The Influence of Hydrocolloids on Storage Quality of 10% Dairy Fat Ice Cream

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Abstract. In the present study, texture and flavour attributes were used to evaluate hydrocolloids (guar gum, carrageenan, xanthan gum and locust bean gum) and their blends on the crystallization of ice cream during a 13 month storage period. Only certain stabilizers retard ice crystal growth. Guar gum and xanthan gum blends attained the better stabilizing effect, improving textural and taste quality. Locust bean gum and carrageenan blends remarkably deteriorated ice cream shelf life.

Key words: crystallization, hydrocolloids, ice cream

INTRODUCTION

Ice cream is a frozen dessert made from dairy products. It is a complex colloidal system consisting of air cells, ice crystals and fat droplets dispersed into serum phase. The functionality of hydrocolloids in ice cream is related to cryoprotection – hindrance of the re-crystallization phenomena, enhancement of ice cream mixes viscosity, improvement of texture and mouthfeel as well as shape retention (Marshall et al., 2003). The quality of frozen foods is influenced by the size and number of ice crystals produced during freezing. The formation of large ice crystals affects sensory properties and texture of frozen foods. During storage several physical and chemical changes occur in ice cream. Growth of crystals during storage, or re-crystallization, is one of the important physical changes because ice crystal size has a strong effect on the texture of ice cream. Proper control of the formation and growth of ice crystals in the ice cream freezer results in a large number of small crystals, which in turn produces smooth texture and good storage stability (Hagiwara & Hartel, 1996).

Each individual hydrocolloid has a particular effect on texture and stability during storage. Guar gum is comprised of a galactomannan polysaccharide made up of a backbone of mannose with single branched galactose units similar in structure to locust bean gum. Carrageenan is derived from an extract of red algal seaweed and is a polymer of galactose with a sulphate ester content of 20% or more. Xanthan is a bacterial exopolysaccharide produced by the growth of *Xanthomonas campestris* in the culture. Xanthan structure is comprised of a main chain of glucose and every other glucose unit has attached to it a trisaccharide side chain consisting of two mannose units and one glucuronic acid unit (Marshall et al., 2003). The objective of this research was to investigate the influences of different hydrocolloids on the ice cream hardness and sensory properties (softness, flavour) during 13 months of storage time.

MATERIALS AND METHODS

Ice cream preparation

A dairy fat vanilla ice cream was used in the experiments. The ice cream consisted of 10% milk fat (provided as fresh cream 35%, Valio Estonia AS, Estonia), 10.5% milk solids nonfat (whey powder, OÜ Põlva Piim, Estonia), 13% sucrose (Danisco A/S, Denmark), 0.1% vanilla flavour (Rhodia Oertaions, France), 0.2% emulsifier (saturated monoglyceride, Danisco A/S, Denmark) and 0.2% stabilizer. Four hydrocolloids were used as stabilizers including locust bean gum (Danisco A/S, Denmark), kappa/iota carrageenan (Danisco A/S, Denmark), guar gum (Danisco A/S, Denmark) and xanthan gum (Carob, S. A. Spain). The fluid and dry ingredients were mixed at 60°C, homogenized in a double-stage homogenizer (Niro Soavi S.p.A, Italy) with homogenization pressure of 150 bar on the first stage and 400 bar on the second stage. The ice cream mix was then pasteurized up to 85°C for 18 to 20 s and cooled at 5°C for 24 h for aging. The aged ice cream mixes were then frozen using a freezer (Armfield FT25-BA, England) at a set draw temperature −5°C, packed into 500 ml containers and 40 ml plastic cups (Papstar, Germany). The iIce cream hardened at −40°C (Dairei, Japan) for 24 h and was stored at −20°C (Brandt, France). The overall experimental design presents a total of 11 formulations (Table 1).

Table 1. Composition of the 10% vanilla ice cream samples used in the present study.

Sample	Hydrocolloid percentage (%)			
	Locust bean gum (L)	Carrageenan (C)	Guar gum (G)	Xanthan gum (X)
L80C20	0.16	0.04	-	-
L50C50	0.1	0.1	-	-
L20C80	0.04	0.16	-	-
G80X20	-	-	0.16	0.04
G50X50	-	-	0.1	0.1
G20X80	-	-	0.04	0.16
G80C20	-	0.04	0.16	-
G50C50	-	0.1	0.1	-
G20C80	-	0.16	0.04	-
X100	-	-	-	0.2
G100	-	-	0.2	-

Rheometry

The rheological measurements were carried out using a rheometer (Physica MCR301) with plate-plate geometry (diameter 25 mm). Both plates were profiled in order to avoid wall slip. A movable hood covering the plate-plate geometry also prevented heat exchange with the environment. The test was performed at −20°C, constant angular frequency $\omega = 10\ s^{-1}$ and constant strain $\gamma = 0.02\%$. The gap width between the plates was adjusted to a constant value of 2 mm. At least two measurements of each ice cream were carried out. In the oscillation test, storage modulus (G') was measured to characterize the elastic behaviour of measured samples.

Sensory analyses

Six panelists were chosen for the assessment of the sensory attributes of the ice cream samples. Three 1-h sessions were conducted to train the panellists. Each sample was coded using a three-digit random number and served to the panelists in individually partitioned booths. Samples were portioned into 30 ml cups with covers. Softness was evaluated following the 9-point scale where 0 – coarse and 8 – soft. A different definition was used for flavour: 0 – strong off-flavour and 8 – natural flavour.

Statistical analyses

Significant differences were defined at $P < 0.05$. ANOVA was performed to evaluate the effects of the hydrocolloids type and percentage on the ice cream sensory properties (Duncan's mean values comparison test).

RESULTS AND DISCUSSION

At low temperatures (−20°C) the rheological behaviour of ice cream is mainly influenced by the ice fraction and microstructure (mostly air bubbles and fat globules). While air bubbles and fat globules give a foamy and creamy structure to ice cream, the ice fraction correlates well with ice cream hardness (Wilbey et al., 1998), an index of storage modulus (G'). Hardness of ice cream is measured as the resistance of the ice cream to deformation when an external force is applied. Both the ice crystal size and ice phase volume contribute to the hardness of ice cream (Muse & Hartel, 2004).
The influence of different stabilizers and their blends on ice cream storage modulus at −20°C during 13 months of storage is shown in Figure 1. The storage modulus of ice cream samples with guar gum and xanthan gum were the lowest of measured samples while the ice cream with guar gum and carrageenan blends in a ratio of 20:80 had the highest storage modulus. Specifically, no difference was observed among other samples. The storage modulus of all ice cream samples increased during storage time, indicating ice re-crystallization. The result of re-crystallization is usually a product that starts out initially with high quality and ends up with undesirable characteristics. Large ice crystals in ice cream indicate a coarser product. Storage time had a detrimental effect on the textural properties for certain samples. Data demonstrate that the storage modulus of ice creams which consisted of blends of locust bean gum and carrageenan were the highest after 13 months of storage. This might be caused by high κ-carrageenan concentration. κ-carrageenan is usually added in ice cream as a secondary stabilizing agent at levels lower than 0.05% to control phase separation caused by the incompatibility of hydrocolloids with milk proteins (Bourriot et al., 1999; Langendorff et al., 2000; Thaiudom & Goff, 2003). Due to the high κ-carrageenan concentration in the analysed samples, the observed cryoprotection cannot be attributed primarily to the melt-diffuse-regrow mechanism.

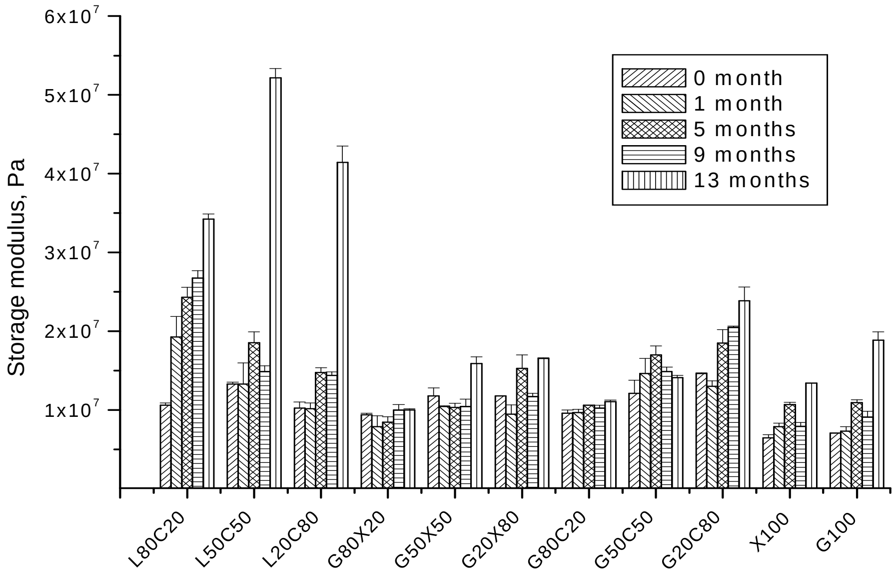

Figure 1. The influence of hydrocolloids and their blends on ice cream storage modulus during 13 months of storage (L – locust bean gum, C – carrageenan, G – guar gum, X – xanthan gum, 100 – 0.2%, 80 – 0.16%, 50 – 0.1%, 20 – 0.04%).

Rheological measurements were confirmed with sensory analyses. The softness of ice creams during storage time is presented in Table 2. All samples were soft after preparing but during storage time the softness decreased. Sensory attribute flavour during storage time is presented in Table 3. All samples had a natural taste that

Table 2. Effect of hydrocolloids and their blends on the sensory attribute softness (mean values) of ice creams during storage time.

Sample[1]	0 month	1 month	5 months	9 months	13 months
L80C20	7.22^{cd}	7.00^{ab}	6.11^{bc}	4.11^{c}	2.22^{d}
L50C50	7.00^{d}	7.00^{ab}	6.11^{bc}	4.11^{c}	2.22^{d}
L20C80	7.22^{cd}	7.00^{ab}	6.67^{ab}	5.78^{b}	2.44^{d}
G80X20	7.78^{abc}	7.56^{a}	6.89^{ab}	7.33^{a}	6.33^{ab}
G50X50	7.89^{ab}	7.89^{a}	7.00^{ab}	7.33^{a}	7.00^{a}
G20X80	7.89^{ab}	6.67^{b}	6.56^{ab}	6.56^{ab}	5.89^{ab}
G80C20	7.44^{abcd}	7.22^{ab}	7.00^{ab}	6.22^{ab}	6.33^{ab}
G50C50	7.00^{cd}	6.67^{b}	6.89^{ab}	6.00^{ab}	6.33^{ab}
G20C80	7.78^{abc}	7.00^{ab}	7.11^{a}	6.11^{ab}	5.00^{bc}
X100	7.33^{bcd}	6.67^{b}	5.44^{c}	5.89^{ab}	5.78^{ab}
G100	8.00^{a}	8.00^{a}	6.22^{abc}	6.00^{ab}	3.78^{cd}

a – d Different letters between the rows indicate significant difference ($P < 0.05$) among the ice cream samples according to Duncan's mean values comparison test.
[1]L – locust bean gum, C – carrageenan, G – guar gum, X – xanthan gum, 100 – 0.2%, 80 – 0.16%, 50 – 0.1%, 20 – 0.04%.

Table 3. Effect of hydrocolloids and their blends on the sensory attribute flavour (mean values) of ice creams during storage time.

Sample[1]	0 month	1 month	5 months	9 months	13 months
L80C20	7.70^{b}	7.20^{b}	7.50^{a}	6.10^{cde}	3.60^{bc}
L50C50	8.00^{a}	7.67^{a}	7.78^{a}	5.67^{de}	2.56^{c}
L20C80	7.70^{b}	7.80^{a}	7.90^{a}	5.10^{e}	3.60^{bc}
G80X20	8.00^{a}	8.00^{a}	7.40^{a}	7.90^{a}	6.00^{a}
G50X50	8.00^{a}	8.00^{a}	7.40^{a}	7.20^{abc}	6.60^{a}
G20X80	8.00^{a}	7.80^{a}	7.30^{ab}	6.30^{cde}	6.20^{a}
G80C20	8.00^{a}	7.80^{a}	8.00^{a}	7.60^{ab}	6.20^{a}
G50C50	8.00^{a}	7.70^{a}	7.80^{a}	7.30^{abc}	5.90^{a}
G20C80	8.00^{a}	8.00^{a}	7.60^{a}	6.50^{bcd}	5.60^{ab}
X100	8.00^{a}	7.80^{a}	6.70^{b}	6.30^{cde}	5.80^{a}
G100	8.00^{a}	8.00^{a}	6.70^{b}	6.30^{cde}	4.70^{ab}

a – e Different letters between the rows indicate significant difference ($P < 0.05$) among the ice cream samples according to Duncan's mean values comparison test.
[1]L – locust bean gum, C – carrageenan, G – guar gum, X – xanthan gum, 100–0.2%, 80–0.16%, 50–0.1%, 20–0.04%.

decreased during storage. Ice creams with locust bean gum and carrageenan blends were strongly rigid and had off-flavour after 13 months of storage. The ice cream samples with guar and xanthan gum blends exhibited soft texture and good taste during 13 months of storage. The highest received scores for softness and taste were for ice creams with guar and xanthan gum blends in ratio 50:50. Xanthan gum also performed a good stabilizing effect. Both hydrocolloids act as cryoprotectants due to their ability to control water diffusion from and to the ice crystals by steric hindrance and water holding (Regand & Goff, 2002; 2003).

Guar gum and carrageenan blends (samples G50C50, G80C20) were able to control ice re-crystallization in ice cream regardless of storage time. Guar gum is functional at inhibiting re-crystallization with other hydrocolloids, but guar gum alone did not retard ice crystal growth and after 13 months of storage the ice cream was strongly rigid and had an unpleasant taste.

CONCLUSIONS

Summarised results of the experiment showed that storage time affects storage modulus and taste of ice cream. The effect of stabilizers on ice cream re-crystallization inhibition during storage was significant only for certain ice creams. Locust bean gum and carrageenan blends had a deteriorating effect on ice cream storage. Guar and xanthan gum blends improved ice cream stability during 13 months of storage.

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