences of Storage Temperature and Periods on the Physical Properties of Ice Cream

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Introduction

Ice cream is a complex food colloid system containing fat globules, air cells and ice crystals dispersed in a freeze−concentrated dispersion/solution of proteins, salts, food hydrocolloids and sugars (Goff *et al.*, 1999). It is generally accepted that quality of ice cream is mainly influenced by a smooth texture without detectable ice crystals (Marshall & Arbuckle, 1996). Especially, storage conditions of temperature and periods have large influence on qualitative and sensorial aspects of ice cream. Min *et al.* (1994) proposed that ice recrystallization and growth are influenced by frozen storage temperature, associated with a quality of frozen food. Park *et al.* (2006) reported the ice recrystallization phenomena in the freeze concentration process, influenced by temperature variation and recrystallization time. In this view, this study was conducted to elucidate the influence of storage temperature and periods on various physical properties of ice cream through ice crystal size, viscosity, melt resistance and color value.

Materials and Methods

1. Frozen Storage

Commercial ice creams, immediately produced from the processing unit, were frozen stored at −18, −30, −50 and −70℃ for 4, 8, 12, 16 and 28 weeks.

2. Ice Crystal Size Analysis

Ice crystal size was measured by the organic solvent extraction method proposed Min et al. (1997). After placing 0.5 g on the pre−cooled slide glass (−50℃), ice crystals were separated from ice cream using organic solvent of hexane and kerosene mixture (10:90, v/v), pre−cooled in the deep freezer before use. The temperature of ice crystal sample was constantly maintained with deep frozen box and cold tray connected with cryostat (RBC−11, JEIO TECH, Seoul, Korea). The cryopolarizing microscope (CX40, Olympus, Tokyo, Japan) and CCD camera (VC45CSHR−12, Olympus, Tokyo, Japan) were located in the cold chamber (−50℃) in order to prevent the melting of ice crystals during measurement. Digitalized image of ice crystal was transmitted to external logging system and analyzed with the image analysis program (Image Tool 3.0, UTHSCSA, Austin, TX, USA), respectively. For a statistical analysis, more than 100 ice crystals were analyzed.

3. Melt Resistance, Flow Behavior and Colour

Melt resistance was determined with melting time of 100g sample in the incubator of 25 ℃. Flow behavior was measured with rotational viscometer (VISCO STAR−L. J.P. Selecta S.A., Abrela, Spain) at 25℃. Color measurement was taken with Colorimeter (CR−10, Minolta, Osaka, Japan). CIELAB L*, a*, and b* value were determined as indicators of lightness, redness, and yellowness, respectively

Results and Discussion

1. Ice Crystal Size

Fig. 1 showed that changes in ice crystal size according to storage temperature and periods. Microscopic images of ice crystal were compared among each storage temperature after 28 weeks (Fig. 2).

Higher storage temperature resulted in more growth of ice crystals in the frozen storage. Maximum ice crystal size of 96.47 μm was observed at the storage temperature of −18℃

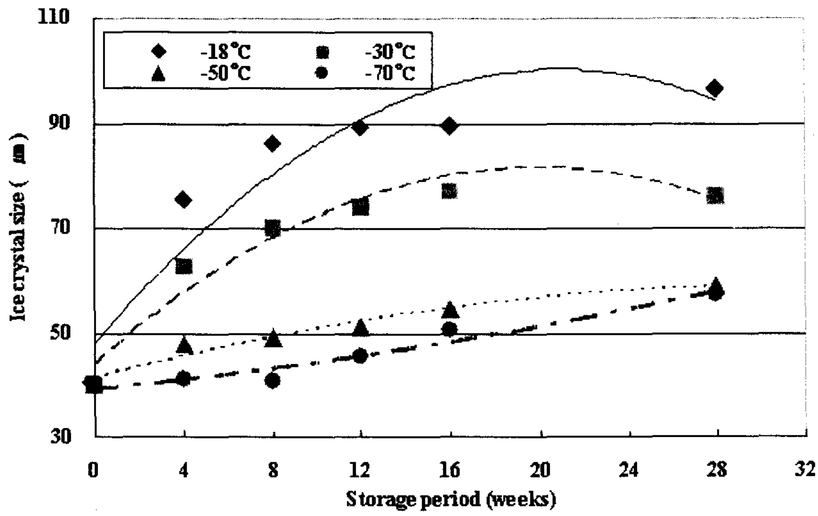

Fig. 1. Changes in ice crystal size according to storage temperature and period.

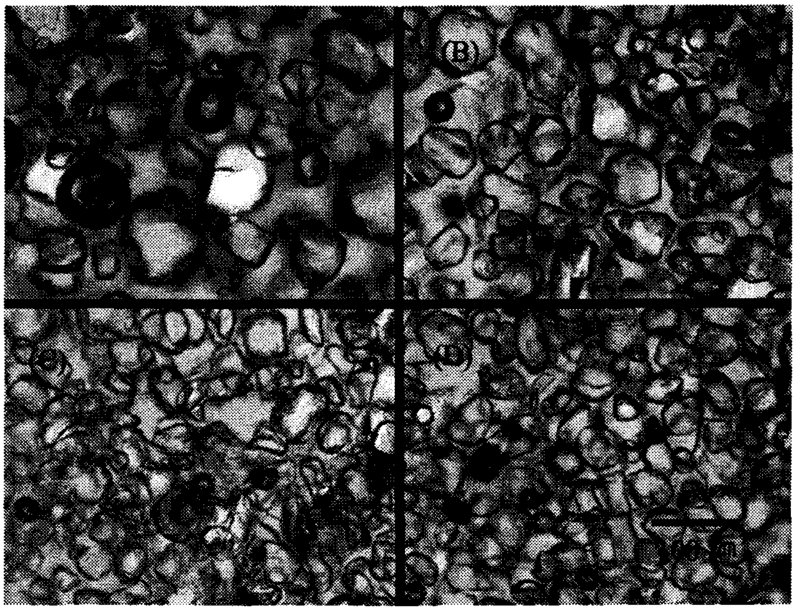

Fig. 2. Microscopic images of ice crystals at each storage temperature after 28 weeks.
(A): −18℃ storage, (B): −30℃ storage, (C): −50℃ storage, (D): −70℃ storage

after 28 weeks storage. Min *et al.* (1997) proposed that the critical ice crystal of commercial ice cream is 55 μm. In this research, samples stored at −18 and −30℃ exceeded this criterion after 4 weeks storage, indicating undesirable influence on consumers' sensorial appeal. Whereas, storage conditions of −50 and −70℃ maintained the smaller ice crystals than critical size up to 16 weeks. It is postulated that higher storage temperature enhanced the recrystallization of ice crystal, resulting in the increment of ice crystal size. These results were in accordance with the research of Donhowe and Hartel (1996). In our research, higher growth rate was observed in the initial storage period, representing similar results with that of Ben−Yoseph and Hartel (1998). It is reco−mmended that storage temperature of ice cream should be lesser than −30℃ to preserve sensorial quality associated with size and distribution of ice crystals.

2. Melt Resistance and Viscosity

High storage temperature and elapse of storage period resulted in pure melt resistance with short melting time (Table 1).

Viscosity represented the inverse correlation with melting time. In this research, low storage temperature has a beneficial influence on shape retention of ice cream, one of important factors in consumers' appeal. Significant increment of viscosity was observed at the storage temperature of −18℃ after 4 weeks, influencing an exceptional increase in melting time. This phenomenon was postulated that higher storage temperature induced enhanced fat destabilization through coalescence phenomena. If the fat globules are very

Table. 1. Influence of storage temperature and period on melt resistance and viscosity

	Storage periods (week)											
	0		4		8		12		16		28	
Temperature (℃)	MT	V	MT	V	MT	V	MT	V	MT	V	MT	V
−18			105	85	93	190	93	182	180	165	176	171
−30	131	13	109	35	95	26	92	24	118	26	182	55
−50			122	23	120	18	123	18	124	12	132	28
−70			129	21	129	17	124	18	176	20	133	31

MT: Melting time, V: Viscosity

unstable, structural collapse may cause coalescence, in which case the structure measurements may not actually represent conditions seen in the frozen system (Goff *et al.*, 1999).

3. Colour Value

Changes in color of frozen ice cream (Fig. 3) were represented by total discoloration (ΔE), calculated with Eq. 1. ΔE increased with elapse of storage time and increase in storage temperature. In the research of Roland *et al.* (1999), color value was influenced by fat content. In our research, it is postulated that discoloration of ice cream was influenced by fat destabilization, similar to viscosity and melt resistance results. Therefore, it is recommended that low storage temperature is desirable for the retention of color value of ice cream.

Eq. 1

$$\triangle E-value=\sqrt{(L-L')^2+(a-a')^2+(b-b')^2}$$

L, a, b: each colour value of control, L', a', b': each colour value of concentrated milk

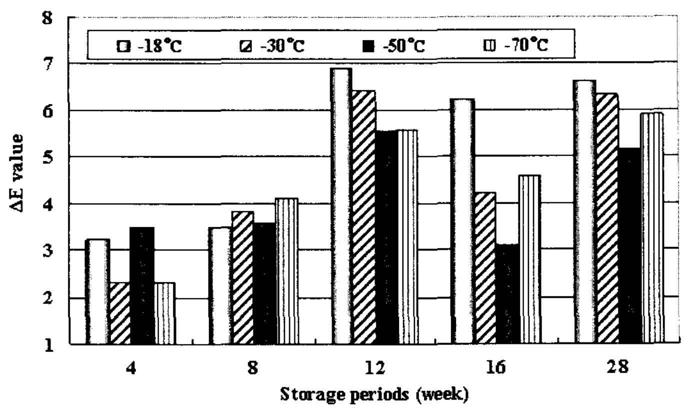

Fig. 3. Changes in total discoloration influence by storage temperature and periods.

Summary

In this research, storage temperature and periods had significant influence on the physical properties of ice cream. Lower storage temperature reduced the ice re-crystallization and discoloration of ice cream. Increased melt resistance was observed at the lower storage temperature, inducing a good shape retention of ice cream.

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