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Full Length Research Paper

Development of a low fat sugar free frozen Dessert

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A study was carried out to assess the effect of use of intense sweetener in the manufacture of low fat frozen dessert, with the intention of developing appropriate technology for the manufacture of a dietetic frozen dessert. The control (C) was formulated to contain 4.5% milk fat, 11.75% milk solids not fat (MSNF), 1.25% whey protein concentrate-70 (WPC-70), 15% sucrose, 0.2% sodium alginate and 0.2% glycerol monostearate. In the experimental products sucralose was used as a sweetener in place of sucrose at the rate of 0.015%. Bulk fillers viz. polydextrose (PD), maltodextrin (MD) and sorbitol (SO) were used in different combinations viz. R1 (6% PD, 3% MD, 6% SO), R2 (7% PD, 2% MD, 6% SO) and R3 (8% PD, 1% MD, 6% SO) the other ingredients being same as that of the basic frozen dessert mixture with the exception of sucrose. Vanilla flavour was used as flavouring in all the products. All the mixtures and the frozen products were analyzed for their physico-chemical and sensory characteristics. From amongst all the experimental samples, R2 was preferred the most. Use of 7% PD, 2% MD and 6% SO and 0.015% sucralose is advocated for manufacture of sugar free frozen dessert. Substitution of sucrose with bulk fillers resulted in 20% reduction in calories in the sugar free product. The calorific value of the developed sugar free product i.e. R2 was 118.19 vs. 197.13 k cal for an average ice cream.

Key words: Frozen dessert, sugar free, low fat, WPC-70, polydextrose, maltodextrin, sorbitol, bulk fillers.

INTRODUCTION

Ice cream, being a rich source of fat, protein and carbohydrate, contributes significantly towards its calorific value. The calorific value of a good average ice cream is approximately 200 kcal/100g. The awareness of consumers for healthier and functional foods has led to development of new technologies for manufacture of such products (Akin *et al*., 2007; Soukoulis *et al*., 2009, Soukoulis and Tzia, 2010). Frozen desserts in particular have the potential for the development of lower-fat, reduced-sugar products which may lead to increased sales (Olson *et al*., 2003).

The successful development of good quality dietetic foods would depend to a large extent on the imitation and simulation of organoleptic properties of the equivalent standard products. Consequently, the development of a completely new formulation is often required to obtain acceptable dietetic frozen desserts for the consumers. Carbohydrate based bulking agents such as maltodextrin and polydextrose are currently used in low-calorie formulations because they produce minimal negative effects on ice cream production, shelf life and price (Roland *et al*., 1999).

Sugar contributes a pure and sweet taste to ice cream, and thus has a crucial regulating effect on the overall taste sensation. Also, the ability of sugar to lower the freezing point has a significant influence on the hardness/ softness of finished frozen desserts. In order to produce ice cream which is sufficiently low in calories as well as to provide a refreshing frozen dessert for diabetics, it is necessary to reduce or remove the sugar content. There are some areas to consider in making compositional adjustments which will minimize the effect of these differences. When sucrose, which is used generally at the rate of about 15 % is to be replaced by intense sweetener, the requirement is in ppm only. Hence, there are two expected problems. The first is to compensate for the total solids to prevent weak body and related defects. This can be generally achieved by use of low calorie bulk fillers/ bulking agents i.e. polydextrose, maltodextrins, etc. However, use of bulking agents will result in a somewhat hard product since they lower the freezing point far less than sucrose.

Removal of sucrose from the ice cream and the loss of

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its freezing point depression effect drastically increases the amount of water frozen at all temperatures. At a typical drawing temperature of -5.56^{o} C, the unsweetened mixture would have twice the water frozen as in the reference mixture (69 and 32 g/ 100 g product, respectively). Even if a comparative sweetness were given to the mixture by including an intense sweetener at a level of 0.1 % (a suggested starting level for aspartame in frozen dessert), differences would remain which would clearly distinguish its behavior from the conventional ice cream both with respect to its characteristics at the freezer and the body and texture properties. Therefore, a bulking agents is required to offset the contribution of sweetener to total solids and a freezing point depressant is required to minimize the change in freezing profile caused by removal of sucrose (Tharp, 1991).

In literature a variety of dietetic/ low calorie ice cream and frozen desserts have been formulated using aspartame as a sweetener and a variety of bulking agents based on polydextrose, microcrystalline cellulose etc. (Wolkstein, 1986). Goff and Jordan in 1984 developed a calorie reduced frozen dessert having 30-40% - reduction in total energy compared to standard ice cream using aspartame and polydextrose. They reported that a usage level of aspartame between 0.05 – 0.1 % and a maximum of 12 % polydextrose produced an acceptable product.

Carbohydrate based bulking agents such as maltodextrin and polydextrose are currently used in reduced fat ice cream formulation because of minimal negative effects on ice cream production, shelf life and price (Soukoulis *et al*., 2009; Soukoulis and Tzia, 2010). Roland *et al*. (1999), stated that sensory analysis panel scored maltodextrin as the overall best single fat replacer in ice cream because of its good thickening and water binding properties.

Rothwell (1985), developed a formulation for diabetic and dietetic ice cream and comprising of 4 % milk fat, 15 % polydextrose, 0.5 % microcrystalline cellulose, 0.2 % sodium citrate, 11.3 % MSNF, 0.75 % stabilizer emulsifier blend and 0.075 % aspartame. Steinsholt and Longava (1985), suggested an acceptable low calorie ice cream product with 50 % less energy than standard ice cream. The ice cream contained 11 % MSNF, 4 % fat, 0.8 % stabilizer, 0.05 % aspartame and 12 % polydextrose and 1 % glycerol. Verma (2002), formulated a dietetic frozen dessert with 5 % milk fat, 12.5 % MSNF, 9.9 % maltodextrin, 9.3 % sorbitol, 1.5 % WPC, 0.3 % stabilizer emulsifier blend and 400 ppm aspartame. Whey protein concentrate (WPC) has been included in ice cream mix formulations for their contribution to favorable sensory and textural qualities. Functional characteristics of WPC such as water binding, emulsification and foaming are important in ice cream. Water binding is a property of WPC that can be utilized in frozen desserts to delay the development of coarseness (Morr, 1989). Pinto *et al*. (2007 a,b), reported that incorporation of WPC at 1.25% level in low-fat dietetic frozen dessert resulted in significant increase in protein content, however it did not show any significant influence on pH and acidity of mixtures. It increased viscosity and whipping ability of the mixtures. It resulted in improved overall acceptability scores compared to control which was prepared without addition of WPC. These authors reported that addition of WPC above 1.25% level in low-fat ice cream resulted in a foamy, frothy, fluffy, slightly slimy and sticky product.

To reduce the hardness of the product and get nearly the same freezing point depression as in standard ice cream various polyols such as sorbitol, lactitol, glycerol, etc. have been used. Sorbitol is used in frozen desserts for diabetics as a replacement for sugar. Sorbitol lowers the reezing point of frozen dessert and makes them softer and easier to scoop. Sorbitol is less prone to cause hyperglycemia (high blood glucose) due to conversion to fructose in the liver; however, its calorie content is equivalent to glucose (Kilara, 1991).

Loeser (1970), developed a low calorie ice cream using sorbitol and artificial sweeteners by replacing 1/3rd of sucrose with sorbitol by weight. Sorbitol is generally used in ice cream at levels of 1 to 5 % (Kilara, 1991). Morley and Ashton (1982), suggested that 10.8 % sorbitol is optimum to produce softness in ice cream. On the other hand Finny *et al*., (1978), obtained an ice cream with 3 % sorbitol. Several other polyols viz. lactitol, maltitol, xylitol, glycerol, etc. have also been used by several investigators in frozen desserts (Abril *et al*., 1982; Marco and Pearson, 1982; Palumbo *et al*., 1995; Kacchi *et al*., 1998). From the literature cited above the scope of employing polyols, especially sorbitol in dietetic frozen desserts is indicated especially for diabetic and health conscious people. This is mainly due to their low glycemic index.

In this study, an attempt was made to select appropriate proportion of different bulking agents viz. polydextrose, maltodextrin and sorbitol in manufacture of a low fat, sugar free frozen dessert with desirable sensory characteristics and to evaluate its physico-chemical characteristics.

MATERIALS AND METHODS

Selection of Bulking Agents

Two bulking agents were used in this study: polydextrose and maltodextrin. Sorbitol was used as a freezing point depressant. For the selection of intense sweetener, four batches of mixes were prepared and sweetened with either, sucrose, aspartame, aspartame and acesulfame-K (1:1) and sucralose. It was found that samples sweetened with aspartame were criticized for having a sweet aftertaste which persisted in the mouth even after swallowing. Samples sweetened with combination of aspartame and acesulfame-K had a slightly harsh coarse

Table 1. Basic formulation of the frozen dessert.

Sr. No.	***Ingredients***	***Rate (%)***
1.	Milk fat	1.50
2.	Sunflower oil coconut oil blend (80:20)	3.00
3.	Sucrose	15.0
4.	MSNF	11.75
5.	WPC	1.25
6.	Stabilizer	0.25
7.	Emulsifier	0.25

Table 2 . Replacement level of sucrose with bulk fillers.

Levels	***Polydextrose (% w/w)***	***Maltodextrin (% w/w)***	***Sorbitol (% w/w)***	***FPD factor***
C	-	-	-	15.0
R1	6	3	6	15.0
R2	7	2	6	15.6
R3	8	1	6	16.2

sweetening effect which was not liked by some judges. While samples sweetened with sucralose generally had the same sweetening characteristics as sucrose and most of the panelists could not distinguish between the two samples. Therefore, in the present study, sucralose was used as the artificial sweetener. Sucralose was added to give the mixtures a calculated relative sweetness level similar to the control sample containing 15 % sucrose. The required quantity of sucralose was mixed with about 50 times its weight (w/w) of water and mixed thoroughly and added to the mixture just before freezing.

The mixtures were formulated to contain the formulation given in Table 1. The control (C) contained 15 % sucrose. Based on preliminary investigations the rates of usages of bulking agents decided were as given below in Table 2. The levels of bulk fillers were selected on the basis of preliminary trials. Sucralose was used as the sweetener. The sweetness in the final product was adjusted taking the relative sweetness of sucralose (600) and sorbitol (0.5) into account.

The quantity of polydextrose, maltodextrin and sorbitol was chosen to get about the same freezing point depression as sucrose i.e. 15. Because sugars do not dissociate in solutions the freezing point of solutions of different sugars can be computed from the concentration and molecular weight. The relative freezing point depression factor of sucrose is taken as one. With a given weights and volumes of solvent the effect of freezing point will be inversely proportional to the molecular weight. Thus, a single molecule of sucrose weights nearly twice as much as glucose and lowers the freezing point only about one half as much. The freezing point depression factor of polydextrose is 0.6 vs. sucrose at 1 (Prasad, 2006) and that of sorbitol is 1.9 (Flack, 1988). Maltodextrin does not contribute directly to the freezing point depression since their molecular weight makes them relatively insoluble (Tharp, 1991).

Frozen Dessert Manufacture

The experimentation involved making of 4 batches of frozen desserts i.e. C, R1, R2 and R3. Each treatment was replicated 4 times. The mixtures were heated to 80^{o} C, homogenized in a clean and sanitized double stage homogenizer (Pal Engineering Ltd., Ahmedabad) at 100 kg/cm^{2} and 35 kg/ cm^{2} pressure in the first and second stage respectively and again pasteurized by holding the mixture at 80^{o} C for 5 min. The pasteurized mixtures were then immediately cooled to about 3-4^{o} C and aged at this temperature for overnight.

The mixture (3.5 kg) was frozen in a motor driven home made ice cream freezer having a capacity of 8 kg. The passage surrounding the metal cylinder was filled with broken ice pieces and coarse salt (25 – 30% of the ice). After assembling the freezer, the beater cum scrapper assembly was revolved with the help of the attached motor fitted to a v-belt at 100-120 rpm by switching on the motor for 10 to 15 min. till the mixture was frozen to the desired consistency as sensed by an increase in the load on the motor and slippage of the belt. Samples of frozen

Skim milk (mixed) + cream
↓
Preheating 40-45° C
↓
Filtration
↓
Addition of sorbitol (70 % liquid)
↓
Heating to about 50° C
↓
Mixing of dry ingredients (WPC, SMP, Polydextrose, Maltodextrin, GMS)
↓
Addition of dry ingredients
↓
Addition of sunflower oil coconut oil blend
↓
Addition of sodium alginate mixed with sugar at 65° C
↓
Heat to 80° C
↓
2 stage homogenization i.e. 100 kg/cm^2 and 35 kg/cm^2
↓
Pasteurization at 80° C for 5 min
↓
Cooling immediately to 3-4°C
↓
Ageing (3-4° C for 4-12 h)
↓
Addition of sucralose (in form of a solution, dissolved in 50 X its wt. of water) and required amount of Vanilla flavour
↓
Freezing (air pressure 10 psi, 2 min at the right consistency, drawing temperature -4.5 to -5° C/ 10-15 min)
↓
Filling in polystyrene cups
↓
Hardening (-18 ± 2° C) overnight
↓
Storage (-12 to -15° C)

Figure 1. Flow chart for manufacture of the dietetic frozen dessert .

desserts after 24 h of hardening at -18 ± 2° C in hardening room were tempered at -12 ± 2° C before being evaluated for organoleptic characteristics by a panel of trained judges from the faculty. The drawing temperatures of all ice creams were in the range of –4.0 to –5.0°C. The flowchart for manufacture of the frozen dessert is given in Figure 1.

ANALYSIS

The frozen dessert mixtures were analyzed for their fat content and titratable acidity as suggested in ISI Hand Book (1989), the total solids of mixture was determined by the standard procedure using a Mojonnier Milk Tester (Model D, Mojonnier Brothers Co., Chicago, USA) according to the standard procedure described in Laboratory Manual (Laboratory Manual, 1959). The pH of the frozen dessert mixtures was determined using a Systronic digital pH meter, Model 335, Systronic Ltd., Ahmedabad, India at 25° C. The protein content of the frozen dessert mixtures was determined by semi micro Kjeldahl method (Menefee and Overman, 1940).

Table 3. Influence of addition of bulk fillers at different rates on the average compositional characteristics, pH and acidity of frozen products mixtures.

Level of bulk fillers in the mixture	*Fat (%)*	*Protein (%)*	*Total solids (%)*	*Titratable acidity (%, lactic acid)*	*pH*
C	4.60±0.05	5.19±0.02	32.93±0.11	0.214±0.00	6.31±0.04
R1	4.55±0.05	5.20±0.04	32.77±0.12	0.209±0.01	6.42±0.05
R2	4.56±0.06	5.18±0.05	32.81±0.14	0.209±0.01	6.43±0.02
R3	4.58±0.04	5.19±0.08	32.80±0.09	0.212±0.01	6.42±0.03
CD (0.05)	NS	NS	NS	NS	NS

- R1 = 6% polydextrose, 3% maltodextrin, 6% sorbitol; R2 = 7% polydextrose, 2% maltodextrin, 6% sorbitol, R3 = 8% polydextrose, 1% maltodextrin, 6% sorbitol
- Figures given in table represent average ± SD of 4 replications
- CD (0.05) = Critical difference at 5% level of probability.

The viscosity of the frozen dessert mixtures was determined using a 'Haake' Viscosimeter (Model VT-550. Gebr, HAAKE GmbH, Germany). The viscosity readings were taken after ageing mixtures at 3 ± 2^o C for about 24 h. Whipping ability was determined by the method of Neshawy *et al*. (1989). The specific gravity of the ice cream and frozen dessert mixtures was determined at 20^o C using a specific gravity bottle according to the method described by Ling (1963). The overrun was determined as per the method given by Sommer (1951). A known volume of mixture was weighed accurately (W1) and then the same volume of frozen dessert was weighed (W2) and the overrun was determined as follows: % Overrun = ((W1-W2)/W2)*100.

The method given by Loewenstein and Haddad (1972), as modified by (Upadhyay *et al*., 1978) was employed for evaluating the ice cream for its melting characteristics. The hardness of the hardened frozen product was measured using FPN3 cone penetrometer (Associated Instrument Manufacturers Pvt. Ltd., India). All the samples were analyzed for Standard Plate Count (within 2 h of hardening) by the method described by Indian Standards (ISI, 1964).

The frozen product samples were tempered to -12±2 ^{o} C for 1-2 h before serving. All the samples were coded with a 3 digit random number, and all orders of serving were completely randomized. The frozen products was subjected to sensory evaluation using a modified version of ADSA ice cream score card (Bodyfelt *et al*., 1988). The ADSA scorecard has been developed by the American Dairy Science Association (Bodyfelt *et al*., 1988). The highest marks that can be given to a product in each of the scorecard categories to the product that meets the standard of ideal ice cream. No defect is recognized or marked when "perfect" score is awarded. The maximum marks that can be allotted to flavor is 10, body and texture is 5, color, appearance and package is 5, melting quality is 3 and bacterial content is 2. The maximum total score is 25. The statistical analysis of the data was carried out as per (Steel and Torrie, 1980) using completely randomized design.

RESULTS AND DISCUSSION

Effect of Addition of Bulk Fillers at Different Rates on the Compositional Attributes, Acidity and pH of Frozen Products Mixtures

The levels of polydextrose, maltodextrin and sorbitol selected in this study were based on preliminary trials. In preliminary trials it was noticed that when polydextrose was added at levels greater than 8% (w/w of mixture), the product was criticized for weak body and lacking sufficient mouth-feel. On the other hand when maltodextrin was used at levels higher than 3% (w/w of mixture), the frozen dessert was very heavy, sticky bodied and was criticized as having an objectionable doughy flavour and was also criticized as being ropy. Based on preliminary studies, it was found that addition of sorbitol at 6% level did not have any adverse effect on flavor of the product and was found to be optimum.

Incorporation of bulking agents like sorbitol, polydextrose, could influence some of the properties of the mixture like acidity and pH values. The control (C) as well as the experimental samples R1, R2 and R3 were analyzed for their fat, protein, total solids, acidity and pH values. The results were statistically analysed and are presented in Table 3.

As seen from the table, the composition of each frozen dessert mixture satisfactorily met the requirements of the experimental plan. As can be seen from the table there were very minor variations in all the components of the mixtures analyzed. The total solids of all the experimental samples varied from 32.77 in R1 to 32.81 in R2 and were slightly lower than that of control i.e. 32.93. Similarly the fat contents of all experimental samples were in the range 4.55 (R1) to 4.58 (R3) and were very marginally lower than that of control i.e. 4.60.

The marginal decline in total solids and fat content of the experimental samples was not found to be statistically significant compared to control (P > 0.05). Also there was no significant differences in the protein content, titratable acidity and pH amongst all the samples (P > 0.05).

Table 4. Influence of addition of bulk fillers at different rates on the viscosity and whipping ability of frozen product mixtures.

Level of bulk fillers in mixture	*Viscosity at 7 ^{0}C (m Pa.s)*	*Whipping ability (cm^3/g) after a period of:*		
		0 min	*3 min*	*5 min*
C	55.82±5.57	0.888±0.001	1.226±0.000	1.203±0.001
R1	69.01±5.41	0.889±0.000	1.183±0.001	1.140±0.003
R2	61.76±6.02	0.891±0.002	1.260±0.003	1.217±0.002
R3	57.70±5.12	0.892±0.001	1.268±0.003	1.228±0.000
CD (0.05)	2.72	NS	0.021	0.033

- R1 = 6% polydextrose, 3% maltodextrin, 6% sorbitol; R2 = 7% polydextrose, 2% maltodextrin, 6% sorbitol, R3 = 8% polydextrose, 1% maltodextrin, 6% sorbitol.
- Figures given in table represent average ± SD of 4 replications.
- CD (0.05) = Critical difference at 5% level of probability.

Replacement of sucrose with bulk fillers did not affect the compositional characteristics of the mixture in any way. A marginal reduction in total solids was observed by replacing sucrose with polydextrose, maltodextrin and sorbitol in varying amounts. In a similar study, no significant differences were observed by Verma (2002) in the compositional attributes, pH and acidity when sucrose was replaced with maltodextrin and sorbitol. Abdou *et al*. (1996), also reported no significant effect on composition of mixtures when sucrose was replaced with a combination of polydextrose and aspartame. The slight decrease in the total solids content in experimental mixtures may be due to the moisture content of the dry ingredients used i.e. polydextrose and maltodextrins. Polydextrose was found to be very hygroscopic in nature.

Effect of Addition of Bulk Fillers at Different Rates on the Viscosity of Mixtures

Viscosity has been considered an important property of ice cream mixtures and up to a certain extent it seems essential for proper whipping and retention of air cells. The viscosity of mixture is also affected by the composition, especially, fat, protein and stabilizer and the quality of ingredients used. Hence, the aged mixtures were subjected to viscosity test. During preliminary trials, it was noticed that polydextrose provides creaminess to the product but does not give the required body effect, giving a slightly weaker body where as maltodextrin improves the consistency of the product but at higher levels (i.e. more than 3 % level) the product tended to become ropy and slimy which gives highly adverse effect on the body and texture characteristics of frozen desserts, making even rejection of the product. The results obtained are presented in Table 4.

There was progressive increase in viscosity of mixtures with increase in level of maltodextrin and decrease in level of polydextrose. The viscosity of control was minimum that is 55.82 m Pa.s, while that of experimental samples varied between 69.01 (R1) to 57.70 (R3). Thus, addition of bulk fillers, in general resulted in increased viscosity of the mixtures.

Though, the bulk fillers in frozen dessert mixtures increased the viscosity, R3 and C were statistically alike ($P > 0.05$). The viscosity of R1 was significantly higher than all the other samples ($P < 0.05$). In all the other experimental samples (R1 and R2), there was significant increase in viscosity compared to C. There was significant variation in viscosity of all experimental mixtures. The combination of 6 % polydextrose and 3 % maltodextrin (that is R1) was found to give significantly higher viscosity compared to all the other samples. Further, there was significant decrease in viscosity from R1 to R3. Thus, the significant decreasing pattern in the viscosity of experimental mixtures was associated with increase in the level of polydextrose and decrease in the level of maltodextrin.

The structure of maltodextrin is such that they have water controlling function in addition to providing bulk. In that respect their use as partial replacement of sugar solids can supplement the role of stabilizer in controlling the elevated water levels in calorie reduced frozen desserts (Tharp, 1991). A positive effect of inclusion of maltodextrin would be to enhance the body of the product through the binding of water by the high molecular weight carbohydrates it provides. It is well documented that maltodextrins can play a key role in improving viscosity of the mixture and mouth feel (Dorp, 1994). However, at higher rates of addition of maltodextrin the product was found to give a ropy and slimy characteristic which was disliked by the judges. Cottrell *et al*. (1980), also indicated that polysaccharides such as starch, restricted ice crystal growth during storage and increased mixture viscosity. Patel *et al*. (2009), reported that addition of sago in gelatinized form increased the viscosity of ice cream mixtures. Cody *et al*. (2007), indicated that addition of rice flour increased the viscosity of ice cream mixtu-

Table 5. Influence of addition of bulk fillers at different rates on the overrun melting characteristics and hardness of frozen products.

Level of bulk fillers in mixture	***Overrun (%)***	***Quantity of frozen dessert melted in 40 min at 37.5° C from 100 g (g)***	***Inverse of hardness (1/10th mm)***	***Average SPC/g frozen dessert (log cfu)***
C	59.93±1.5	42.68±2.1	124.5±4.7	4.674 (47200)
R1	54.50±2.4	43.08±4.0	119.0±7.1	4.722 (52700)
R2	62.58±2.9	44.19±3.5	122.8±6.2	4.753 (56600)
R3	61.40±3.1	44.58±2.9	123.5±4.9	4.746 (55700)
CD (0.05)	1.901	NS	NS	NS

- R1 = 6% polydextrose, 3% maltodextrin, 6% sorbitol; R2 = 7% polydextrose, 2% maltodextrin, 6% sorbitol, R3 = 8% polydextrose, 1% maltodextrin, 6% sorbitol
- Figures given in table represent average ± SD of 4 replications
- CD (0.05) = Critical difference at 5% level of probability
- Cfu = colony forming unit, figures in parenthesis show the actual cfu values.

res. Abdou *et al*. (1996), observed only slight increase in the viscosity of frozen dessert mixtures containing polydextrose, which was not found significant. Verma (2002), observed marked increase in viscosity of mixtures with increased levels of maltodextrin. Thus, the fact that maltodextrin cause the increase in viscosity as was observed in the present study is substantiated by the above reported literature.

Effect of Addition of Bulk Fillers at Different Rates on the Whipping Ability of Mixtures

The whipping ability of mixtures is an important property because of its relation to the quality of the frozen dessert and profit. Whipping ability of the mixtures is affected by composition of the mixture, ingredients used especially surfactants/ emulsifiers, history and processing of the mixture, and the freezing process. Hence, the whipping ability of aged mixtures were monitored. These tests were carried out after aging the mixtures for 24 h at 3 ± 2 °C. Sugar decreases the whipping ability except when added after homogenization (Arbuckle, 1986). Replacement of sucrose with bulk fillers could affect the whipping properties of mixture.

Table 4 depicts the average values of the whipping abilities of frozen dessert mixtures (C, R1, R2 and R3) expressed as specific volume (cm^3/g). The average values of specific volume of unwhipped samples showed a slight increase from 0.888 for C to 0.892 for R3. The trend of rise in specific volume up to 3 min. whipping and the subsequent decrease at 5 min whipping was similar to the one observed earlier. However, it can be observed clearly from the table that at the highest level of maltodextrin and lowest level of polydextrose used in this study (R1) the whipped volume (cm^3/g) decreased over control. Further, with increasing the level of maltodextrin and increasing the level of polydextrose the increase in whipping ability was also noticed.

The statistical values arrived at on the basis of data depicted in Table 4 indicated a significant effect of addition of bulk filler on the specific volume. After 3 min of whipping R3 and R2 had significantly ($P < 0.05$) higher specific volumes than C and R1 but both being at par with each other statistically ($P > 0.05$). The control also had significantly higher specific volume than R1 ($P < 0.05$). Thus, improvement in whipping ability was statistically established at R2 and R3 levels. After 5 min a significant decrease ($P < 0.05$) in whipping ability in R1 was observed. The significant improvement in the whipping ability was observed in R2 compared to R1. Samples C, R2 and R3 were statistically indistinguishable ($P > 0.05$).

The reason for the marginal increase in whipping ability may be due to increase in viscosity of mixtures caused by the stabilizer which would have improved the whipping ability of such mixtures. In this study presence of WPC may have contributed to the slight increase in the whipping ability. Marshall and Arbuckle (1996) stated that certain level of viscosity is necessary for suitable whipping and retention of air in the ice cream freezer; as the viscosity of the ice cream mixture is raised, the resistance to melting and the smoothness of body increases, but the whipping rate decreases. A certain ice cream mixture viscosity cannot predict the outcome of the texture of ice cream. Generally speaking, ice cream mixture with high viscosity accompanies good textured ice cream. To achieve the desired ice cream mixture viscosity, the mixture must be properly balanced for composition, concentration and quality of ingredients and then appropriately processed.

An increase in whipping ability of the mixtures with increase in the viscosity of mixtures has been reported and discussed earlier. In this part of the study it may be held true, at least partly for R2 and R3 having higher whipping ability over the control. R1, having the highest viscosity was found to contain lower whipped volume compared to all the other samples; in both cases i.e. after 3 and 5 min of whipping.

The whipping ability of mixtures may generally depend on the stability of air bubbles incorporated. Excessive viscosity as was observed in R1 (69.01 m Pa.s) might be hindering the incorporation of air and thus reduced whipped volume. Further, the air lamellae formed and its structure, decided by the bulk fillers employed in this study might also be responsible for the observed effect of viscosity and whipping ability. Excessive increase in viscosity of mixtures (Table 4) also causes slow whipping and can adversely affect the whipping ability (Bhandari, 2001).

Effect of Addition of Bulk Fillers at Different Rates on the Overrun of Frozen Products

The overrun of a frozen dessert is an important property since it directly has relation with the yield and profit. It also affects the body, texture and palatability of the final product. The major physical characteristics of frozen desserts that concerns regulatory agencies is weight per unit volume of the product, and this is affected by the overrun developed in the product.

As is evident from Table 5, the overrun of control was 59.93 %. The overrun of R1 was lower than control and that of R2 and R3 were higher than control.

From the critical difference calculations displayed in Table 5, it can be seen that the overrun of R2 and R3 were at par with each other statistically ($P > 0.05$) and the overrun of C and R3 were also statistically undistinguishable ($P > 0.05$). Control had significantly ($P < 0.05$) lower overrun than R2 while R1 had significantly lower overrun than all the other samples analyzed ($P < 0.05$). Thus, mixtures containing 3 % maltodextrin and 6 % polydextrose obtained the lowest overrun.

The overrun as discussed earlier would depend on the stability of the foam/ air bubbles incorporated. Hence, the same discussion for overrrun may be in part responsible for the observed behavior. Verma (2002), noticed an increase in viscosity with increase in the level of maltodextrin as was observed in the present study (R3 to R1) (Table 5).

However, he observed that the overrun of the product increases with the increase in viscosity up to a limit and above certain level of viscosity; he also observed a drastic reduction in overrun. Thus, it is in agreement with the present study.

Effect of Addition of Bulk Fillers at Different Rates on the Melting Resistance of Frozen Products

Ice cream should melt down to a liquid of smooth consistency, suggestive of a rich cream. Meltdown is an important property of ice cream affecting its sensory quality. It is important from at least two main points of view – eye appeal and mouth feel – which may differ according to the type of ice cream (Flack, 1988). It is also important that the ice cream is not too hard or should not melt quickly. Ice cream with desirable melting quality begins to show definite melting within 15-20 min of having being dipped and placed at room temperature. The melted product flows readily and forms a homogenous fluid with the appearance of unfrozen mixture and with little foam (Marshall *et al*., 2003). Deviation in the melting property from ideal condition can make the ice cream defective (Sommer, 1951). Hence, the melting resistance of control as well as of experimental samples were monitored.

The control as well as the experimental samples (R1, R2 and R3) were analyzed for their melting resistance in terms of grams of frozen dessert melted in 40 min at 37.5^{o} C per 100 g frozen dessert. All the experimental samples had higher melting rate compared to control. The meltdown of experimental samples were in the range of 43.08 (R1) to 44.58 (R3) as against 42.68 g of frozen dessert melted in 40 min at 37.5 °C for control.

From the critical difference values given in Table 5 it can be seen that none of the samples could be distinguished statistically ($P > 0.05$) with respect to their melting rates. Verma (2002), reported insignificant effect of maltodextrin on the melting rate. Abdou *et al*. (1996) and Roland *et al*. (1999), also observed almost no difference in melting rates between samples containing sucrose, maltodextrin and polydextrose in general. Interestingly, the freezing point depression factor of R3 was slightly lower than R1 (i.e 15 vs. 16.2) and this could also be one of the reasons for its slightly higher meltdown compared to R1. Similar observations are obtained for R2 compared to R1. Specter and Setser (1994), reported that sugar free ice cream containing polydextrose had a tendency towards poor meltdown. In this study, the level of polydextrose increases from R1 to R3, giving increased meltdown. Thus, the observed effect of bulk fillers on melting resistance could be explained on the basis of literature at least partly.

Effect of Addition of Bulk Fillers at Different Rates on the Hardness of Frozen Products

Hardness of the product at the temperature at which it has the optimum consistency for dipping or scooping is an important consideration. Hardness is affected by several factors: principally melting point, total solids, overrun, amount and type of stabilizer, etc. When an ice

Table 6. Influence of addition of bulk fillers at different rates on the sensory attributes of frozen products.

Level of bulk filler in mixture	***Flavour score (max. 10)***	***Body and texture score (max. 5)***	***Colour, appearance and package score (max. 5)***	***Melting quality score (max. 3)***	***Total score (max. 25)***
C	7.69±0.11	4.06±0.15	4.02±0.11	2.52±0.09	20.29±0.29
R1	7.06±0.15	3.52±0.12	4.10±0.10	2.15±0.07	18.83±0.25
R2	7.40±0.19	4.10±0.18	4.25±0.16	2.46±0.10	20.21±0.31
R3	7.35±0.17	3.88±0.16	4.23±0.00	2.33±0.05	19.79±0.24
CD	0.270	0.301	0.148	0.223	0.441

- Full marks 2/2 were awarded for bacterial count.
- R1 = 6% polydextrose, 3% maltodextrin, 6% sorbitol; R2 = 7% polydextrose, 2% maltodextrin, 6% sorbitol, R3 = 8% polydextrose, 1% maltodextrin, 6% sorbitol.
- Figures given in table represent average ± SD of 4 replications
- CD (0.05) = Critical difference at 5% level of probability.

cream store keeps several containers of product in a single cabinet from which each is to be dipped or scooped, only one temperature setting is available. Therefore, it is desirable to have the melting points and overruns of all the flavours of ice cream nearly the same. This is not easy to accomplish because formulae involve several variables that affect the concentration of the dissolved substances, and therefore, the melting point. Freezing and melting point decrease as the concentration of water soluble substances increase. The ice cream formulator must carefully choose the amounts and type of ingredients because they affect the freezing point of the mixture. Considering this, the hardness attribute was incorporated in this study.

Table 5 depicts the average hardness of sample. The values given in the table indicate that there was a very slight increase in the hardness of the samples with increasing levels of maltodextrin (1.0 to 3.0 % i.e. R3 to R1). The hardness values were in the range 124.5 in C to 119.0 in R1. However, the frozen dessert product containing 3.0 % maltodextrin (highest in this study) and the lowest level of polydextrose in this study i.e. 6.0 % was found to give a harder frozen product compared to the control as well as R2 and R3, though very slightly.

None of the frozen desserts could be distinguished statistically ($P > 0.05$) with respect to the hardness as revealed by the pertaining statistical analysis.

However, the hardness could depend on the overall structure of the product. Incorporation of bulk fillers (maltodextrin) was generally found to increase the hardness of the frozen dessert compared to control, though marginally, which may be in part due to the superior ability of maltodextrin to bind water (Tharp, 1991). However, increasing the level of polydextrose from 6 to 8 % and decreasing the level of maltodextrin from 3 to 1 % was found to decrease the hardness which may be again attributed to the structure obtained by incorporating them into the mixtures. Verma (2002), observed a slight decrease in penetrometer reading (that is increase in hardness) by increased addition of maltodextrin, the same was observed in this study which was insignificant statistically.

Effect of Addition of Bulk Fillers at Different Rates on the Sensory Attributes of Frozen Products

The fate of any food product has always rested on the acceptance of the product by the consumers. The quality of the frozen desserts judged by consumers rests on its flavour, body and texture characteristics, melting behavior and to some extent its colour. Keeping in view these aspects, the sensory quality of the ice cream samples were adjudged by a panel of 6 judges using the score card recommended by Bodyfelt *et al*., (1988). The frozen desserts were served in lidded plastic cups at -12 to -14^{o} C.

The serving order was randomized. The results presented in Table 6 represent the influence of addition of WPC on the organoleptic attributes of the frozen products (that is scores for flavour, body and texture), melting quality, colour and bacterial count, the maximum scores allotted were 10, 5, 3, 5 and 2, respectively. Full marks (that is 2/2) were given for bacterial count in the score card.

The panelists were requested to give their critical comments for sweetness, richness, smoothness and whiteness of the product.

To identify a bulk fuller for use in sugar free frozen dessert one must determine and quantify the sensory and physical attributes of the bulk filler. The objective of this part, therefore, was to identify and quantify the flavour, mouth feel appearance of these bulk fillers in comparison with these characteristics of 15 % sucrose frozen dessert. The sensory evaluation scores of all dietetic frozen desserts are listed in Table 6.

Flavour Scores

High quality vanilla ice cream should be pleasantly sweet, suggest a creamy background sensation, exhibit a delicate vanilla flavour, and leave a most pleasant, but brief, rich aftertaste. The flavour intensity of the vanilla, the sweetener and the various ingredients should not be so pronounced that, when first tasted, one component of the overall flavour seems to predominate over the others. All the ingredients should blend to yield a pleasant, balanced flavour (Bodyfelt *et al*., 1988). Flavour is the single most important characteristic in deciding the acceptability of any product. The flavour score of all the samples varied in a narrow range of 7.06 (R1) to 7.69 (C). Further, it can be observed that flavour profile wise the preferred sequence was C > R2 > R3 > R1.

All the samples except R2 and R3 could be distinguished statistically ($P < 0.05$). From the statistical analysis of the flavour scores obtained during this part of the investigation, the superiority of R2 and R3 is confirmed over R1. However, they scored significantly ($P < 0.05$) lower scores compared to control which was sweetened with only sucrose. Amongst the experimental samples, containing intense sweeteners in place of sucrose, R2 possessed the highest score being significantly ($P < 0.05$) higher than R1. However, the score of R2 was significantly ($P < 0.05$) lower than control.

As the level of maltodextrin in the sample increased it was criticized for doughy flavour and that is why sample R1 scored lowest flavour scores. The replacement of sucrose with sucralose could be judged by the panelists and the frozen desserts containing sucralose scored slightly lower marks than the control. Maltodextrins have a slightly masking effect on the 'milk flavour' which otherwise is imparted by polydextrose (Tharp, 1991). It was also found in this study that 7 % polydextrose and 2 % maltodextrin (R2) obtained highest score amongst experimental samples followed by R3 (containing 8 % polydextrose and 1 % maltodextrin). While R1 (containing 6 % polydextrose and 3 % maltodextrin) was preferred the least, giving powder like doughy flavour. Polydextrose is claimed to retain creaminess and impart the qualities of smoothness, appropriate texture and mouthfeel in low calorie ice cream and frozen desserts (Jana *et al*., 1994). Abdou *et al*. (1996), could not observe any effect of substitution of milk fat by hydrogenated palm kernel oil and polydextrose and aspartame in place of sucrose on organoleptic properties of ice cream. Verma (2002), observed an increasing trend in the sensory score with increase in maltodextrin level with respect to flavour, body and texture, melting quality and overall acceptability. However, they varied the level of fat, sorbitol and WPC along with the level of maltodextrin.

Hence, it may be the combined effect responsible for the observed behavior. Further, the type of maltodextrin employed by them and that which was utilized in this study may also be, at least partly, responsible for the changes observed in flavour score. These differences may be ascribed to the differences in the composition of the inherent mixtures used and the types of bulking agents used.

Body and Texture Scores

The ideal body of a frozen dessert is sufficiently firm to give the sensation of abundant solid matter in the product, yet not so firm as to restrict easy dipping at the usual temperature. The product does not stick to the dipper or break apart when dipped. Texture of the ideal frozen dessert should be velvety smooth and creamy. Neither ice crystals nor air cells are large enough to be detected by the tongue. The mouth is not coated with fat or any other substances on expectoration of the sample (Marshall *et al*., 2003). A coarse texture is the most frequently cited defect in ice cream (Marshall and Arbuckle, 1996). Body and texture are important criteria for the evaluation of ice cream and frozen desserts. The importance of body and texture to consumer acceptance and sales of ice cream and related products is unquestioned. The effect of addition of bulk fillers at different rates in sugar free frozen desserts sweetened with sucralose on the body and texture scores is presented in this section.

From the body and texture score point of view, the R2 obtained the highest score of 4.10 followed by C scoring 4.06. The frozen dessert containing 3.0 % maltodextrin and 6.0 % polydextrose (R1) obtained the minimum score of 3.52, while R3 contained medium score between R1 and R2. It can also be seen from Table 6 that the body and texture scores of control, R2 and R3 were undistinguishable statistically ($P > 0.05$) while R1 had significantly lower scores than all the other frozen products ($P \leq 0.05$). However, body and texture score wise, though R2 scored the highest marks, C and R2 were at par statistically ($P > 0.05$).

In general, R3 was criticized for having a slightly weak body whereas R1 was severely criticized for having a ropy body. R2 had a creamy body with a good mouth feel. There is no single bulk filler which has all the desirable properties. Therefore, a balance of bulk fillers can be used which give the optimum body and texture to the dietetic frozen product. From this part of the study it is established that the use of bulk fillers at R2 level i.e. 7 % polydextrose, 2 % maltodextrin and 5 % sorbitol gave the optimum body and texture characteristics to the dietetic product which is comparable to control, though having a very marginal edge over it.

Colour and Appearance Score

The colour of vanilla ice cream or ice milk should be attractive, uniform, pleasing, and typical of the flavour stated on the label. The shade of colour must reasonably

Table 7. Calculated calorific value of the dietetic frozen dessert mix vs. and average ice cream mix (per 100 g mix).

Sr. No.	*Ingredient*	*Dietetic frozen dessert (%)*	*Calories*	*Average ice cream (%)*	*Calories*
1.	Fat	4.5	39.55	11	96.69
2.	MSNF (approx. protein 36%, lactose 55%)	11.75	43.06	11	40.31
3.	WPC-70 (protein 71.09, fat 1.99)	1.25	4.01	-	-
4.	Sugar	-	-	15	58.05
5.	Maltodextrin	2	7.74	-	-
6.	Polydextrose	7	7.00	-	-
7.	Sorbitol	6	14.4	-	-
8.	Sodium alginate	0.25	0.96	0.20	0.77
9.	GMS	0.25	2.19	0.15	1.31
	Total calories		118.91		197.13

resemble the natural colour (carotene pigment) of cream, being neither too pale nor too vivid. Colour criticisms are generally resisted for vanilla-flavoured products (Bodyfelt *et al*., 1988).

The colour and appearance scores given in Table 6 indicate that R2 scored the highest i.e. 4.25 followed by R3 (4.23), C (4.02) and R1 (4.10). The statistical analyses reveal that R2 and R3 scored significantly higher scores than C and R1 ($P \leq 0.05$). Also the colour and appearance scores of C and R1 were at par ($P > 0.05$). All the products prepared with bulking agents were whiter than control sample. As the level of maltodextrin in the samples increased the sample was appreciated for being whiter in colour. Roland *et al*. (1999) also reported that maltodextrin sample was as white as 10 % fat ice cream. Polydextrose samples were more yellow (Roland *et al*., 1999). The combination of 2 % maltodextrin and 7 % polydextrose (R2) obtained the maximum score in this study. This may be attributed to the combined effect of maltodextrin and polydextrose.

Melting Quality

High quality vanilla ice cream should show little resistance toward melting when a dish is exposed to room temperature for at least 10 to 15 min. During the melting phase, the mixture should flow from the center portion (initially placed in the dish), as rapidly as it melts. The melted product should be expected to form a smooth, uniform and homogenous liquid in the dish (Bodyfelt *et al*., 1988). The effect of addition of bulk fillers at varying levels on the melting quality scores of home made dietetic frozen dessert is discussed and delineated in this section.

Though a very marginal variation was observed in the melting quality score between 2.15 (R1) to 2.52 (C), a decrease in the score was observed in R1 followed by an increase in R2 (2.46) and finally a decrease in R3 (2.33). The melting quality scores of control, R3 and R2 were statistically alike ($P > 0.05$).

R1 had the significantly lower melting quality scores than all the other samples.

R3 containing 3 % maltodextrin scored minimum marks in this study. The sample was criticized for its delayed melting quality. This may be attributed to the fact that maltodextrin binds water. However, improvement in the melting quality of R2 (containing 7 % polydextrose and 2 % maltodextrin) observed may be attributed to desired meltdown due to decreased level of maltodextrin from 3 to 2 % as well as the desirable effect of polydextrose.

Total Score

It can be seen from Table 6 that the total score of C was the highest i.e. 20.29 followed very closely by R2 scoring 20.21. These were followed by R3 and R1 scoring minimum marks. From the relevant statistical analysis it can be noticed that the total score of R2 and R3 were at par with C ($P > 0.05$). The total score of R3 was significantly lower than all the other samples ($P < 0.05$). Polydextrose effectively compensated for functional properties that normally are conferred by sucrose and some that are conferred by milk fat (Specter and Setser, 1994).

Comparison of Energy Value of the Dietetic Frozen Dessert with an Average Ice cream

Ice cream is an excellent source of food energy. The fact that the constituents of ice cream are almost completely assimilated makes ice cream an especially desirable food for growing children and for people who need to put on weight. For the same reason, its controlled use finds a place in the diet of persons who need to reduce weight (Marshall *et al.*, 2003). The energy value was calculated by taking the energy value of fat, protein and carbohydrates as 8.79, 4.27 and 3.87 kcal/g respectively. The energy value for sorbitol and maltodextrin is 2.6 and 4 kcal/g respectively. Based on the above values, the energy value of an average ice cream mix containing 11% milk fat, 11% MSNF, 15% sucrose, 0.2% stabilizer and 0.15% emulsifier is 197.13 kcal/100g and the energy value of the frozen dessert was 118.19 kcal/100g (Table 7). Thus, the developed frozen dessert can be classified as a low calorie frozen desserts which needs 33% reduction in energy as compared to a standard frozen dessert like ice cream.

It is evident that amongst all the levels tried in experimental samples, R2 was preferred the most with respect to flavour, body and texture, colour and appearance, melting quality as well as total scores. Further, compared to control, R2 obtained higher scores for body and texture and colour and appearance. The total solids of both of them were almost similar. Hence a level of replacement of sucrose with 7 % polydextrose, 2 % maltodextrin and 6 % sorbitol was found suitable for use in sugar free low fat partially filled frozen dessert.

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