Perception of Melting and Flavor Release of Ice Cream Containing Different Types and Contents of Fat

L. Hyvönen,* M. Linna,* H. Tuorila,* and G. Dijksterhuis†

*University of Helsinki, Department of Food Technology,
P.O. Box 27, FIN-00014 Helsinki, Finland

†Royal Veterinary and Agricultural University of Copenhagen,
Sensory Science Group, Department of Dairy and Food Science,
Denmark

ABSTRACT

Temporal effects of dairy and vegetable fats (0 to 18%) on perception of strawberry flavor release and melting of ice cream were studied using the time intensity sensory method. Also, aroma and flavor attributes of the ice cream samples were evaluated. Only slight effects of fat on the rate of flavor release and flavor intensity were perceived. A slightly faster flavor release from the vegetable fat compared with dairy fat was noticed. Polydextrose and maltodextrin as bodying agents in the fat-free ice cream significantly increased flavor release and melting rate of the ice cream. Increasing fat content slightly retarded melting of ice cream in the mouth. No significant effect of the fat quality on perceived melting was noticed. Significant differences in aroma and flavor attributes of the fat-free and other samples were perceived. Intensity and sharpness of the strawberry aroma and flavor were greater in fat-free samples and they were perceived as nontypical. Fattiness and creaminess were highly correlated. Maltodextrin and polydextrose increased perceived fattiness and creaminess of fat-free ice cream.

(**Key words:** melting, flavor release, ice cream, time intensity study)

Abbreviation key: PCA = principal component analysis, TI = time intensity

INTRODUCTION

The essential role of fat as a solubilizer and reservoir of the lipophilic flavor compounds is supposed to be the main reason for the perceived change in flavor release and flavor quality of reduced fat products (Matheis 1995). Lee and Pangborn (1986) reported that the unsaturation degree of the fat clearly had an effect on

the time intensity (TI) flavor properties of butter-like products. Fat content and even a partial replacement of fat by the so-called fat substitutes most likely affects the perceived rate of melting of the food, too (Lawless et al., 1996; Guinard et al., 1997). Only a few TI studies report melting of food in the mouth due to fat content. Tuorila and Vainio (1993) studied melting rates of table spreads. Lawless et al. (1996) studied melting of a confectionery-like model food, which contained varying amounts of cocoa butter substituted by varying amounts of microcrystalline cellulose and guar gum.

The aim of this study was to examine effects of different types (dairy and vegetable) and contents (0 to 18%) of fat on perception of strawberry flavor release and melting of ice cream. Aroma and flavor attributes of the ice creams were also evaluated. In addition to experimental samples that were systematically varied by fat type and content, further ice cream samples were prepared by modifying the texture of samples containing 0 and 18% fat.

MATERIALS AND METHODS

Experimental Samples

Ice cream samples were prepared using dairy and vegetable fat at five fat levels: 0, 5, 9, 14, and 18%. All mixes contained sugar, starch syrup, skimmed milk, skimmed milk powder, emulsifier (E471), and thickeners (E410, E412, E407). The amount of dry matter was 24% in nonfat ice cream and 30, 34, 38, and 43% in 5, 9, 14, and 18% dairy or vegetable fat ice creams, respectively. The amount of nonfat milk solids was 11% in all the ice creams. Samples with modified textures were prepared from ice creams with 0 and 18% fat contents (Table 1). Dry matter of ice cream without fat was increased to the level of ice cream containing 9% fat by adding 6% polydextrose (E1200) and 2.1% maltodextrin as bodying agents. Texture of the 18% fat containing ice creams was modified to resemble ice cream containing 14% fat, when whipped. The modified 18% dairy fat ice cream was changed by reducing the emulsi-

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Corresponding author: L. Hyvönen; e-mail: Lea.Hyvonen@Helsinki.Fi.

Table 1. Evaluated samples in the time intensity studies (TI) and in the sensory attributes study (A).

	Fat content				
	0%	5%	9%	14%	18%
Normal ice creams					
Dairy fat ice cream	TI, A	A	TI, A	A	TI, A
Vegetable fat ice cream	TI, A	A	TI, A	A	TI, A
Modified ice creams					
Dairy fat ice cream	TI, A				TI, A
Vegetable fat ice cream	TI, A				TI, A

fier and stabilizer content to one third of the 9% fat containing original recipe. In the modified 18% vegetable fat ice cream the amount of the original emulsifier was reduced to one half. These modified samples resembled the products on the market and were of interest to the industrial partner. All samples were flavored with 0.08% of strawberry fruit (16-I) aroma (Danisco Ingredients).

Samples were prepared in a pilot plant of the collaborating dairy plant. All mixes were heated to 82°C and homogenized for 5 min, then cooled to 4°C and aged for 1 to 2 d. After aging, the mixes were flavored with strawberry flavoring and colored with beetroot color (E162). The mixes were whipped (Frigomat Gelateria 625, Italy) and then immediately frozen in 1-L plastic containers, and stored at -28°C until transportation to the University, where they were stored at -20°C.

Fat-free, modified fat-free, 9 and 18% vegetable and dairy fat and modified 18% vegetable and dairy fat ice creams were evaluated in the TI melting and flavor release studies. In addition 5 and 14% dairy fat and vegetable fat ice creams were included in the sensory attributes study.

Time-Intensity Study

TI panel. Fifteen panelists, six men and nine women, were students and staff of the University of Helsinki. One assessor constantly produced very deviant curves and was therefore omitted, thus the final data consist of ratings from 14 panelists. Their mean age was 28 yr. They were asked to take part in the study by using an e-mail list or by personal contacts. All of them had taken part in earlier sessions in which the intensity of the aroma, flavor, and texture of experimental samples were rated (see below).

Training sessions. Two sessions were organized to make panelists familiar with the TI procedure and the evaluation technique. In the first training session, they were introduced to the idea of the TI procedure, the meaning of rated attributes, and the use of the Compusense Five computer program for sensory analysis (CSA

Computerized Sensory Analysis System, Compusense Inc., Guelph, Canada, version 5.0). After a demonstration, the panelists practiced evaluation. In the second training session samples were evaluated as in the actual study.

Session organization. Four sessions were arranged. Four samples were evaluated at a time, and all eight samples were rated twice. Both melting in the mouth and strawberry flavor intensity were evaluated within a session. Presentation order was randomized for each panelist over the eight samples. Samples were coded with a three-digit random number between 100 and 999, and ratings were conducted in individually partitioned booths.

Sample preparation. Samples were taken to -16°C about 24 h before sensory testing. Samples were portioned and put into white plastic cups that were closed with plastic lids about 1.5 h before each session. Each cup contained two scoops (about 7 g), one to evaluate melting in the mouth and the other to rate strawberry flavor intensity. After preparation, cups were put on trays and returned to the freezer (-16°C). Each panelist had samples for one particular session on one tray. Trays were taken from the freezer right before a panelist started the evaluation.

Sample evaluation. Instructions on the evaluation were presented on the computer screen. When panelists started a session they received a tray with samples to evaluate and one warming-up sample, a 14% dairy fat ice cream, to prevent the first experimental sample to be rated differently compared with the following ones. Panelists rinsed their mouths with lukewarm water after evaluation of each sample. Each TI evaluation lasted 40 s, and the computer registered the position of the slider on the line-scale every second.

First, panelists evaluated *melting in the mouth*, by putting the first samples into their mouths while they used the mouse to click a "start button" on the computer screen. The panelists indicated with a slider, shown on the screen, the position on the evaluation scale that corresponded to the perceived melted portion of the sample. When the sample was completely melted, panelists had moved the cursor from the left (nothing melted) to the right end (100% melted). The panelists saw a little clock on the screen showing elapsed time.

Subsequently, panelists evaluated the perceived *intensity of the strawberry flavor* (0 = none, 100 = strong flavor). They put the sample in their mouth and used the mouse to click the start button on the computer screen. Analogously to the evaluation of *melting in the mouth*, panelists indicated the strength of perceived intensity on the slider; however, they now expectorated the samples after 15 s and the rating was continued as

after taste evaluation. Panelists saw the time and a notice about the expectoration on the screen.

Sensory Attributes: Single Point Ratings

Panel. The panel consisted of 35 people (12 men and 23 women) who were students and staff of the University of Helsinki. Their mean age was 31 y (range 20 to 65 y). All panelists had earlier experience in sensory evaluation.

Sample preparation and evaluation. The samples were prepared similarly to those for TI evaluations, except that the sample size was one scoop weighing about 30 g. One orientation session was arranged before the experimental sessions to clarify the procedure and to familiarize the panel with the variations of ice cream to be evaluated. For ratings of 12 samples, four sessions were arranged. During a session, each panelist judged three samples. Presentation order of the 12 samples, coded with three-digit codes, was randomized for each panelist. Evaluations were conducted in individually partitioned booths under red light in order to eliminate any visual clues.

A subgroup of panelists participated in a session in which the attributes to be rated were chosen. The choice was based on that the attribute was easy to understand and to demonstrate, to the panel in the orientation session using coded experimental samples. Nine-point scales anchored at the ends were used to evaluate strawberry aroma (by sniffing) and flavor (in the mouth) for intensity (weak to strong), typicality (not strawberry-like to strawberry-like) and sharpness (not sharp to sharp). In addition, fattiness (not fatty to fatty), creaminess (not creamy to creamy) mouthfeel, and sweetness (not sweet to sweet) were evaluated. The panelists first evaluated aroma after opening the lid of the cup, and then the flavor attributes and sweetness, and finally fatty and creamy mouthfeel separately. The mouth was rinsed with warm water between the samples.

Statistical Analysis

Standard TI parameters (time to maximum, maximum intensity, area under the curve, increase angle, decrease angle, and decrease area see, e.g., Lee and Pangborn, 1986; Cliff and Noble, 1990) were calculated for the TI curves. Schematic presentation of the flavor TI parameters is shown in Figure 1. The TI parameters relevant for use in the present melting study here were t_{max} , increase angle, and increase area. T_{max} means the time when 100% of ice cream is perceived as melted. Increase angle describes the rate of melting as perceived by panelists. Increase area is a perceived measure of the melted ice cream.

Figure 1. Schematic presentation of the flavor TI parameters: t_{max} , I_{max} , increase angle, decrease angle, decrease area, and area under curve.

Analysis of variance and multiple range tests were used to find differences between the TI parameters and ratings for the sensory attributes of the ice cream samples. Principal component analysis (PCA) was performed on the mean line scale data from the assessors. Paired t -test was used to find the effects of modification on the sensory attributes of 0 and 18% fat ice creams.

RESULTS AND DISCUSSION

Melting Rates

Variation in the perceived melting rate of ice cream among panelists was large. Some panelists reported that the ice cream sample was not completely melted after the 40 s, although most of them perceived 100% melting. Mean TI melting curves of the samples are shown in Figure 2A.

The exceptional melting behavior of the texturally modified fat-free ice cream can be easily noticed in Figure 2A. Figure 2B indicates that the fat level has more effect on the perceived melting than the fat type. The higher fat content seems to retard melting. Further ANOVA analyses of the melting TI parameters proved t_{max} ($P < 0.0001$), increase angle ($P = 0.003$) and increase area ($P = 0.036$) significant in differentiating melting of the ice creams. Mean values of the significant melting TI parameters of the strawberry-flavored ice creams are presented in Figure 3.

The parameters, t_{max} , increase angle (Inc ang), and increase area (Ainc) of the melting TI curves differentiated only the modified fat-free ice cream from the others. It melted faster than the other variants. The significant effect of maltodextrin and polydextrose addition on the melting via decreasing of freezing point could be perceived in the modified fat-free ice cream. Surprisingly, the fat-free ice cream (without bodying

Figure 2. Mean “perceived portion melted” curves, (A) of the eight ice cream samples and (B) ice creams containing 9 and 18% dairy and vegetable fat.

Figure 3. Mean values for time to maximum (tmax), increase angle, and increase area (Ainc) of the melting TI curves of the strawberry ice cream samples. Homogeneous groups, according to LSD test, are shown by identical shading of the bars.

agents) did not significantly differ in melting behavior from the fat containing samples.

The difference in melting behavior of the dairy and vegetable fat was not observed in this study. The melting behavior of the partly hydrogenated vegetable fat and dairy fat was probably not so different that it could be clearly perceived in ice cream. Tuorila and Vainio (1993) found that table spreads containing 90% vegetable oil melted fastest in the mouth, and those with 100% dairy fat the most slowly. Yet the decreasing effect of the higher fat content on perceived melting rate of ice cream was seen from the TI melting curves. Guinard

Figure 4. Mean flavor TI curves of eight strawberry ice cream variants.

et al. (1997) concluded that the fat content had a greater effect on the perceived melting rate than the sugar content. Their melting data also suggested interaction of fat and sugar in melting behavior. Surprisingly, Guinard et al. (1997) found no relationship between instrumental and sensory melting rates, perhaps due to the different environment (e.g., the weight of drip at 25°C vs. melting at mouth temperature including mixing effects) in the measurements. Similar contradiction is evident in the study reported by Li et al. (1997). Melting rate increased as fat content increased, when measured physically as a percentage of weight melted. However, such a textural attribute as fast melt was related to reduced-fat ice creams in Proccustes analysis of free-choice profiling (Li et al., 1997). Also, Roland et al. (1999) reported similar discrepancy between physical and sensory measurements of melting characteristics of ice creams. Increasing fat content increased physical melting rate, when sensory meltability of the ice cream was decreased. The effect of total solids via melting point most likely is essential for the rate of melting as physically determined. Melting in the mouth includes the sensation of liquefying of both ice and fat crystals. Consequently the ice cream with higher fat content is sensed to melt slower. The ice crystals are melting at lower temperatures than the fat crystals.

Flavor Release

The flavor TI data showed the typical properties of TI studies, e.g., large individual differences. The mean (over assessors) flavor TI curves for eight strawberry-flavored ice creams are presented in Figure 4.

The mean flavor TI curve of the texturally modified fat-free ice cream clearly stands out from the others,

Table 2. Significant flavor TI parameters.

Parameter	<i>P</i> value
Time to maximum (tmax)	0.045
Maximum intensity (Imax)	0.000
Area under curve (Atot)	0.009
Increase angle (IncAng)	0.020
Decrease angle (DecAng)	0.032
Decrease area (Adec)	0.023

which form a tight group of curves. On the basis of the ANOVA on the TI parameters the parameters in Table 2 proved significant ($P < 0.05$) in differentiating flavor release of the ice cream samples.

Mean values of the significant flavor TI parameters and differentiation of the strawberry ice cream samples with respect to perceived flavor release are presented in Figure 5.

Time to maximum, as an indicator of the rate of flavor release, showed a faster flavor release only from the modified fat-free and 18% vegetable ice creams. A tendency of the higher fat levels to retard flavor release was not unambiguously shown by this parameter. Flavor intensity at the maximum was lowest in 18% dairy fat ice cream and highest in modified fat-free ice cream. Flavor intensity of the fat-free and 18% vegetable fat ice creams was also significantly higher than that of 18% dairy fat ice cream. The slight effect of fat content as well as fat quality can be seen from the Imax parameter. Dairy fat as more saturated than the vegetable fat retarded the strawberry flavor release at the highest level, which is in accordance to the earlier findings (Lee, 1986). The effect of bodying agents on Imax was significant in the fat-free ice cream. Modifications in the amounts of emulsifier and stabilizer did not cause sig-

Figure 5. Mean values for time to maximum (tmax), maximum intensity (Imax), area under curve (Atot), increase angle (Inc ang), decrease angle (Dec ang) and decrease area (Adec) of the flavor TI curves of the strawberry ice cream variants. Identical shading of the bars shows homogeneous groups according to the LSD test. Letters show, whether the ice cream belongs to more than one group.

nificant changes in $I_{\max}$ of the 18% fat containing ice creams.

The area under curve (Atot) differentiated the modified fat-free ice cream from all the other samples. The biggest increase angle (Inc ang) parameter indicated the fastest flavor release from the modified fat-free ice cream. The other differences were not significant. The slower release from saturated than from unsaturated fat could not be seen in the Inc ang parameter.

The decrease angle (Dec ang) parameter described flavor release as a kind of after-taste after expectoration at 15 s. Significant differences were perceived only between the fat-free and modified 18% vegetable fat and 18% dairy fat ice creams. The smallest decrease angles of texturally modified 18% vegetable fat and 18% dairy fat ice creams TI curves show a tendency to slow down flavor release from these high fat ice creams. The decrease angles did not significantly differentiate flavor release from fat-free ice creams from the five other strawberry-flavored ice creams (Figure 5).

The decrease area (Adec) parameter differentiated the modified fat-free ice cream from all the other ice creams except the modified 18% vegetable fat ice cream. This might indicate faster flavor release from unsaturated fat, but the phenomenon was not evident at the lower vegetable fat level nor in the 18% vegetable fat ice cream, which contained more emulsifier than the texturally modified product.

The significant difference in flavor release between the fat-free ice cream and the modified fat-free ice cream was probably due to polydextrose and maltodextrin, which were used as bodying agents in the texturally modified fat-free ice cream. Decreased melting point of ice cream due to maltodextrin addition, obviously has an effect on the flavor release.

Sensory Attributes: Single-Point Ratings

Biplots of the rated sensory intensities show the positions of the 10 strawberry-flavored ice cream samples and the sensory attributes after PCA (Figure 6). 68.1% of the variance was explained by the first and 18.8% by the second factor of the biplot. Principal component 1 most probably is the fat content of the ice cream. The biplot clearly shows that the presence of fat and the fat content, not of the fat type affect the sensory attributes of ice cream.

Ratings for nine sensory attributes of 9 strawberry-flavored ice creams containing either dairy or vegetable fat ranging in fat content from 0 to 18% are given in Table 3.

Perceived intensity and sharpness of aroma and flavor were significantly greater in fat-free ice creams than in the fat containing samples. In fact, no significant

Figure 6. Sensory attributes and positions of the ten strawberry ice cream samples after principal component analysis. AI = aroma intensity, FI = flavor intensity, AS = aroma sharpness, FS = flavor sharpness, SW = sweetness, CR = creamy mouthfeel, FA = fatty mouthfeel, FT = flavor typicality, AT = aroma typicality; d refers to dairy fat, v to vegetable fat, the number shows the fat level and an apostrophe is associated with textural modification.

difference was perceived between the intensities of aroma and flavor of the ice cream samples whose fat content varied from 5 to 18%. Flavor was also perceived as nontypical in fat-free and reduced-fat samples and typical in 9% or higher fat ice creams. Strawberry aroma was regarded as less typical in fat-free, 5 and 14% vegetable fat ice creams. Typicality of strawberry flavor increased as the dairy fat content of the ice cream increased.

Unexpectedly, it was difficult to perceive difference in fattiness of the ice cream below a fat content of 14%. Creaminess of dairy fat ice cream was constantly perceived a little higher than creaminess of the corresponding vegetable fat sample. The difference was not significant, however. As can be seen in Figure 6, these two attributes were highly correlated. A high positive correlation between creaminess and perceived fat con-

Figure 7. Fattiness of fat-free, 18% dairy fat, and 18% vegetable fat ice creams as well as their modified variants.

Table 3. Ratings for nine sensory attributes of nine strawberry-flavored ice cream samples containing different fat type and fat content¹.

	Fat type (fat content)								
	Fat-free (0%)	Dairy (5%)	Vegetable						
			(9%)	(14%)	(18%)	(5%)	(9%)	(14%)	(18%)
Aroma									
Intensity	6.9a	5.4b	4.8b	5.1b	5.3b	5.3b	5.0b	5.0b	4.8b
Sharpness	6.5a	4.3b	3.8b	3.9b	3.5b	4.3b	3.9b	3.5b	3.6b
Typicality	4.0a	4.9b	5.2b	5.5b	5.5b	4.7b	5.3b	4.7a	5.5b
Flavor									
Intensity	7.0a	6.1b	5.9b	5.8b	5.5b	5.8b	5.9b	6.3b	6.0b
Sharpness	6.8a	4.6b	4.1b	3.4c	3.9c	5.1b	4.8b	4.1c	3.9c
Typicality	2.9a	4.4b	5.1c	5.1c	5.3c	3.8b	4.6c	5.1c	4.7c
Sweetness	5.4a	5.8a	5.9a	6.1a	6.2ab	5.7b	5.7a	6.0a	5.9a
Fattiness	3.9a	3.9a	4.3a	5.6b	6.2cd	4.1b	3.9a	5.3b	6.9c
Creaminess	3.8a	3.8a	4.5a	5.7b	6.8c	3.4a	4.2a	5.4b	6.2bc

¹Values with different letters in a row are significantly different at the 5% level (Tukey test).

tent has also been observed by Mela (1988). Richardson et al. (1993) concluded that the sensation of creaminess is the combination of small fat droplets and an adequately high viscosity. To be perceived as creamy, a smooth but viscous fluid layer is needed between the tongue and palate. Creaminess is, however, also used to describe the typical flavor of dairy products, which explains why the ratings of creaminess tend to be higher for dairy than for vegetable fat ice creams. Richardson-Harman et al. (2000) reported a similar phenomenon in liquid dairy products ranging in fat content from 0.1 to 40%.

Modification of the fat-free ice cream by maltodextrin and polydextrose additions increased perceived fattiness and creaminess (Figure 7). Thus, carbohydrates may cause a similar mouthfeel as fat does which justifies the use of carbohydrates as fat substitutes in reduced fat products. Perceived sweetness of the experimental samples was not clearly affected by their fat content. Only 18% fat containing ice creams were perceived somewhat sweeter than the fat-free ice cream. Neither did Li et al. (1997) find a significant effect of fat content of ice cream on sweetness perception.

CONCLUSIONS

Fat content slightly affected the perceived rate of flavor release and flavor intensity of strawberry-flavored ice cream. A slight indication of a faster flavor release from the more unsaturated vegetable fat ice cream could be noticed. The effect of polydextrose and maltodextrin on the melting behavior and flavor release of the fat-free ice cream was large and obviously due to the lowered melting point of these samples. Otherwise it turned out that the fat level, and not the fat type affected the melting behavior of the ice cream samples.

Total absence of fat caused significant changes in aroma and flavor profiles of the ice cream. In ice creams containing 9% or more fat the strawberry aroma and flavor were perceived as typical and only slight differences were noticed between different variants.

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