Influence of stabilizers addition on the rheological properties of the model ice cream mixtures*

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Summary

The quality of ice cream is in great extent determined by its sensoric properties. Therefore, it is important to know and to predict the effect of the hydrocolloid and emulsifier addition on the consistency of the ice cream mixtures.

In this work, the influence of several carboxymetylcellulose hydrocolloids (DIKO, YO-EH, HVEP) and emulsifier E-420 (mixture of sorbitol, monoglicerids and diglicerids) on the rheological properties of the model ice cream mixture as well as their ability to prevent crystallization and recrystallization were examined.

The rheological properties as well as electroconductivity before and after pasteurization were measured at 20 °C.

The results of these investigations have shown that the viscosity of all ice cream mixtures significantly increased after pasteurization. All investigated systems exhibited non-Newtonian characteristics. Hydrocolloid YO-EH showed the greatest influence on the rheological properties of the model systems. After pasteurization conductivity increased for all investigated samples. Sensory evaluation have shown that the most acceptable product was that prepared with emulsifier E-420.

Key words: ice cream mixtures, rheological properties, hydrocolloids, emulsifier, pasteurization

Introduction

The knowledge of the rheological properties of foodstuffs and the influence of various ingredients and additives (hydrocolloids and emulsifiers) on those properties is important in defining the product's and process quality control, predicting product stability during storage as well as creating the food texture (Kokini, 1987; Hegedušić, 1991; Hegedušić, 1994; Goff, 1994; Davidson 1996; Demetriades, 1997).

Hydrocolloids, macromolecular carbohydrates are usually added in many foodstuffs in order to achieve the appropriate rheological properties, to prevent

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a sinerasis, to control crystallization process or to inhibit recrystallization of ice (Carr, 1993).

In emulsion-based food products, like ice cream, very important ingredients are stabilizers because of theirs emulsifying properties and ability to prevent recrystallization during storage at low temperatures (Dickinson, 1992; Damodaran, 1996).

The physicochemical properties of emulsions depend first of all on the nature, strength and range of attractive and repulsive forces among droplets (Phillips et al., 1994; Dickinson and McClements, 1995; Dalgleish, 1996). Van der Waals and electrostatic forces as well as hydrophobic reactions can cause the overall interaction potential between a pair of droplets.

Mathematical equation defining these forces has been published by Walstra, 1996.

Hydrophobic interactions have been suggested to be important in determining the stability of heated emulsions (Hunt and Dalgleis, 1994; Monahan et al, 1996).

The strength of hydrophobic interactions depends on the distribution, and the amount of hydrophobic groups on the surface of colloidal particles (Israelachivili, 1992).

Sutton et al. (1994, 1996a, 1996b) have developed a model which determines recrystallization rate in aqueous solutions of carbohydrates and ice creams. Many investigations are related to the effectiveness of hydrocolloids on the recrystallization in frozen desserts and ice cream mixtures (Hegedušić 1995; Miller-Livney, 1995; Vafiadis, 1997).

Goff et al. (1993) found that the ice crystal sizes before and after frozen storage are smaller in ice cream mixtures with stabilizer addition compared to those without stabilizers.

However, Muhr and Blanshard (1986) and Minn (1994) showed that the stabilizer addition did not prevent but did delay recrystallization of ice crystals in aqueous solutions of carbohydrates and ice cream mixtures.

In this work, the influence of three carboxymetylcellulose hydrocolloids and emulsifier E-420 (mixture of sorbitol, monoglicerids and diglicerids) on the rheological properties of model ice cream mixtures as well as their ability to prevent crystallization and recrystallization were examined.

Materials and methods

Investigations were carried out with the model ice cream mixtures prepared according to recipes shown in Table 1. The following ingredients were used:

1. milk - pasteurized, 3,2% milk fat "Dukat"
2. sugar - N crystal - sugar refinery "Županja"
3. egg yolk - S class of eggs from "Agrokoka"
4. sorbitol p.a. "Merck"
5. hydrocolloids - DIKO, YO-EH, HVEP - "Guliver-Chemie", Wiener Neudorf
6. emulsifier E-420 (mixture of sorbitol, mono and diglicerids)

Table 1: Recipes for the model ice cream mixture preparation

Tablica 1: Recepti za pripravu modelnih sladolednih smjesa

Recipe	Milk (g)	Water (g)	Sugar (g)	Sorbitol (g)	Egg yolk (g)	Solid matter (%)		Stabilizer (g)
						Before pasteurization	After pasteurization	
1	78	-	14,4	0,4	7,0	29,5	31,4	0,2
2	78	-	14,2	0,4	7,0	26,3	29,3	0,4
3	39	39	14,2	0,4	7,0	23,4	25,9	0,4
4	39	39	14,4	0,4	7,0	24,2	26,3	0,2

Model ice cream mixtures (marked asrecipes 1 and 2) were prepared by mixing egg yolk and sugar in a blender. Hydrocolloid was mixed with sorbitol, dissolved in a part of warm milk and then added to the prepared mention mixture. Afterwords the rest of the milk was added and the whole suspension was homogenized in a blender.

Model ice cream mixtures (marked as recipes 3 and 4) were prepared in the same way, except that 50% of milk was replaced with water. The mixture was pasteurized in a hot water bath for 30 minutes at 71°C.

Pasteurized model ice cream mixtures were frozen in "Philips" ice cream maker. Frozen samples were placed in the polyethylene containers (volume of 150 ml) and stored for 5 days at -18°C. After storage sensory properties were determined by 5 assessors using 20 points scale.

Rheological properties of investigated model ice cream mixtures, before and after pasteurization, were determined at 20 °C using a Brookfield DV-III rotational viscometer. 8 ml of sample was poured in to a fixed coaxial cylinder and shear stress vs. shear rate was measured. The measurements were performed at shear rates increasing from the lowest ($3s^{-1}$) to the highest ($158s^{-1}$) value, and then backwards to the lowest shear rate ($3s^{-1}$). Ostwald - Reiner's power-law model was applied for calculating the rheological parameters.

$$\tau = k\,\gamma^n$$

where: k = consistency coefficient (Pa s^n)
n = flow index

Electroconductivity was measured at 20 °C using a conductometer ("Iskra", Kranj) with Ni-electrode.

Mass fraction of solid matter in model systems was determined by drying at 105 °C to the constant weight.

Discussion

The quality of ice creams is, primary determined by theirs taste and consistency. Therefore, the sensory evaluation is one of the most important parameters in the quality control of these products.

Table 2: Sensory evaluation of the model ice cream mixture

Tablica 2: Senzorska analiza modelnih sladolednih smjesa

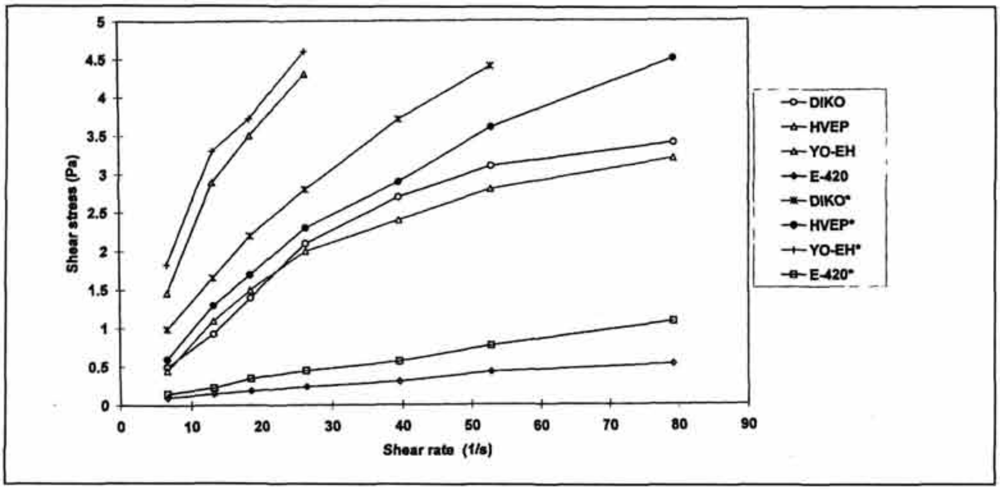
Quality parameter	RECIPE 1				RECIPE 2				RECIPE 3				RECIPE 4			
	DIKO	YO-EH	HVEP	E-420	DIKO	YO-EH	HVEP	E-420	DIKO	YO-EH	HVEP	E-420	DIKO	YO-EH	HVEP	E-420
Taste	5.8	4,8	5,0	5,8	6,6	6,4	6,2	6,2	4,8	4,2	4,2	4,2	4,6	3,8	4,6	4,4
Odour	2,4	2,0	2,2	2,2	2,4	2,4	2,4	2,4	2,2	2,2	2,0	2,2	2,2	2,0	2,0	2,0
Consistency	4,8	4,6	4,2	4,6	5,6	4,8	4,8	5,4	4,0	2,8	3,2	4,2	4,6	4,2	3,8	4,2
Colour	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0	2,0
Total	15,0	13,4	13,4	14,6	16,6	15,4	15,6	16,0	13,0	11,2	11,4	12,6	13,4	12,0	12,4	12,6

In Table 2 the average results of sensory properties evaluation of investigated model ice cream mixtures are shown. The highest scores are obtained for the ice cream mixtures containing the highest amount of milk and stabilizers (recipe 2). Significant differences exist in the sensory properties of samples prepared using a variety of stabilizers or emulsifier. The best ice cream mixture is proved to be the one containing E-420 emulsifier indicating that special attention must be paid in order to create stabilized emulsions, (with positive effect on the sensory properties) rather than to use hydrocolloids to prevent ice crystals formation or the recrystallization of water. The ideal solution is to use hydrocolloid which main functional characteristics could prevent ice crystals growth, create a smooth texture and, at the same time, achieve the emulsifying affects.

DIKO hydrocolloid, because of its functional characteristics (emulsifying properties) is used only in the ice cream preparation. This is also confirmed by sensory evaluation, as the ice cream prepared with DIKO hydrocolloid, rather than with YO-EH and HVEP hydrocolloids which do not possess these emulsifying properties, is significantly better evaluated.

The electroconductivity of ice cream mixtures depends on the mass fraction of solid matter and stabilizer presence. Ice-cream mixtures prepared in accordance with recipes 1 and 2 (higher solid mater content) showed lower conductivity than mixtures 3 and 4 (lover solid mater content). However, the conductivity of all mixtures depends on the type of hydrocolloids or emulsifiers added. In the ice-cream mixtures containing emulsifier E-420 the highest conductivity is determined. This is closely related to the ability of water binding capacity of hydrocolloid, thus causing a decrease in electroconductivity.

Fig. 1: Shear stress vs. shear rate of the model ice cream mixtures prepared according to the recipe 2
Slika 1: Odnos između napona smicanja i brzine smicanja kod modelnih sladolednih smjesa pripremljenih prema receptu 2.



The results of the investigation of rheological properties showed that all the investigated ice-cream mixtures possess non-Newtonian characteristics. The regression coefficient for all investigated systems is extremely high (between 0.96 and 0.99), which means that the rheological properties of ice creams can be described by Ostwald - Reiner's power-law model. The flow behavior index of all the ice cream mixtures, before and after pasteurization, ranged from 0.50 and 0.85 indicating pseudoplastic characteristics of the mixtures. The consistency of ice cream mixtures expressed as consistency coefficient value (Tables 4, 5, 6, 7) depends on the mass fractions of solid matter, hydrocolloid and stabilizer, type of stabilizer used, as well as phase of investigation (before or after

Table 3: Rheological characteristics of the ice cream mixtures prepared according to the recipe 1

Tablica 3: Reološke karakteristike sladolednih smjesa pripremljenih prema receptu 1

Sample	Apparent viscosity (mPas)	Flow index	Consistency coefficient (Pas^n)	Regression coefficient	Flow
1 DIKO	29,1	0,59	0,087	0,984	pseudoplastic
1 DIKO*	87,0	0,84	0,134	0,997	pseudoplastic
1 YO-EH	29,1	0,70	0,062	0,999	pseudoplastic
1 YO-EH*	96,9	0,77	0,173	0,999	pseudoplastic
1 HVEP	30,3	0,68	0,075	0,996	pseudoplastic
1 HVEP*	41,1	0,77	0,083	0,999	pseudoplastic
1 E-420	10,7	0,64	0,016	0,999	pseudoplastic
1 E-420*	33,6	0,80	0,083	0,998	pseudoplastic

*after pasteurization
*nakon pasterizacije

Table 4: Rheological characteristics of the ice cream mixtures prepared according to the recipe 2

Tablica 4: Reološke karakteristike sladolednih smjesa pripremljenih prema receptu 2

Sample	Apparent viscosity (mPas)	Flow index	Consistency coefficient (Pas^n)	Regression coefficient	Flow
2 DIKO	70,5	0,80	0,119	0,999	pseudoplastic
2 DIKO*	126,0	0,58	0,506	0,960	pseudoplastic
2 YO-EH	214,0	0,72	0,457	0,998	pseudoplastic
2 YO-EH*	288,0	0,83	0,465	0,999	pseudoplastic
2 HVEP	63,9	0,82	0,103	0,999	pseudoplastic
2 HVEP*	77,7	0,71	0,170	0,998	pseudoplastic
2 E-420	6,0	0,82	0,010	0,996	pseudoplastic
2 E-420*	17,4	0,71	0,037	0,998	pseudoplastic

*after pasteurization
*nakon pasterizacije

pasteurization) (Hegedušić, 1994). The type of stabilizer had a significant effect on the consistency of the investigated systems. The lowest value of consistency coefficient is obtained in the ice cream mixtures containing E-420 emulsifier, which is understandable due to its functional characteristics. By increasing amount of the emulsifier no significant influence on the rheological parameters is observed. However by increasing the mass fraction of all hydrocolloids (from 0.2 to 0.4%) a significant effect on the coefficient consistency value is observed.

Table 5: Rheological characteristics of the ice cream mixtures prepared according to the recipe 3
Tablica 5: Reološke karakteristike sladolednih smjesa pripremljenih prema receptu 3

Sample	Apparent viscosity (mPas)	Flow index	Consistency coefficient (Pas^n)	Regression coefficient	Flow
3 DIKO	39,6	0,76	0,069	0,998	pseudoplastic
3 DIKO*	55,2	0,56	0,187	0,961	pseudoplastic
3 YO-EH	75,3	0,85	0,106	0,998	pseudoplastic
3 YO-EH*	93,6	0,81	0,152	0,999	pseudoplastic
3 HVEP	42,0	0,81	0,068	0,998	pseudoplastic
3 HVEP*	57,3	0,83	0,090	0,999	pseudoplastic
3 E-420	5,4	0,83	0,007	0,999	pseudoplastic
3 E-420*	12,0	0,76	0,024	0,999	pseudoplastic

*after pasteurization
*nakon pasterizacije

Table 6: Rheological characteristics of the ice cream mixtures prepared according to the recipe 4
Tablica 6: Reološke karakteristike sladolednih smjesa pripremljenih prema receptu 4

Sample	Apparent viscosity (mPas)	Flow index	Consistency coefficient (Pas^n)	Regression coefficient	Flow
4 DIKO	13,5	0,79	0,021	0,997	pseudoplastic
4 DIKO*	32,1	0,78	0,053	0,997	pseudoplastic
4 YO-EH	26,1	0,76	0,044	0,999	pseudoplastic
4 YO-EH*	35,7	0,77	0,061	0,998	pseudoplastic
4 HVEP	26,7	0,69	0,057	0,994	pseudoplastic
4 HVEP*	30,9	0,76	0,054	0,996	pseudoplastic
4 E-420	5,9	0,56	0,033	0,989	pseudoplastic
4 E-420*	15,9	0,61	0,047	0,994	pseudoplastic

*after pasteurization
*nakon pasterizacije

Remarkable increase in viscosity occurred in all ice-cream mixtures after pasteurization. The highest increase in viscosity (2,5 to 3 times) is determined for the ice cream mixtures containing E-420 emulsifier.

Conclusion

Investigated model ice cream mixtures exhibited non-Newtonian characteristics before and after pasteurization. The most significant influence of

Table 7: Electroconductivity of the model ice cream mixtures
Tablica 7: Elektroprovodnost modelnih sladolednih smjesa

Stabilizers	ELEKTROCONDUCTIVITY ($\mu S\ cm^{-1}$)			
	RECIPE 1	RECIPE 2	RECIPE 3	RECIPE 4
DIKO	286	440	594	448
DIKO*	350	502	598	591
YO-EH	518	560	628	590
YO-EH*	535	625	670	600
HVEP	439	540	690	547
HVEP*	514	653	730	591
E-420	583	711	571	593
E-420*	629	718	589	600

*after pasteurization
*nakon pasterizacije

pasteurization is observed on the ice cream mixtures containing E-420 emulsifier.

All hydrocolloids had a significant effect on the consistency coefficient value, with YO-EH hydrocolloid having the most significant influence.

E-420 emulsifier showed the lowest influence on the rheological properties of the investigated systems. However, ice cream mixtures prepared with this emulsifier are better sensory evaluated, which means that during the production of ice cream special attention should be paid in order to create a stable emulsion.

UTJECAJ DODATAKA STABILIZATORA NA REOLOŠKA SVOJSTVA MODELNIH SLADOLEDNIH SMJESA

Sažetak

Kakvoću sladoleda u velikoj mjeri određuju njegova senzorska svojstva, te je važno znati kakav će utjecaj na njih, posebno na konzistenciju, imati dodatak hidrokoloida odnosno emulgatora.

U ovom radu ispitan je utjecaj hidrokoloida na bazi karboksimetilceluloze (DIKO, YO-EH, HVEP) i emulgatora (smjesa sorbitola, monoglicerida i diglicerida, E-420) na reološka svojstva modelnih sladolednih smjesa kao i njihova sposobnost da spriječe kristalizaciju i rekristalizaciju vode te u vodi otopljenih tvari.

Reološka svojstva određena su u rotacionom reometru Brookfield DV-III kod temperature od 20 °C prije i poslije pasterizacije. Nakon provedene pasterizacije i smrzavanja izmjerena je provodljivost na konduktometru "Iskra" Kranj pri temperaturi od 20 °C.

Rezultati ispitivanja su pokazali da je nakon provedene pasterizacije došlo do značajnog povećanja viskoznosti svih modelnih smjesa. Svi sastavi su pokazali nenewtonski karakter. Najveći utjecaj na reološka svojstva modelnih sustava imao je hidrokoloid YO-EH. Mjerenje elektroprovodljivosti pokazalo je da tijekom pasterizacije te smrzavanja dolazi do kontinuiranog rasta provodljivosti. Ocjena senzorskih svojstava pokazala je da se upotrebom emulgatora E-420 dobiva senzorski najprihvatljiviji proizvod.

Ključne riječi: sladoledne smjese, reološka svojstva, hidrokoloidi, emulgatori, pasterizacija

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