Effect of fat and sugar substitution on the quality characteristics of low calorie milk drinks

Shikha Mittal · Usha Bajwa

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Abstract The study was undertaken to develop low calorie functional milk drinks using inulin and sucralose as fat and sugar substitutes, respectively. Cardamom was incorporated as a flavouring ingredient. The milk fat varied from 0.5 to 1.0%, sugar replacement from 0 to 100%, and inulin incorporation from 0 to 8%. The effect on total solids (TS), total soluble solids (TSS), specific gravity, viscosity and sensory scores was studied. Sugar replacement considerably decreased TS, TSS, viscosity and sensory scores. However, increase in inulin significantly improved these parameters. Addition of 4% inulin was found to impart viscosity and sensory properties equivalent to that of control (2% fat). The cardamom flavoured milk drinks were prepared by replacing sugar and adding 4% inulin in milk of 0.5% fat and 8.5% milk solid-not-fat. The calorific value decreased by 43% in the experimental milk drink compared to control.

Keywords Milk · Low calorie · Inulin · Sugar replacement · Sucralose · Viscosity · Sensory quality

Introduction

Budgeting calories and dieting have now become accepted social practices, representing conscious decisions to adapt eating patterns in pursuit of a healthier lifestyle (Barndt and Jackson 1990). Good tasting foods and beverages can be produced with the use of low calorie artificial sweeteners (Arora et al. 2001). Arora et al. (2007) used high-intensity

low-calorie sweeteners saccharin, acesulfame-K, sucralose and aspartame as a replacement for sucrose in the manufacture of *burfi*. The *burfi* sweetened with low calorie sweeteners ranked lower but was still acceptable in various textural attributes in comparison to the control with sucrose. Use of artificial sweeteners has also been allowed in sweets like *halwa*, *khoya*, *burfi*, *rasogolla*, *gulabjamun* and other milk products (Arora et al. 2006).

Codex (2005) has allowed the use of sucralose to a maximum limit of 300 ppm in dairy-based drinks, flavored and/or fermented and 250 ppm in dairy-based desserts e.g. ice-cream, ice milk, pudding, fruit or flavored yoghurt. Porto-Pinto et al. (2003) found sucralose suitable for use in formulations for low calorie dairy Mousses. Chocolate dessert containing sucralose had a 31% lower calorie content and acceptability of 79.2% compared with 89.9% for conventional chocolate product.

The viscosity of milk is a vital characteristic with regards to overall satisfaction. Whole milk has a creamy and heavy mouthfeel while low fat milks usually have a lighter and watery consistency. These differences in texture are caused by the milk fat (Phillips et al. 1995a). Food texture becomes especially important as customers look for food products containing reduced fat and calories but are not willing to accept lower eating quality. Inulin is a rheology modifier and can be used to enhance the organoleptic properties of foods. It can form a creamy, fat-like gel when dissolved in water (Silva 1996). Niness (1999b) stated that due to its longer chain length, inulin was less soluble in water than oligofructose and had the ability to form inulin micro-crystals when sheared in water or milk. These crystals were not accurately perceptible in the mouth, but they interact to form smooth creamy texture and provided a fat-like mouth feel. Tarrega and Costell (2006) found that skimmed milk samples of fat-free dairy desserts showed lower consistency

S. Mittal · U. Bajwa (✉)
Department of Food Science and Technology,
Punjab Agricultural University,
Ludhiana 141004 Punjab, India
e-mail: ushabajwa@rediffmail.com

and lower shear thinning than either whole milk or inulin-skimmed milk samples. Also, inulin addition increased viscosity values.

Villegas and Costell (2007), in a milk beverage model system, found that the viscosity of 3.1% fat whole milk could be approximated by skim milk with 4–6% long chain inulin. Villegas et al. (2007) studied the effect of adding different types of inulin (short chain, native and long chain) as a fat replacer in skim milk beverages. They found the whole milk and skim milk samples with added inulin were perceived as significantly thicker and creamier than samples without inulin. They concluded that the fat mimetic capacity of the inulin depended not only on the chain length, but also on the concentration of added inulin. Also, in order to obtain milk beverages with reduced fat content having similar thickness and creaminess to those perceived in whole milk beverages, it was necessary to add long chain inulin at concentrations greater than 8%. Clinical studies using commercial inulin demonstrated that regular daily consumption of 40–70 g has no adverse effects. A conservative ADI for inulin has been established at 40 g (Silva 1996). Being a soluble dietary fiber, it passes virtually unchanged into the large intestine where it shows “bifidogenic effect” and provides 1.5–2.0 kcal/g of useful energy (Niness 1999a). Considering the consumers expectation for foods to be low in fat, sugar and total calories and assured health promoting properties, present study was conducted to study the effect of fat and sugar substitution on the characteristics of low calorie milk drinks incorporating high potency artificial sweetener as a sugar substitute and ‘inulin’ as a functional ingredient.

Materials and methods

Milk was procured from Dairy Processing Plant of the university. It was separated at 35 °C in a cream separator (Elecram, France) to obtain skim milk. It was pasteurized and blended with the pasteurized standardized milk (4.5% fat) to achieve desired fat levels. The milk solids-not-fat (MSNF) was standardized to 8.5% using skim milk powder (Verka brand, Ludhiana, India). Long chain inulin (Beneo ST, degree of polymerization >10) of *Orafti –active food ingredients*, was procured as dry, amorphous powder, from DPO Food Specialities Pvt. Ltd, Mumbai. Cardamom, sugar and sucralose (*Splenda low calorie sweetener –minis*) in the form of mini tablets (containing 76.9% lactose, 11% sucralose, 10% alanine and 0.7% sodium) were purchased from local market. The sucralose tablets and black seeds of cardamom were powdered for use in experimental samples. A level of 660 ppm *Splenda* (equivalent to 72.6 ppm sucralose) was found to provide sweetness comparable to 6% sugar.

Effect of variables The effect of following variables was studied: Milk fat content- 0.5 and 1.0%; Dietary fibre ‘inulin’- 0, 2, 4, 6 and 8%; Level of sugar replacement- 0, 25, 50, 75 and 100% and Drink types: Control and low-calorie.

Preparation of blends Preliminary trials were conducted to optimize the level of sugar in milk drink. It was estimated by sensory evaluation using preference test (Ranganna 1994) whereby addition of sugar at 6% was perceived as most appropriate sweetness. Hence, 6% sucrose was used in control drinks for comparison with experimental samples prepared using sucralose. For replacement of sugar with sucralose, sweetness level was maintained equivalent to that of 6% sugar. A level of 660 mg/L *Splenda* equivalent to 72.6 ppm sucralose was found to impart sweetness that of 6% sugar.

Preparation of cardamom flavoured milk drinks The process of preparation of cardamom flavoured milk drinks (CFD) was optimised. Fat content was standardized to 2 and 0.5% for control and low calorie drink (experimental), respectively. Thereafter, 6% sugar was added in control drink and optimized levels of sucralose powder and inulin were added in low calorie drink. Cardamom powder (0.2%) was added in the drinks, heated to 65 °C and properly stirred to dissolve sugar and/or sucralose and inulin. The contents were filtered, homogenized at 2,500 psi, filled in sterilized glass bottles (200 ml), sealed, pasteurized (75 °C for 15 s), cooled, labelled and stored at 5.0±0.1 °C.

Physicochemical analyses For each parameter, the samples were analysed in three replications. Milk, sucralose tablets, inulin and prepared milk drinks were analysed for moisture content, total nitrogen and ash using AOAC (2000) methods. A conversion factor of 6.38 was used for milk and milk drinks. For estimation of fat content, Gerber’s method (BIS 1981) was used for milk drinks and Soxhlet method (AOAC 2000) for inulin and sucralose powder. Hand refractometer (Erma, Japan) was used to determine total soluble solids (TSS°B) of milk drink samples at 20 °C. Lane and Eynon method for determination of lactose as described by BIS (1981) was used to determine lactose content of milk drinks. Calorific value of the drinks was calculated by taking the sum of calories provided by the individual components. The pH of all the samples was determined using pocket pH meter (Model IQ 125, IQ Scientific, USA). The titratable acidity of milk and milk drinks was determined by titrating 10 ml of sample against 0.1 N NaOH and expressed as% lactic acid. Specific gravity of the drinks was measured at 20 °C using pycnometer (50 ml). Dynamic viscosity in centipoise (cP) of all the milk drinks was measured using the Hoppler Viscosimeter (design type BH2, Surrey, England) at 20 °C. The time of

fall of a ball in a cylindrical tube (internal diameter=15.94 mm) inclined by 10° with respect to the vertical plane and filled with the liquid to be examined, was measured. Ball no. 1 was used to measure the dynamic viscosities of the drinks. The time taken by the ball to fall from first annular mark to the last annular mark (distance of fall=100 mm) was recorded using a stopwatch. The dynamic viscosity was calculated using the following formula:

$$\eta = t X(\rho_1 - \rho_2) X K$$

where, η = dynamic viscosity in cP; t = fall time of the ball in sec (s); ρ_1 = density of the ball at measurement temperature in gcm^{-3} (ball no. 1=2.404 gcm^{-3}); ρ_2 = density of the sample liquid at measurement temperature in gcm^{-3} ; K = ball constant in $\text{cP.cm}^3 .\text{g}^{-1} .\text{s}^{-1}$ (ball no. 1=0.009956).

Sensory evaluation Paired comparison test as described by Ranganna (1994) was performed to determine the difference between the consistency, mouth-feel and sweetness of two types of milk drinks. In one drink, 6% sugar was used as sweetener whereas in other 100% sugar was replaced by sucralose to an equi-sweet level. The two samples were presented to 20 semi-trained panelists from the department and were asked to indicate if the samples were different in the specific sensory attribute i.e. consistency, mouthfeel and sweetness. A positive answer was required. Each of the attribute was tested for difference separately.

All the milk drink samples were evaluated for appearance/colour, flavour, consistency and mouthfeel and overall acceptability by 8 semi-trained panelists from the department using a 9-point hedonic scale (Meilgaard et al. 1999) with scores ranging from liked extremely (9) to disliked extremely (1).

Statistical analysis The data collected from the studies was subjected to analysis of variance (Snedecor and Cochran 1968) using CPCS1 software developed by the Department of Mathematics, Statistics and Physics of the university. The means were compared using Duncan's multiple range test (Duncan 1955).

Results and discussion

The proximate composition of milk used as control and sample preparation, inulin and commercial sucralose is presented in Table 1.

Effect of fat content on physico-chemical and sensory characteristics of milkdrink Total solids and TSS increased ($p<0.05$) with increase in fat content of milk (Table 2). This increase may be the contribution of MFGM's (milk fat globule membrane) proteins that participate in emulsion formation with the water in milk and hence influence the TSS of milk (Walstra and Jenness 1984). The specific gravity of the milk decreased while the viscosity of milk increased marginally with the increase in fat content. Fat is the lightest constituent of milk, the increase of which decreased the density of the product (De 1988). However, Phillips et al. (1995a) observed that increase in fat content of milk from 0.06 to 2% caused a corresponding increase in its viscosity. 2% fat milk (control) had a slightly higher appearance/colour score (8.4) than that of 0.5 and 1.0% fat milk. As reported by Miller (2000), appearance of whole milk and low fat milk varied greatly due to differences in fat concentration. The MFGM also has casein micelles emulsifying proteins that reflect light and contribute to the white appearance of milk. The flavour scores of the milk

Table 1 Proximate composition of milk, inulin and commercial sucralose

	Milk		Inulin	Commercial sucralose
	Control	Experimental		
Moisture, %	89.5	91.0	0.50	1.40
Total solids, %	10.5	9.0	99.5	98.6
Fat, %	2.0	0.50	ND	ND
Protein, %	3.2	3.26	ND	10.0
Ash, %	0.71	0.70	ND	0.70
Carbohydrates, % (by difference)	4.6	4.54	99.5	87.9
Titrateable acidity, % lactic acid	0.14	0.14	—	—
pH	6.6	6.6	—	—

ND Non-detectable, Control -2.0%fat, Sample-0.5%fat (n=3)

Table 2 Effect of fat content on physico-chemical and sensory characteristics of milk

	Fat, %			CD, 5%
	0.5	1.0	2.0	
Total solids, %	9.4 ^a	9.9 ^b	10.7 ^c	0.027
TSS, °B	7.0 ^a	7.4 ^b	7.9 ^c	0.137
Specific gravity	1.034	1.033	1.031	NS
Viscosity, cP × 10 ⁻²	189.9	198.1	208.0	NS
Appearance/Colour	8.4	8.4	8.4	NS
Flavour	8.1 ^a	8.2 ^{ab}	8.6 ^b	0.448
Consistency and mouthfeel	8.1	8.2	8.2	NS
Overall acceptability	8.2	8.3	8.4	NS

TSS Total soluble solids; NS non-significant; Values with different superscripts in a row (a, b and c) differ significantly ($n=3$ and 8, respectively for physico-chemical and sensory characteristics)

increased significantly ($p<0.05$). This might be due to the rich flavour imparted by fat. Fat enhances the flavour of whole milk by contributing naturally occurring flavour compounds that are removed from milk when fat is removed (Phillips et al. 1995b). The consistency and mouthfeel scores of milk did not differ significantly as the difference could not be perceived by panelists. On the other hand, Phillips et al. (1995a) had reported that the flavour and mouthfeel increased as the fat content of the milk increased from 0.06 to 2%. The overall acceptability scores of the milk were marginally higher for samples with more fat.

Effect of milk fat content and sugar replacement on total solids, viscosity and sensory scores Total solids content increased ($p<0.01$) with the rise in fat from 0.5 to 1.0%, however, it significantly ($p<0.01$) declined with higher levels of sugar replacement for both fat levels (Table 3). Also, there was a significant ($p<0.01$) loss in viscosity as sugar replacement increased to 100%. It was due to the loss in bulk that corresponded to the decrease in amount of sugar. Jenner and Smithson (1989) found viscosities of sucrose and sucralose solutions of same concentrations to be comparable. Thus, when sucralose was added to replace sugar in the milk at an equi-sweet level, very low amount was used and thus viscosity of the samples declined. The appearance scores didn't differ significantly with sugar replacement. Flavour scores were higher for 1% fat due to liking for rich taste of fat. For the drinks with increasing levels of sugar replacement, the sweet aftertaste of sucralose was perceived and thus the scores declined. Similar trend was observed for consistency and mouthfeel scores. With lowering fat content and with increase in replacement thin mouthfeel was perceived by the panelists. The overall acceptability scores also decreased ($p<0.01$) with the lowering in fat and increase in sugar replacement. The results indicated that by replacing 100% sugar with sucralose in 0.5% fat milk, a product of moderate liking could be prepared. Further, the quality and acceptability of the product could possibly be improved by the addition of some bulk improvers.

Increase in sugar replacement also caused a significant ($p<0.01$) reduction in the consistency and mouthfeel scores (Table 3). Stamp (1990) reported that using high intensity sweeteners to replace sucrose diminishes the bulking properties that sucrose provides to food. Since, the high potency sweetener replaced only the sweet taste of the sugar and lowered its bulk, therefore, the samples were perceived to have a watery mouthfeel. The overall acceptability scores declined in the same way. The 100% sugar replaced sample had an overall acceptability score of 7.6. Thus, full replacement of sugar by sucralose was undertaken for further experimentation.

Table 3 Effect of fat content and sugar replacement on total solids, viscosity and sensory scores of milk drink

Fat, %	Sugar replacement, %				
	0	25	50	75	100
Total solids, %					
0.5	15.4 ^{am}	13.9 ^{bm}	12.4 ^{cm}	10.9 ^{dm}	9.4 ^{em}
1.0	15.8 ^{an}	14.4 ^{bn}	12.9 ^{cn}	11.4 ^{dn}	9.9 ^{en}
Viscosity, cP × 10 ⁻²					
0.5	284.4 ^{am}	277.4 ^{bm}	256.8 ^{cm}	237.5 ^{dm}	232.1 ^{em}
1.0	296.6 ^{an}	289.3 ^{bn}	267.8 ^{cn}	247.7 ^{dn}	242.1 ^{en}
Appearance/Colour					
0.5	8.5 ^m	8.5 ^m	8.5 ^m	8.5 ^m	8.5 ^m
1.0	8.7 ⁿ	8.7 ⁿ	8.7 ⁿ	8.7 ⁿ	8.7 ⁿ
Flavour					
0.5	8.3 ^{am}	8.2 ^{abm}	8.0 ^{bm}	7.7 ^{cm}	7.2 ^{dm}
1.0	8.5 ^{an}	8.2 ^{bn}	8.1 ^{bn}	7.8 ^{cn}	7.5 ^{dn}
Consistency and mouthfeel					
0.5	8.3 ^{am}	8.2 ^{abm}	8.1 ^{bm}	7.8 ^{cm}	7.2 ^{dm}
1.0	8.5 ^{an}	8.2 ^{bn}	8.2 ^{bm}	7.9 ^{cn}	7.5 ^{dn}
Overall acceptability					
0.5	8.4 ^{am}	8.3 ^{am}	8.2 ^{am}	8.0 ^{bm}	7.6 ^{cm}
1.0	8.6 ^{an}	8.4 ^{ab m}	8.3 ^{bcm}	8.1 ^{cm}	7.9 ^{dn}

Values with different superscripts in a row (a, b, c, d and e) and in a column (m and n) differ significantly ($n=3$ and 8, respectively for physico-chemical and sensory characteristics)

Table 4 Effect of fat content and inulin on total solids, viscosity and the sensory scores of milk drink (sucralose, 72.6 ppm)

Fat, %	Level of inulin, %				
	0	2	4	6	8
Total solids, %					
0.5	9.0 ^{am}	11.0 ^{bm}	13.0 ^{cm}	15.0 ^{dm}	17.0 ^{em}
1.0	9.5 ^{an}	11.5 ^{bn}	13.5 ^{cn}	15.5 ^{dn}	17.5 ^{en}
Viscosity, cP × 10 ⁻²					
0.5	189.9 ^{am}	199.0 ^{am}	212.0 ^{bm}	242.7 ^{cm}	289.1 ^{dm}
1.0	198.1 ^{am}	210.8 ^{bm}	220.4 ^{bcm}	254.5 ^{cm}	298.7 ^{dm}
Appearance/Colour					
0.5	7.9 ^{am}	8.0 ^{bm}	8.1 ^{cm}	8.0 ^{bm}	8.2 ^{cm}
1.0	8.0 ^{an}	8.1 ^{abm}	8.1 ^{bcm}	8.2 ^{cdn}	8.2 ^{dn}
Flavour					
0.5	7.2 ^{am}	7.4 ^{bm}	8.0 ^{cm}	8.2 ^{dm}	8.3 ^{dm}
1.0	7.4 ^{an}	7.8 ^{bn}	8.2 ^{cn}	8.4 ^{dn}	8.4 ^{dm}
Consistency and mouthfeel					
0.5	7.0 ^a	7.3 ^b	8.0 ^c	8.1 ^c	8.3 ^d
1.0	7.1 ^a	7.5 ^b	8.0 ^c	8.1 ^c	8.4 ^d
Overall acceptability					
0.5	7.4 ^a	7.6 ^a	8.0 ^b	8.1 ^{bc}	8.3 ^c
1.0	7.5 ^a	7.8 ^b	8.1 ^c	8.2 ^{cd}	8.4 ^d

Values with different superscripts in a row (a, b, c and d) and in a column (m and n) differ significantly ($n=3$ and 8, respectively for physico-chemical and sensory characteristics)

Comparative effect of sugar and sucralose on the selected sensory characteristics of milk drinks (0.5% milk fat; 8.5% MSNF) Two samples of milk drinks, one with 6% sugar and the other with sucralose (72.6 ppm/660 ppm *Splenda*) were compared for the difference in the consistency, mouthfeel and sweetness using paired-comparison test. Although, the samples were different with respect to the three attributes under consideration, only 30% of the

panelists could perceive the sucralose containing sample having thinner consistency than the sugar containing sample. However, 75% of the panelists were able to detect the difference in the mouthfeel of two samples. They reported the sugar containing sample provided a better mouthfeel as compared to the other that was described as watery. For sweetness attribute, only 35% of the panelists perceived the difference and reported the sucralose containing sample having lingering sweetness.

Effect of fat and inulin content on the total solids, viscosity and the sensory scores of milk drink For both the fat levels, total solids and viscosity increased ($p<0.01$) as inulin incorporation was augmented from 0 to 8% (Table 4). Increase in viscosity with the incorporation of inulin could be attributed to the gel forming property of inulin with the water phase in milk. Villegas and Costell (2007) reported that viscosity of 3.1% fat whole milk could be approximated by skim milk with 4–10% short chain inulin, with 6–8% native inulin or with 4–6% long chain inulin. Also, Nagar et al. (2002) observed increased viscosity of the low fat yog-ice cream premix when inulin was added at 5, 7 or 9%. Tarrega and Costell (2006) reported that inulin addition increased the viscosity values of fat-free dairy dessert as compared to the skimmed milk samples without inulin.

Appearance scores improved significantly ($p<0.01$) with the increase in inulin as well as fat (Table 4). On the contrary, Aryana et al. (2007) reported that inulin addition did not affect colour and appearance of the fat-free plain yoghurt when added at 1.5% w/w of the yoghurt mix. A similar trend was observed for flavour scores which improved with higher fat and inulin content. This improvement was more prominent with augmented inulin than that with enhanced fat. Being low in acidity and acetaldehyde content, the inulin containing yoghurt was found to have significantly higher flavour scores than control (Aryana et

Table 5 Effect of inulin on the physico-chemical and sensory characteristics of milk drink

	Level of inulin, %						CD, 5%
	Control ^a	0	2	4	6	8	
Total solids, %	10.7 ^a	9.4 ^b	11.4 ^c	13.4 ^d	15.4 ^e	17.4 ^f	0.030
TSS, °B	7.89 ^a	7.0 ^b	9.0 ^c	10.8 ^d	13.1 ^e	15.0 ^f	0.139
Specific gravity	1.031 ^a	1.034 ^b	1.041 ^c	1.048 ^d	1.054 ^e	1.061 ^f	0.001
Viscosity, cP × 10 ⁻²	208.0 ^a	190.0 ^b	199.0 ^c	212.0 ^a	242.7 ^d	289.1 ^e	0.051
Appearance/Colour	8.2 ^a	7.9 ^b	8.0 ^{ab}	8.1 ^{ab}	8.0 ^{ab}	8.1 ^{ab}	0.311
Flavour	8.0 ^a	7.4 ^b	7.4 ^{ab}	8.0 ^{ab}	7.6 ^{ab}	7.6 ^{ab}	0.629
Consistency and mouthfeel	8.1 ^a	7.1 ^b	7.3 ^{bc}	7.9 ^{bc}	7.7 ^{abc}	7.6 ^{abc}	0.725
Overall acceptability	8.1 ^a	7.5 ^b	7.6 ^b	8.0 ^a	7.8 ^{ab}	7.7 ^{ab}	0.385

^a Milk fat=2.0% and MSNF=8.5%; Values with different superscripts in a row (a, b, c, d, e and f) differ significantly ($n=3$ and 8, respectively for physico-chemical and sensory characteristics)

Table 6 Effect of sugar replacement and inulin on total solids and viscosity of milk drink (0.5% fat)

Sugar replacement,%	Level of inulin,%				
	0	2	4	6	8
Total solids,%					
0	15.4 ^{ak}	17.4 ^{bk}	19.4 ^{ck}	21.4 ^{dk}	23.4 ^{ek}
25	13.9 ^{al}	15.9 ^{bl}	17.9 ^{cl}	19.4 ^{dl}	21.9 ^{el}
50	12.4 ^{am}	14.4 ^{bm}	16.4 ^{cm}	18.4 ^{dm}	20.4 ^{em}
75	10.9 ^{an}	12.9 ^{bn}	14.9 ^{cn}	16.9 ^{dn}	18.9 ^{en}
100	9.4 ^{ao}	11.4 ^{bo}	13.4 ^{co}	15.4 ^{do}	17.4 ^{eo}
Viscosity, cP×10 ⁻²					
0	284.3 ^{ak}	297.9 ^{bk}	317.4 ^{ck}	363.4 ^{dk}	386.5 ^{ek}
25	277.4 ^{al}	290.6 ^{bl}	309.6 ^{cl}	354.5 ^{dl}	379.5 ^{el}
50	256.8 ^{am}	269.0 ^{bm}	286.5 ^{cm}	329.0 ^{dm}	358.9 ^{em}
75	237.5 ^{an}	248.8 ^{bn}	281.1 ^{cn}	303.5 ^{dn}	339.6 ^{en}
100	232.1 ^{ao}	243.2 ^{bo}	273.3 ^{co}	296.7 ^{do}	334.2 ^{eo}

Values with different superscripts in a row (a, b, c, d and e) and in a column (k, l, m, n and o) differ significantly ($n=3$)

al. 2007). The increase in inulin concentration, in the study, caused a remarkable ($p<0.01$) increment in the consistency and mouthfeel scores of the milks. Earlier Aryana et al. (2007) observed that the yoghurts containing long chain inulin had better body and texture than the control. Also, Tarrega and Costell (2006) noticed that adding inulin to fat-

free dairy model desserts increased thickness and creaminess as compared to the full fat milk samples. The change in the overall acceptability scores of milk with varying fat was not significant while with increasing inulin concentration was significant ($p<0.01$). The scores of the two samples with varying fat and 4% inulin did not differ

Table 7 Effect of sugar replacement and inulin on sensory scores of milk drink

Sugar replacement,%	Level of inulin,%				
	0	2	4	6	8
Appearance					
0	7.9 ^{ak}	8.1 ^{bk}	8.2 ^{ck}	8.2 ^{cdk}	8.1 ^{bdk}
25	7.8 ^{al}	8.0 ^{bl}	8.2 ^{ck}	8.0 ^{bl}	8.0 ^{bl}
50	7.8 ^{al}	8.0 ^{bl}	8.1 ^{cl}	8.0 ^{bl}	8.0 ^{bl}
75	7.8 ^{al}	8.0 ^{bl}	8.0 ^{bm}	8.0 ^{bl}	8.0 ^{bl}
100	7.8 ^{al}	8.0 ^{bl}	8.0 ^{bm}	8.0 ^{bl}	8.0 ^{bl}
Flavour					
0	8.0 ^{ak}	8.1 ^{bk}	8.3 ^{ck}	8.2 ^{dk}	8.1 ^{bdk}
25	8.0 ^{ak}	8.1 ^{abk}	8.2 ^{cl}	8.2 ^{ckl}	8.1 ^{bek}
50	7.8 ^{al}	7.9 ^{bl}	8.2 ^{cl}	8.1 ^{cdl}	8.1 ^{dk}
75	7.7 ^{am}	7.9 ^{bl}	8.0 ^{cm}	8.0 ^{cm}	8.0 ^{cl}
100	7.5 ^{an}	7.8 ^{bm}	8.0 ^{dm}	7.9 ^{cdn}	7.9 ^{cm}
Consistency and mouthfeel					
0	7.8 ^{ak}	7.9 ^{bk}	8.3 ^{ck}	8.2 ^{dk}	8.2 ^{ek}
25	7.8 ^{ak}	7.9 ^{bk}	8.1 ^{cl}	8.2 ^{dk}	8.2 ^{dkl}
50	7.8 ^{al}	7.8 ^{al}	7.9 ^{bm}	8.1 ^{cl}	8.1 ^{clm}
75	7.7 ^{alm}	7.6 ^{bm}	7.9 ^{cn}	8.0 ^{dm}	8.1 ^{em}
100	7.7 ^{bm}	7.5 ^{an}	7.8 ^{co}	7.4 ^{dn}	8.0 ^{en}
Overall acceptability					
0	7.9 ^{ak}	8.0 ^{bk}	8.3 ^{ck}	8.2 ^{bek}	8.1 ^{bk}
25	7.9 ^{ak}	8.0 ^{bkl}	8.1 ^{cl}	8.1 ^{bek}	8.1 ^{bek}
50	7.8 ^{akl}	7.9 ^{alm}	8.0 ^{blm}	8.1 ^{bkl}	8.1 ^{bkl}
75	7.7 ^{alm}	7.8 ^{am}	8.0 ^{cm}	8.0 ^{ckl}	8.0 ^{bcl}
100	7.7 ^{am}	7.4 ^{bn}	7.9 ^{cm}	8.0 ^{cl}	8.0 ^{cl}

Values with different superscripts in a row (a, b, c and d) and in a column (k, l, m and n) differ significantly ($n=8$ panelists)

Table 8 Effect of sugar replacement on the sensory characteristics of cardamom flavoured milk drink (0.5% milk fat; 8.5% MSNF and 4% inulin)

Sugar replacement, %	Appearance/colour	Flavour	Consistency and mouthfeel	Overall acceptability
0 (control)	8.3	8.2	8.3	8.3
25	8.3	8.2	8.1	8.2
50	8.3	8.1	7.9	8.1
75	8.2	8.0	7.9	8.1
100	8.2	7.9	7.8	8.0

(n=8)

significantly. Moreover, the viscosity of the milk having 0.5% fat and 4% inulin was comparable to that of milk containing 2% fat. This observation was consistent with Villegas et al. (2007). Therefore, keeping in view the fat content, viscosity and the overall acceptability scores of the drinks, a combination of 0.5% fat with 4% inulin with an overall acceptability score of 8.0 was selected for further studies.

Effect of inulin on the physico-chemical and sensory characteristics of milk drink (0.5% fat; 8.5% MSNF) The total solids content of control milk were recorded as 10.7% (Table 5). The inclusion of inulin up to 8% level increased ($p<0.05$) the total solids and TSS of the milk. Inulin is a soluble carbohydrate therefore it caused an increment in the total solids by incorporation of additional solids in the milk through inulin. Inulin had a direct effect on soluble solids content of the drink due to its partial solubility in water. Control drink had a lower specific gravity of 1.031 than those with augmented amount of inulin. Specific gravity increased from 1.041 to 1.061 in the samples containing 2–8% inulin, respectively. Inulin had a specific gravity of 1.35 and a molecular weight of 1,600 (Silva 1996). The viscosity of milk increased ($p<0.05$) by the incorporation of inulin. This increase could be explained by the interactions of the dietary fibre and liquid phase of the milk. Inulin, being highly hygroscopic, would bind water and form a gel-like network that, in addition to the other components, would modify the rheology of low fat milk (Nagar et al. 2002). Also, the dynamic viscosity of milk containing 4% inulin (2.108 cP) was analogous to that of control milk (2.080 cP) containing 2% fat without inulin. Villegas and Costell (2007) obtained similar results with long chain inulin.

Inulin incorporation in milk had a significant ($p<0.05$) effect on the appearance scores (Table 5). Appearance of control drink was liked most because it was whiter than other drinks due to higher fat content of 2%. Guven et al. (2005) also reported that colour and appearance scores were high in control yoghurt with 3% fat and indicated that increasing levels of inulin negatively affected the colour and appearance scores. A similar trend was observed with flavour scores of milk. The flavour scores differed

significantly ($p<0.05$) with the addition of inulin in the drink (Table 5). They increased from 7.4 (without inulin) to 8.0 (4% inulin) and thereafter, showed minor decrease to 7.6 for 8% inulin. Earlier Guven et al. (2005) had reported the higher organoleptic scores for the control yoghurt with 3% fat than that of added inulin. The control had highest consistency score (8.1) due to perception of rich mouthfeel. Scores improved with the inulin incorporation up to 4% and further increase caused decline in scores. This may be attributed to the residual starchy mouthfeel perceived in the samples containing inulin greater than 4%. Villegas et al. (2007) found the whole milk and skim milk samples with added inulin were perceived thicker and creamier than samples without inulin and concluded that the fat-mimetic capacity of the inulin depended on the concentration of added inulin. The significant ($p<0.05$) difference perceived in the individual sensory scores with the increase in inulin affected the overall acceptability scores in the similar fashion.

Effect of sugar replacement and inulin on the total solids, viscosity and sensory scores of milk drinks Increase in inulin quantity raised total solids considerably whereas replacement of sugar caused a significant ($p<0.01$) decline

Table 9 Proximate composition and nutritional information of the milk drinks

Components	Cardamom flavoured drinks	
	Control	Low calorie
Moisture, %	84.1	87.3
Total solids, %	15.9	12.7
Fat, %	1.89	0.48
Protein, %	3.0	3.1
Ash, %	0.67	0.67
Carbohydrates		
Sucrose, %	6.0	Nil
Lactose, %	4.3	4.3
Inulin, %	Nil	4.0
Sucralose, ppm	Nil	72.6
Calorific value, kcal/100 ml (n=3)	70.2	40.0

(Table 6). The incorporation of inulin caused a noticeable improvement in the viscosity of milk drink. This rise in viscosity may be ascribed to the hygroscopic nature of inulin which improved viscosity of the low-fat milks by forming a gel-like network with the liquid phase of the low fat milk. Silva (1996) reported that dry inulin powder with specific gravity of about 1.35 and molecular weight of 1,600 had a water binding capacity of about 2:1.

The appearance scores of low fat milk decreased and increased ($p < 0.01$) with the increase in sugar replacement and inulin concentration respectively (Table 7). The flavour scores improved up to 4% inulin level, thereafter, they declined due to the starch-like taste of high amount of inulin. However, the increase in sugar replacement caused a reduction ($p < 0.01$) in flavour scores (Table 7). Weit et al. (1993) concluded that sucralose was more similar to aspartame in onset, bitterness and aftertaste than to sucrose whereas Samundsen (1985) described the aftertaste of aspartame as having a lingering sweetness, a bitter-sweetness and that of sucrose as sweet, drying with only a slight bitterness. Thus it could be concluded that sucralose imparts a sugar-like sweet taste to the product but its lingering sweet aftertaste led to the observed decrease in the flavour scores. The consistency and mouthfeel scores decreased significantly ($p < 0.01$) with increasing levels of sugar replacement while a significant ($p < 0.01$) improvement was observed with increase in inulin levels (Table 7). Consistency and mouthfeel of the low-fat milk containing 4% inulin without sugar replacement was liked most by the panelists. This might be due to the optimum fat-like mouth coating provided by inulin to the drink. Ninness (1999b) stated that due to its longer chain length, inulin is less soluble in water and had the ability to form inulin micro crystals when sheared in water or milk. These crystals are not accurately perceptible in the mouth, but they interact to form smooth creamy texture and provide a fat-like mouth feel. Schaller-Povolny and Smith (2002) found inulin containing samples to be less icy and chewier than non-inulin ones. They reported that it might be the result of interaction between inulin and milk proteins. The overall acceptability scores of the drink improved significantly ($p < 0.01$) up to 4% inulin level and thereafter, deterred slightly with increase up to 8% inulin (Table 7). This trend was observed irrespective of the level of sugar replacement. The sample without any sugar replacement along with added inulin (4%) was liked the most (8.3).

Effect of sugar replacement on the sensory characteristics of cardamom flavoured milk drink (0.5% milk fat; 8.5% MSNF and 4% inulin) The scores for all the sensory characteristics of the cardamom flavoured milk drink decreased with the increase in sugar replacement (Table 8),

however, the decrease was non-significant. In this experiment, the fat replacer inulin was added, at 4% level, to the drink to make it equivalent to milk with 2% fat; in terms of viscosity and sensory properties. Therefore, when sugar was replaced with artificial sweetener, sucralose, difference observed in the sensory scores was non-significant. The overall acceptability score of the sample with 100% sugar replacement was high (8.0).

Proximate composition and nutritive value of the milk drinks The total solids and fat contents were higher in control drink (Table 9). However, the lactose content was higher in low calorie drink. The calorific value of the control drink was high being 70.2 kcal/100 ml. The significant reduction in calorific value of the formulation as compared to control was achieved by replacing fat and/or sucrose with inulin having calorific value of 1.5 kcal/g (Ranhotra et al. 1993; Roberfroid et al. 1993) and sucralose (high potency low calorie sweetener), respectively.

Conclusion

Calorific value of the milk drinks could substantially be lowered by reducing fat and replacing sugar with low calorie sweetener. Reduction of fat and replacement of sugar adversely affected the viscosity and sensory attributes particularly consistency and mouthfeel of drinks necessitating the addition of texture modifier. Besides being used as a fat replacer and rheology modifier, inulin could be added as a functional ingredient due to its well established prebiotic and health promoting effects. The low calorie milk drink simulating the control drink (2% fat and 6% sucrose) in viscosity and consistency and mouthfeel was developed by incorporation of 4% inulin and 660 ppm *Splenda* (72.6 ppm sucralose) powder in milk containing 0.5% milk fat and 8.5% SNF. The palatability of the milk drinks could be enhanced by the addition of flavours similar to those of flavoured milks.

References

- AOAC (2000) Official methods of analyses, 16th edn. Association of Official Analytical Chemists, Washington DC
- Arora S, Nayak SK, Sindhu JS, Seth R (2001) Artificial sweeteners in formulation of dairy products. *Indian Food Ind* 20:62–66
- Arora S, Sharma V, Sharma GS, Wadhwa BK, Singh AK (2006) High potency sweeteners for formulating new dairy products. *Indian Dairyman* 58:39–45
- Arora S, Singh VP, Yarrakula S, Gawande H, Narendra K, Sharma V, Wadhwa BK, Tomer SK, Sharma GS (2007) Textural and microstructural properties of *burfi* made with various sweeteners. *J Texture Stud* 38:684–697

- Aryana KJ, Plausche S, Rao RM, McGrew P, Shah NP (2007) Fat-free plain yoghurt manufactured with inulin of various chain lengths and *Lactobacillus acidophilus*. *J Food Sci* 72:M79–84
- Barndt RL, Jackson G (1990) Stability of sucralose in baked goods. *Food Technol* 44(1):62–66
- BIS (1981) ISI Handbook of food analysis. IS: SP: 18 Part XI Dairy products. Bureau of Indian Standards, Manak Bhawan
- Codex (2005) Proposed draft amendments of the codex general standard for food additives. www.codexalimentarius.net (Accessed on 20 November 2008)
- De S (1988) Outlines of dairy technology. Oxford University Press, Delhi
- Duncan DB (1955) New multiple range and multiple F tests. *Biometrics* 11:1–42
- Güven M, Yasar K, Karaca OB, Hayaloglu AA (2005) The effect of inulin as a fat replacer on the quality of set-type low-fat yoghurt manufacture. *Int J Dairy Technol* 58:180–84
- Jenner MR, Smithson A (1989) Physico-chemical properties of the sweetener sucralose. *J Food Sci* 54:1646–1649
- Meilgaard M, Civille GV, Carr BT (1999) Sensory evaluation techniques. CRC, Boca Raton, pp 385–387
- Miller G (2000) Handbook of dairy chemistry. CRC, Boca Raton
- Nagar EG, Clowes G, Tudorica CM, Kuri V, Brennan CS (2002) Rheological quality and stability of yog-ice cream with added inulin. *Int J Dairy Technol* 55:89–93
- Ninness K (1999a) Breakfast foods and the health benefits of inulin and oligofructose. *Cereal Food World* 44:79–81
- Ninness KR (1999b) Inulin and oligofructose: what are they? Nutritional and health benefits of inulin and oligofructose. *J Nutr* 129:1402S–1406S
- Phillips LG, McGiff ML, Barbano DM, Lawless HT (1995a) The influence of fat on the sensory properties, viscosity and colour of low fat milks. *J Dairy Sci* 78:1258–1266
- Phillips LG, McGiff ML, Barbano DM, Lawless HT (1995b) The influence of non-fat dry milk on the sensory properties, viscosity and colour of low fat milks. *J Dairy Sci* 78:2113–2118
- Porto-Pinto E, Teixeira AM, Lopes-Sopena L, Pires-da-Rosa V, Mello-Luviélmo MD (2003) Sucralose in the development of light milky desserts. *Bol Cent Pesqui Processamento Alimentos* 21:49–60
- Ranganna S (1994) Handbook of analysis and quality control for fruits and vegetables products. Tata McGraw Hill Publishing Company Limited, New Delhi, pp 9–12, 99–101, 281–307
- Ranhotra GS, Gelroth JA, Glasen BK (1993) Usable energy value of selected bulking agents. *J Food Sci* 58:1176–1178
- Roberfroid MF, Gibson GR, Delzenne N (1993) The biochemistry of oligofructose, a non digestible fiber: An approach to calculate its caloric value. *Nutr Rev* 51:137–146
- Samundsen JA (1985) Has aspartame an aftertaste? *J Food Sci* 50 (1510):1512
- Schaller-Povolny LA, Smith DE (2002) Interaction of milk proteins with inulin. *Milchwissenschaft* 57:494–497
- Silva RF (1996) Use of inulin as a natural texture modifier. *Cereal Food World* 41:792–794
- Snedecor GW, Cochran WG (1968) Statistical methods. Oxford and IBH, New Delhi, p 339
- Stamp JA (1990) Sorting out the alternative sweeteners. *Cereal Food World* 35:395–400
- Tarrega A, Costell E (2006) Effect of inulin addition on rheological and sensory properties of fat-free starch-based dairy desserts. *Int Dairy J* 16:1104–1112
- Villegas B, Costell E (2007) Flow behaviour of inulin-milk beverages. Influence of inulin average chain length and of milk fat content. *Int Dairy J* 17:7767–7781
- Villegas B, Carbonell I, Costell E (2007) Inulin milk beverages: sensory differences in thickness and creaminess using R-index analysis of the ranking data. *J Sens Stud* 22:377–393
- Walstra P, Jenness R (1984) Dairy chemistry and physics. Wiley, New York
- Weit SG, Ketelson SM, Davis TR, Beyts PK (1993) Fat concentration affects sweetness and sensory profiles of sucrose, sucralose and aspartame. *J Food Sci* 58:599–602