Intransience of functional components and distinctive properties of *amla* (Indian gooseberry) ice cream during short-term storage

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Abstract Inclusion of processed *amla* have been found to enhance the functional properties and nutritional value of ice cream by augmenting the fiber content, total phenols, tannins, ascorbic acid and antioxidant activity. The present investigation assessed the changes in these constituents, color values (L, a* and b*), melting rate, sensory scores and microbiological quality of ice cream containing *amla* shreds, pulp, preserve, candy and powder during 60 days' storage at -18 to -20 °C. The total solids increased slightly whereas the antioxidant activity, total phenols, ascorbic acid and tannins decreased on storage. The L values declined whereas a* and b* values amplified, the rate of change being highest in candy containing sample followed by preserve. The first drip time of all the samples increased whereas melting rate decreased. The overall acceptability scores declined non significantly. Standard plate count of all the ice cream samples decreased significantly whereas yeast and molds were not detected throughout the storage. The psychrophiles were not spotted up to 30 days, thereafter, a small increase was observed.

Keywords Ice cream · *Amla* · Physico-chemical · Phytochemical · Functional · Sensory quality · Storage

Introduction

In recent past, the focus on nutritional enrichment has shifted from the provision of deficient nutrient to the pursuit of optimal health and dietary intake. The consumers are now looking for foods that have added beneficial compounds such as antioxidants, phenolics and phytosterols. Therefore, food manufacturers encompass a variety of functional additives and ingredients to food items to attract the attention of health-conscious consumers and formulate novel products. Frozen dairy desserts serve healthy carriers of nutraceuticals because of their low storage temperature, ability to stabilize ingredients and popularity among consumers. These can be used successfully to deliver unique additional and nutritional benefits to consumers. Ice cream is a valuable frozen dessert containing highly nutritive constituents for human health. It has become one of the essential consumer products without seasonal restrictions. There are many varieties and brands of ice cream available in the market with novel formulations. The diverse ingredients such as cola extracts, soy protein, flaxseed oil, citrus fiber and hazelnut flour had been studied as new ingredients for the development of ice cream formulation with peculiar flavor, taste and texture. Ice cream formulations with functional properties have also been developed including probiotic and yogurt ice cream and that enriched with dietary fiber and natural antioxidants (Singh et al. 2006). Therefore, assorted ice creams are continually emerging targeting the health conscious consumers.

Amla (*Emblica officinalis*) is one of the superb natural sources of nutraceuticals and functional components. It is second richest natural source of vitamin C (ascorbic acid); has a high content of tannin; contains gallic acid, a potent polyphenol; and a rich source of pectin, a valuable form of

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dietary fiber. It has excellent therapeutic value; therefore, it is extensively used in Ayurvedic medicines like *Chyavanprash*, *Triphalahurna*, *Brahmi rasayan* and *Madhume-hga*. There is a definite consumer trend toward the purchase of improved products with strong inclination on health aspects. In keeping with the consumers' demand for foods with health promoting ingredients, Goraya and Bajwa (2015) could enhance functional properties and nutritional quality of ice cream by incorporating processed *amla* which significantly increased the phytochemical content of ice cream including fiber, total phenols, tannins, ascorbic acid and also antioxidant activity. However, it is imperative to investigate the storage stability of such functional components of the products so developed before launching them for commercial application. Moreover, it is also crucial to retain the optimized allocated shelf space among competing products, a fundamental problem in retailing (Corstjens and Doyle 1981). The produce with the longer stability of functional components will acquire the confidence of consumers and be able to spread out its apportioned place and in general realizes enhanced marketability.

Immediately after freezing, ice creams go through hardening, shipping and handling system designed to deliver the product to the consumer with highest possible quality. However, this quality is dependent on various factors mainly temperature and its fluctuation that lead to structural or textural changes (Goff and Hartel 2013). Utmost care is taken that product may not suffer such defects. However, changes in chemical, sensory and functional components (depending upon the formulation and enrichments) cannot be ruled out. Mahran et al. (1987) observed that organoleptic properties of the ice cream deteriorated with the increase in storage time and temperature. Palich (1994) reported that frozen storage of coffee, Smetana and cocoa flavored ice cream caused a decline in sensory quality and fluffiness. The melting characteristics deteriorated with increasing storage time. García-Alonso et al. (2003) found the color parameters and the concentration of different antioxidant compounds were affected by storage conditions of dessert made from the grape, cherry and berries. Bajwa et al. (2003) concluded that physico-chemical and sensory properties of ice cream formulated using strawberry pulp were affected significantly by storage. There was a progressive weakening in all sensory parameters. In another storage study of fig incorporated ice cream, Murtaza et al. (2004) observed that storage had a significant effect on overrun, standup time, meltdown, moisture, total solids, pH, acidity and lactose contents and non-significant effect of storage on overall acceptability. Differences in creaminess, hardness and vanilla flavor were noticed in ice cream after 170 days of storage by Dolan et al. (1985). Guzeler et al. (2011)

observed that acidity and all physical properties of low-fat ice cream except viscosity had altered during storage along with significant decline in the sensory scores. During storage, a decrease in the color and appearance, structure and density, taste and smell scores of ice cream was observed. They recommended 1 month as the most appropriate storage time for ice cream. Therefore, the objective of the investigation was to assess the changes during 2-month storage of ice cream incorporated with processed *amla*. This was envisaged by investigating changes in physico-chemical properties, functional components, sensory scores and microbiological quality occurring during frozen storage of ice cream.

Materials and methods

Fresh whole milk was obtained from Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana. Cream, skim milk powder, sugar, sodium alginate, glycerol monostearate and *amla* (*E. officinalis*) were procured from the local market. *Amla* was processed into shreds, pulp, preserve, candy and powder as per procedure detailed by Goraya and Bajwa (2015).

Preparation of processed *amla* incorporated ice cream

The ingredients of the mix were calculated using the formulae given by Arbuckle (1997). The plain/control ice cream mix having a composition of 11% fat and SNF, 15% sugar, 0.5% emulsifiers and stabilizer (0.15 + 0.35) was prepared using fresh milk, cream, skim milk powder, sugar, glycerol mono-stearate and sodium alginate. It was pre-heated, homogenized at 65 °C using laboratory homogenizer (Taj, New Delhi) at 2000 and 500 psi in two stage process, pasteurized at 80 °C for 25 s, cooled and aged overnight at 5 °C. The incorporation level of processed *amla* was optimized by Goraya and Bajwa (2015). The processed *amla* preparations @ 5% shreds and pulp, 10% preserve and candy and 0.5% powder, were added into the cooled and aged ice cream mix prior to freezing. The mix was frozen in a batch type mechanical freezer of 5 kg capacity (Sigma Sales Corporation, New Delhi) for 8 min. The frozen ice cream was drawn at -4 ± 1 °C from the freezer, packaged in plastic cups, hardened in a cabinet freezer at -18 to -20 °C for 12 h and stored at the same temperature for further studies.

Physicochemical analyses

Three hardened ice cream cups from each lot were collected for the analyses. These were combined in a glass jar

and mixed properly before drawing the test sample. Each ice cream sample was analyzed in triplicate. The total solids/moisture, protein, ash and titratable acidity were determined according to AOAC (2000) methods. The fat content of cream was estimated using Gerber's method (BIS 1981). The fiber content was determined using Fibertec (Foss instrument, Sweden). The pH of samples was determined using pocket pH meter (IQ Scientific USA, Model IQ 125). The color of ice cream was recorded on Hunter Color Lab (Ultra Scan, Hunter Lab, USA) in terms of 'L', a^* and b^* values. Ascorbic acid was determined by titration against 2,6-dichlorophenol indo-phenol. Total phenols were determined after refluxing the sample with methanol twice, reacting with Folin-Ciocalteu reagent and reading the absorbance. The phenols were quantified using gallic acid as a standard. Tannins were estimated using Folin Denis reagent and saturated sodium carbonate in refluxed sample and absorbance read at 760 nm (Ranganna 2001). Antioxidant activity was estimated as free radical scavenging activity using 1,1-diphenyl-2-picryl-hydrazil (DPPH). Five g of ice cream sample was extracted with 50 ml of 80% methanol for 2 h, filtered and re-extracted for 1 h. The absorbance of the resultant solution was measured at 517 nm. DPPH scavenging activity of samples measured as decrease in the absorbance was calculated as % inhibition as per formula

$$\text{AA activity (\% inhibition of DPPH)} = \frac{\text{Control OD} - \text{Sample OD}}{\text{Control OD}} \times 100$$

The specific gravity of ice cream samples was estimated at 20 °C by filling a cup of known weight and volume, with the resultant ice cream and recording its weight. The overrun of ice cream samples was calculated on the weight basis. The melting property of ice cream was analyzed at 20 ± 1 °C whereby hardened ice cream was placed on a wire sieve having 2 mm wide square openings. The time of the first drop on melting of ice cream was recorded as first drip time and melting rate was expressed as %W/W.

Sensory evaluation

The samples of control ice cream along with experimental samples incorporating processed *amla* were evaluated for sensory attributes of appearance, flavor, body and texture and overall acceptability scores on a 9-point hedonic scale at regular interval of 15 days by a semi-trained panel of judges (Poste et al. 1991). The hardened ice cream samples removed from the deep freezer were immediately placed in a sealed thermal box to get and maintain the sample temperature (approx. 10 °C) just for softening before serving to the sensory panel.

Microbiological analyses

The ice cream samples were analyzed for Standard Plate Count (SPC) and psychrophilic count using nutrient agar and yeast and mold count using glucose yeast agar as per standard APHA (1992) procedures.

Statistical analysis

Each value was a mean of three observations. The experimental data was analyzed for analysis of variance (ANOVA) using CPCS-1 software of Punjab Agricultural University, Ludhiana.

Results and discussion

Physico-chemical properties during storage of ice cream incorporating processed *amla*

The total solid content of ice creams with different processed *amla* preparation were variable in fresh samples (36.19–41.59%). However, it increased gradually in all the samples due to moisture loss during storage (Table 1). The greatest moisture loss was observed in ice cream incorporating pulp (6.49%) and smallest with powder (2.09%). This was due to the differential moisture range of the ingredients being incorporated in the ice cream, being maximal fall in ice cream with the inclusion of pulp and smallest with powder. The results are in concordance with Murtaza et al. (2004) in fig paste ice cream samples. They reported that during storage moisture content decreased which resulted in an increment of total solids. Similar, results were earlier reported by Bajwa et al. (2003) in strawberry pulp ice cream. An increase in the total solid content of ice cream with soymilk and skim milk blends during 30 day storage was also observed by Abdullah et al. (2003) and recently by Singh et al. (2014). The fat, protein, ash and fiber content of ice cream did not show apparent changes during storage. Bajwa et al. (2003) also reported that fat content of ice cream with strawberry pulp was not affected much during storage. The results are in accordance with Murtaza et al. (2004) for fig paste ice cream.

The overrun values of ice cream with processed *amla* ranged from 68.92 to 44.3% on the start of storage, being highest in control and least in candy. A substantial and significant loss in overrun was observed after 60 days storage due to the shrinkage of ice cream (Table 1). The loss was higher in candy and preserve than other three preparations. This might be due to presence of randomly distributed segregate chunks of both candy and preserve in the ice cream, which resulted in disruption of air cells formed during whipping of ice cream by restricting the

Table 1 Physico-chemical properties during storage of ice cream incorporating processed *amla*

Processed <i>amla</i> [@]	Storage, days				
	0	15	30	45	60
Total solids, %					
Control	37.50 ^{abn} ± 0.46	37.72 ^{ao} ± 0.02	37.89 ^{ao} ± 0.05	38.21 ^{ap} ± 0.01	38.54 ^{ap} ± 0.04
Shreds	36.29 ^{co} ± 0.11	36.64 ^{bcp} ± 0.04	37.15 ^{bp} ± 0.06	37.82 ^{bn} ± 0.01	38.63 ^{an} ± 0.02
Pulp	36.19 ^{co} ± 0.11	36.53 ^{bcp} ± 0.04	37.02 ^{bq} ± 0.02	37.7 ^{bq} ± 0.04	38.54 ^{ap} ± 0.04
Candy	41.59 ^{bl} ± 0.06	41.92 ^{bl} ± 0.02	42.4 ^{abl} ± 0.04	43.04 ^{al} ± 0.04	43.78 ^{al} ± 0.03
Preserve	39.93 ^{cm} ± 0.04	40.32 ^{bcm} ± 0.01	40.79 ^{bm} ± 0.03	41.44 ^{bm} ± 0.03	42.25 ^{am} ± 0.05
Powder	37.82 ^{abn} ± 0.03	38.02 ^{an} ± 0.02	38.27 ^{an} ± 0.03	38.52 ^{ao} ± 0.01	38.61 ^{ao} ± 0.03
Overrun, %					
Control	68.92 ^{al} ± 0.02	67.98 ^{bl} ± 0.04	66.86 ^{cl} ± 0.03	64.51 ^{dl} ± 0.03	61.78 ^{el} ± 0.01
Shreds	61.54 ^{ao} ± 0.03	60.34 ^{bo} ± 0.04	59.02 ^{co} ± 0.02	56.81 ^{do} ± 0.04	54.27 ^{eo} ± 0.03
Pulp	63.92 ^{an} ± 0.01	62.96 ^{bn} ± 0.03	61.37 ^{cn} ± 0.03	59.08 ^{dn} ± 0.03	56.30 ^{en} ± 0.12
Candy	52.15 ^{aq} ± 0.06	51.19 ^{bq} ± 0.04	49.33 ^{cq} ± 0.02	47.06 ^{dq} ± 0.05	44.30 ^{eq} ± 0.02
Preserve	55.72 ^{ap} ± 0.01	54.65 ^{bp} ± 0.05	53.02 ^{cp} ± 0.02	50.72 ^{dp} ± 0.01	47.89 ^{ep} ± 0.06
Powder	65.96 ^{am} ± 0.04	64.88 ^{bm} ± 0.10	63.41 ^{cm} ± 0.05	60.83 ^{dm} ± 0.01	58.02 ^{em} ± 0.05
Specific gravity					
Control	0.533 ^{cq} ± 0.001	0.537 ^{dq} ± 0.004	0.541 ^{cq} ± 0.001	0.547 ^{bq} ± 0.003	0.556 ^{aq} ± 0.004
Shreds	0.558 ^{en} ± 0.003	0.563 ^{dn} ± 0.002	0.566 ^{cn} ± 0.002	0.575 ^{bn} ± 0.001	0.583 ^{an} ± 0.002
Pulp	0.554 ^{co} ± 0.003	0.559 ^{do} ± 0.006	0.561 ^{co} ± 0.003	0.566 ^{bo} ± 0.003	0.578 ^{ao} ± 0.004
Candy	0.591 ^{el} ± 0.004	0.599 ^{dl} ± 0.003	0.604 ^{cl} ± 0.001	0.613 ^{bl} ± 0.002	0.621 ^{al} ± 0.005
Preserve	0.582 ^{cm} ± 0.001	0.585 ^{dm} ± 0.001	0.589 ^{cm} ± 0.004	0.597 ^{bm} ± 0.003	0.612 ^{am} ± 0.004
Powder	0.541 ^{cp} ± 0.003	0.547 ^{dp} ± 0.002	0.553 ^{cp} ± 0.003	0.561 ^{bp} ± 0.004	0.571 ^{ap} ± 0.006
Acidity, % lactic acid					
Control	0.171 ^{aop} ± 0.013	0.174 ^{aop} ± 0.006	0.176 ^{ap} ± 0.004	0.179 ^{ap} ± 0.004	0.183 ^{ap} ± 0.001
Shreds	0.387 ^{abl} ± 0.002	0.389 ^{al} ± 0.008	0.392 ^{al} ± 0.004	0.396 ^{al} ± 0.006	0.410 ^{al} ± 0.066
Pulp	0.321 ^{bm} ± 0.006	0.329 ^{bm} ± 0.007	0.341 ^{abm} ± 0.01	0.356 ^{am} ± 0.002	0.374 ^{am} ± 0.003
Candy	0.194 ^{ao} ± 0.002	0.201 ^{ao} ± 0.006	0.208 ^{ao} ± 0.003	0.216 ^{ao} ± 0.003	0.224 ^{ao} ± 0.005
Preserve	0.190 ^{abo} ± 0.005	0.190 ^{abo} ± 0.01	0.206 ^{ao} ± 0.004	0.213 ^{ao} ± 0.005	0.214 ^{ao} ± 0.008
Powder	0.204 ^{bn} ± 0.004	0.223 ^{bn} ± 0.003	0.241 ^{abn} ± 0.009	0.263 ^{an} ± 0.002	0.274 ^{an} ± 0.003

ND non-detectable, values with superscripts (a, b, c, d, and e) in a column and (l, m, n, o, p and q) in a row differ significantly at $p < 0.05$. @ 5% shreds, 5% pulp, 10% preserve, 10% candy and 0.5% powder

movement of proteins toward oil–water interface, thereby it not only reduced air holding capacity but also caused easy collapsing of air cells in the system during storage (Qayyum et al. 2017). According to Potter and Hotchkiss (1995) the shrinkage in the ice cream during storage was caused by the loss of air owing to the collapse of weakened films of mix from ice cream leading to a loss in volume. Palich (1994) described that frozen storage of coffee, Smetana and cocoa flavored ice cream caused a decline in fluffiness. Bajwa et al. (2003) also reported similarly on overrun values of ice cream incorporated with strawberry pulp. Guzeler et al. (2012) did observe matching trends. The overrun decreased and specific gravity increased significantly ($p < 0.01$) during the storage of ice cream

containing cookies and cakes as ingredients (Singh et al. 2014).

The specific gravity values of ice cream increased significantly in all the samples with progress in storage (Table 1). In the course of the storage of ice cream, air cells collapsed, causing the ice cream to drop its volume, thus leading to shrinkage and making the product heavy and dense which resulted in increased specific gravity. The increase was higher in samples containing candy, preserve and powder than shred and pulp. This may be due to the fact that former three *amla* preparations contained less moisture/more solids thus had high specific gravity and their dense nature prevented the formation of strong air holding matrix.

The acidity of all ice cream samples increased significantly ($p < 0.05$) during storage (Table 1). The acidity was found to be highest in shreds samples followed by pulp, powder, candy and preserve at 0 day and subsequent progress of storage. The increase in the acidity may be attributed to the evaporation of moisture as well as subsequent slow release of intrinsic acids from *amla* preparations in the ice cream during storage. The relative increase was highest in powder ice cream due to easy leaching owing to large surface area of powder, whereas the acid ooze was lower in candy and preserve due to the predominant sugar coating on these. The findings are similar to Abdullah et al. (2003) and Murtaza et al. (2004) who found that there was a gradual increase in acidity on storage of ice cream with soymilk blend and fig ice cream respectively. The variation in acidity causes changes during storage which affect the pH as well as acceptance of ice cream. The pH has a direct effect on the flavor perception of the dairy products (Hegenbart 1991).

Antioxidant activity, total phenols, tannins and ascorbic acid during storage of ice cream incorporating processed *amla*

There was a significant ($p < 0.01$) variation in antioxidant activity, total phenols and tannins of ice cream with storage period (Table 2). The antioxidant activity decreased in all the samples after storage of 60 days, the percent reduction was slight being maximal in *amla* shred (0.86) followed by pulp, powder, candy and minimal in preserve (0.51) incorporated ice cream. The decline might be due to loss of bioactive compounds such as total phenols and ascorbic acid, which decreased significantly ($p < 0.01$) during storage (Table 2). The reduction of phenols was maximal in powder ice cream (22.22%) and minimal in shred (3.21%). The decrease in phenols during storage may be attributed to decrease in individual phenolic compounds like kaempferol and caffeic acid resulting in loss of total phenols (Bhattacharjee et al. 2014). Tannins were not detected in ice cream sample with *amla* powder after 45 days indicating 100% loss. The loss of total phenols and tannins during storage could be due to oxidation and their condensation into colored pigments. The decrease in phenols and tannins were also reported by Tripathi et al. (1988) in *amla* candy. Nayak et al. (2011) also noted a reduction in tannins of *amla* syrup after 9 days of storage. A similar trend was noted by Reddy and Chikkasubbanna (2008) in lime blend *amla* squash. García-Alonso et al. (2003) found that the concentration of different antioxidant compounds was affected by storage conditions of a dessert made from the grape, cherry and berries. The tannin content in blanched walnuts was positively related ($r = 0.92$) to astringency scores (Sze-Tao et al. 2001) and storage of

21 days at 25 °C significantly reduced (20–40%) the assayable tannin content. The ascorbic acid content of samples decreased considerably with the progress in storage period, irrespective of low storage temperature. The ascorbic acid content was highest in shreds incorporated ice cream samples followed by pulp, powder, preserve and candy samples on 0 days which decreased progressively during storage. All *amla* incorporations were subjected to different pre-treatments during their conversion from raw *amla* to product formation that therefore, contributed differently towards loss of ascorbic acid. The loss was least in shreds because least preparatory treatment was given to it and highest in candy which had undergone a series of processing steps. Loss of ascorbic acid might be due to its oxidation to dehydro-ascorbic acid followed by its further degradation (Reynold 1965). The decline in ascorbic acid in *amla* candy during storage was also reported by Tripathi et al. (1988).

Color attributes (L, a* and b* values) during storage of ice cream incorporating processed *amla*

Color is one of the most important attributes of foods and therefore, food colors constitute a major additive as it enhances the acceptance and appeal of a food item. The 'L' value represents lightness to darkness, a* value greenness to redness and b* value yellowness to blueness. The color (L, a* and b*) values of ice cream differed significantly ($p < 0.01$) both with the type of processed *amla* and storage. The 'L' value decreased significantly ($p < 0.01$) as a result of the formation of colored compounds from non-enzymatic browning reaction (Rehmacha et al. 1992). Moreover, oxidation of total phenols and tannins leads to the dusky tint in the product, which causes an increase in a* and b* values on storage. The 'L' value was lowest in candy ice cream proceeded by preserve samples because of its somewhat dark color, that cannot be differentiated with eyes (Table 3). Multi-colored Tutti-frutti which is candied fruit especially of raw papaya, is commonly used in cold deserts and as toppings for the ice-creams and sundaes to make the product diverse and colorful.

For all the ice creams a significant ($p < 0.01$) increase in a* and b* value was observed during storage indicating that greenness of the product decreased and yellowness increased. The values of a* (redness/greenness) were towards greenness in fresh samples and progressed toward redness whereas b* values (yellowness) were highest in candy followed by preserve that increased throughout the storage period. García-Alonso et al. (2003) observed the effect of storage conditions on color parameters of dessert made from the grape, cherry and berries. The differences in color values may be correlated well to oxidation of phenols and tannins and their condensation into colored pigments

Table 2 Functional components during storage of ice cream incorporating processed *amla*

Processed <i>amla</i> [@]	Storage, days				
	0	15	30	45	60
Antioxidant activity, % inhibition of DPPH					
Control	15.00 ^{an} ± 0.026	14.72 ^{an} ± 0.044	14.41 ^{abn} ± 0.053	14.09 ^{bn} ± 0.07	13.81 ^{bcn} ± 0.995
Shreds	19.84 ^{al} ± 0.056	19.79 ^{al} ± 0.026	19.75 ^{al} ± 0.035	19.71 ^{al} ± 0.079	19.67 ^{al} ± 0.062
Pulp	19.48 ^{alm} ± 0.026	19.45 ^{alm} ± 0.056	19.42 ^{alm} ± 0.035	19.38 ^{alm} ± 0.026	19.35 ^{alm} ± 0.01
Candy	22.73 ^{al} ± 0.085	22.70 ^{al} ± 0.114	22.66 ^{al} ± 0.017	22.63 ^{al} ± 0.061	22.59 ^{al} ± 0.026
Preserve	23.60 ^{al} ± 0.096	23.57 ^{al} ± 0.062	23.54 ^{al} ± 0.053	23.50 ^{al} ± 0.056	23.48 ^{al} ± 0.087
Powder	19.66 ^{al} ± 0.046	19.62 ^{al} ± 0.05	19.69 ^{al} ± 0.026	19.66 ^{al} ± 0.046	19.53 ^{al} ± 0.01
Total phenols, g/100 g GAE					
Control	ND ^{aq}	ND ^{aq}	ND ^{aq}	ND ^{aq}	ND ^{aq}
Shreds	0.187 ^{al} ± 0.002	0.185 ^{al} ± 0.001	0.185 ^{al} ± 0.001	0.183 ^{bl} ± 0.001	0.181 ^{bl} ± 0.006
Pulp	0.082 ^{ao} ± 0.006	0.080 ^{ao} ± 0.026	0.080 ^{ao} ± 0.026	0.077 ^{bo} ± 0.004	0.076 ^{bo} ± 0.002
Candy	0.087 ^{an} ± 0.002	0.086 ^{an} ± 0.005	0.084 ^{an} ± 0.003	0.084 ^{an} ± 0.002	0.081 ^{bn} ± 0.006
Preserve	0.091 ^{am} ± 0.002	0.090 ^{am} ± 0.061	0.088 ^{am} ± 0.004	0.088 ^{am} ± 0.004	0.086 ^{bm} ± 0.002
Powder	0.018 ^{ap} ± 0.006	0.018 ^{ap} ± 0.003	0.016 ^{ap} ± 0.001	0.015 ^{ap} ± 0.001	0.014 ^{bp} ± 0.004
Tannins, mg/100 g Tannic acid					
Control	ND ^{ap}	ND ^{ap}	ND ^{ap}	ND ^{ao}	ND ^{ao}
Shreds	0.133 ^{al} ± 0.007	0.132 ^{al} ± 0.003	0.129 ^{abl} ± 0.006	0.129 ^{bl} ± 0.006	0.127 ^{bl} ± 0.002
Pulp	0.007 ^{an} ± 0.002	0.007 ^{an} ± 0.003	0.005 ^{an} ± 0.002	0.004 ^{abn} ± 0.001	0.003 ^{bn} ± 0.003
Candy	0.0165 ^{am} ± 0.001	0.0163 ^{am} ± 0.015	0.0163 ^{am} ± 0.001	0.0162 ^{am} ± 0.001	0.015 ^{am} ± 0.004
Preserve	0.0184 ^{am} ± 0.001	0.0182 ^{am} ± 0.003	0.0181 ^{am} ± 0.001	0.0181 ^{am} ± 0.001	0.0179 ^{abm} ± 0.001
Powder	0.003 ^{ao} ± 0.001	0.003 ^{ao} ± 0.003	0.001 ^{ao} ± 0.001	0.001 ^{an} ± 0.005	ND ^{bo}
Ascorbic acid, mg/100 g					
Control	ND ^{ap}	ND ^{ao}	ND ^{ao}	ND ^{ao}	ND ^{ao}
Shreds	25.56 ^{al} ± 0.026	24.15 ^{al} ± 0.044	23.56 ^{abl} ± 0.026	22.81 ^{bl} ± 0.040	21.94 ^{bcl} ± 0.017
Pulp	6.02 ^{am} ± 0.026	5.43 ^{am} ± 0.026	3.87 ^{bm} ± 0.026	2.91 ^{cm} ± 0.061	2.07 ^{cm} ± 0.026
Candy	1.10 ^{ano} ± 0.053	0.81 ^{ano} ± 0.036	0.63 ^{ano} ± 0.026	0.37 ^{an} ± 0.026	0.11 ^{an} ± 0.036
Preserve	1.69 ^{an} ± 0.056	1.36 ^{bn} ± 0.026	1.09 ^{bn} ± 0.020	0.68 ^{bn} ± 0.061	0.33 ^{bn} ± 0.017
Powder	3.08 ^{an} ± 0.036	2.53 ^{an} ± 0.046	1.97 ^{an} ± 0.044	1.48 ^{abn} ± 0.056	0.94 ^{bn} ± 0.044

ND non-detectable, values with superscripts (a, b and c) in a column and (l, m, n and o) in a row differ significantly at $p < 0.05$. @ 5% shreds, 5% pulp, 10% preserve, 10% candy and 0.5% powder

during storage. The correlation coefficient between L values with total phenols as well as tannins was found to be positive and significant being in the range of 0.954–0.972 and 0.820–0.968 except for preserve (0.333). On the other hand, the correlation coefficient of a^* and b^* values of ice cream with phenols and tannins were negative and significant (a^* value range from -0.933 to -0.964 with phenols and -0.742 to -0.947 with tannins; b^* value from -0.966 to -0.985 with phenols and -0.803 to -0.985 with tannins) except for preserve (-0.412 and -0.411 respectively). The study indicated that phytochemicals degraded during the storage period.

First drip time and melting rate during storage of ice cream incorporating processed *amla*

The time for the first drip increased with the addition of processed *amla* as well as storage period. It was 4.27 min in control which increased three to four folds in *amla* added ice cream samples (Fig. 1). The increase in the first drip time during storage was due to the decrease in moisture content and enlargement of ice crystals during storage that required longer time to melt (Muse and Hartel 2004). Guzeler et al. (2011) reported that first drip time of milk powder, maltodextrin and polydextrose incorporated ice cream increased during 3 month storage period. The melting rate was reduced (Fig. 2) as the storage period rose from 0 to 60 days. The reduction in melting rate was higher

Table 3 Color attributes (L, a* and b* values) and overall acceptability scores during storage of ice cream incorporating processed *amla*

Processed <i>amla</i> [@]	Storage period, days				
	0	15	30	45	60
L values					
Control	68.45 ^{al} ± 0.053	68.40 ^{al} ± 0.056	68.33 ^{al} ± 0.017	68.26 ^{al} ± 0.062	68.05 ^{al} ± 0.061
Shreds	67.36 ^{al} ± 0.017	67.20 ^{am} ± 0.046	67.01 ^{am} ± 0.044	66.89 ^{am} ± 0.062	66.57 ^{am} ± 0.079
Pulp	65.08 ^{am} ± 0.036	64.75 ^{an} ± 0.026	64.51 ^{an} ± 0.026	64.22 ^{bn} ± 0.056	64.03 ^{bn} ± 0.026
Candy	53.57 ^{ao} ± 0.036	53.35 ^{ap} ± 0.046	53.12 ^{ap} ± 0.017	52.87 ^{ap} ± 0.026	52.63 ^{abp} ± 0.017
Preserve	56.85 ^{an} ± 0.036	56.54 ^{ao} ± 0.044	56.31 ^{ao} ± 0.036	55.94 ^{abo} ± 0.036	55.72 ^{bo} ± 0.053
Powder	67.89 ^{al} ± 0.075	67.61 ^{am} ± 0.036	67.43 ^{am} ± 0.017	67.16 ^{am} ± 0.053	66.85 ^{abm} ± 0.036
a* values					
Control	− 1.54 ^{bcm} ± 0.044	− 1.50 ^{bm} ± 0.087	− 1.46 ^{bm} ± 0.026	− 1.37 ^{bm} ± 0.017	− 1.15 ^{am} ± 0.010
Shred	− 1.68 ^{am} ± 0.061	− 1.67 ^{am} ± 0.026	− 1.43 ^{am} ± 0.072	− 1.20 ^{am} ± 0.078	− 0.92 ^{am} ± 0.017
Pulp	− 1.25 ^{am} ± 0.017	− 1.03 ^{am} ± 0.017	− 0.84 ^{am} ± 0.010	− 0.76 ^{am} ± 0.046	− 0.61 ^{alm} ± 0.082
Candy	− 0.11 ^{abl} ± 0.036	0.23 ^{al} ± 0.017	0.54 ^{al} ± 0.020	0.61 ^{al} ± 0.036	0.86 ^{al} ± 0.053
Preserve	− 0.23 ^{al} ± 0.053	− 0.12 ^{abl} ± 0.017	0.09 ^{al} ± 0.046	0.31 ^{al} ± 0.089	0.68 ^{al} ± 0.079
Powder	− 0.91 ^{alm} ± 0.053	− 0.80 ^{alm} ± 0.173	− 0.64 ^{alm} ± 0.044	− 0.41 ^{alm} ± 0.072	0.08 ^{al} ± 0.036
b* values					
Control	3.56 ^{bo} ± 0.026	3.61 ^{bo} ± 0.026	3.84 ^{abo} ± 0.044	4.08 ^{ao} ± 0.036	4.26 ^{ao} ± 0.056
Shreds	3.27 ^{bcp} ± 0.026	3.46 ^{bp} ± 0.010	3.63 ^{bp} ± 0.010	3.94 ^{ap} ± 0.010	4.11 ^{ap} ± 0.046
Pulp	4.33 ^{bcn} ± 0.020	4.46 ^{bn} ± 0.036	4.69 ^{bn} ± 0.046	4.96 ^{an} ± 0.010	5.13 ^{an} ± 0.036
Candy	5.60 ^{dl} ± 0.010	5.75 ^{dl} ± 0.036	6.03 ^{cl} ± 0.010	6.35 ^{bl} ± 0.061	6.75 ^{al} ± 0.026
Preserve	5.26 ^{cm} ± 0.017	5.43 ^{cm} ± 0.017	5.72 ^{bm} ± 0.017	5.90 ^{bm} ± 0.046	6.18 ^{am} ± 0.056
Powder	3.65 ^{co} ± 0.02	3.81 ^{co} ± 0.036	4.00 ^{co} ± 0.062	4.29 ^{bo} ± 0.053	4.65 ^{ao} ± 0.044
Overall acceptability scores[#]					
Control	8.00 ^{al} ± 0.71	7.91 ^{al} ± 0.65	7.53 ^{al} ± 0.63	7.38 ^{al} ± 0.59	7.16 ^{al} ± 0.53
Shreds	8.38 ^{al} ± 0.52	8.09 ^{al} ± 0.42	8.09 ^{al} ± 0.67	8.03 ^{al} ± 0.57	7.69 ^{al} ± 0.50
Pulp	8.15 ^{al} ± 0.58	8.09 ^{al} ± 0.60	7.87 ^{al} ± 0.55	7.81 ^{al} ± 0.40	7.19 ^{al} ± 0.97
Candy	8.31 ^{al} ± 0.56	8.28 ^{al} ± 0.62	8.09 ^{al} ± 0.65	7.75 ^{al} ± 0.40	7.56 ^{al} ± 1.20
Preserve	7.97 ^{al} ± 0.60	7.94 ^{al} ± 0.69	7.84 ^{al} ± 0.50	7.80 ^{al} ± 0.57	7.39 ^{al} ± 0.68
Powder	8.28 ^{al} ± 0.62	8.16 ^{al} ± 0.64	8.09 ^{al} ± 0.58	7.81 ^{al} ± 0.53	7.75 ^{al} ± 1.12

ND non-detectable, n = 3, # n = 8, values are ± standard deviation. Values with different superscripts (a, b, c and d) in a column and (l, m, n, o and p) in a row differ significantly at $p < 0.05$. @ 5% shreds, 5% pulp, 10% preserve, 10% candy and 0.5% powder

for preserve and candy due to the incorporation of chunks/pieces which hindered the flow of serum phase through the mesh. Palich (1994) also observed that the melting characteristics of frozen storage of coffee, Smetana and cocoa flavored and watermelon seed flour incorporated ice cream, respectively deteriorated with increasing storage time. Singh et al. (2014) experienced an increase in first drip time and melting rate of ice cream with the inclusion of cookies and cakes. The melting behavior of ice creams incorporating substantial amount of juice from kiwifruit with green, gold or red flesh had been observed to be different in each case due to the intrinsic composition and enzymes (Waterhouse et al. 2013).

Sensory scores of ice cream during storage of ice cream incorporating processed *amla*

The scores for all the sensory attributes differed with the inclusion of *amla* preparations because of variation in the base material. The appearance/color, body and texture, mouthfeel (data not presented) and overall acceptability scores of all ice cream samples decreased with progress in storage Table 3). The decline in flavor scores was mild and non-significant, and the comparative decline in sensory scores was least of ice cream containing *amla* powder. This was due to the reason that powder mingled well with mix and produced a reasonably smooth and consistent product which did not show many alterations during storage. Differences in creaminess and hardness were noticed in ice

Fig. 1 First drip time during storage of ice cream incorporating processed *amla*

Fig. 2 Melting rate during storage of ice cream incorporating processed *amla*

cream after 170 days of storage by Dolan et al. (1985). Mahran et al. (1987) and Guzeler et al. (2011) reported that sensory quality of the ice cream decreased with increase in storage time. Bajwa et al. (2003) and Murtaza et al. (2004) observed a gradual decline in scores for all the sensory features of ice cream samples during storage of strawberry and fig ice cream. A weakening in overall acceptability scores had also been reported by Palich (1994) in coffee, Smetana and cocoa flavored ice cream, Butt et al. (1999) in the use of combination stabilizers and emulsifiers and Abdullah et al. (2003) in soymilk blended ice cream during storage. Singh et al. (2014) observed a progressive decline in all sensory scores during storage at $-18 \pm 1^\circ\text{C}$ of ice cream containing vanilla and chocolate flavored cookies and cakes as novel ingredients.

Microbial quality during storage of ice cream incorporating processed *amla*

The SPC (Standard Plate Count) of all the ice cream samples decreased significantly ($p < 0.01$) during storage period (Table 4). This reduction was due to the destruction of microbes at low-temperature storage primarily because of the ice crystal formation that damaged the cell wall of microorganism leading to lysis of the cell (Davidson et al. 2000). The SPC values for all the ice cream samples were within the acceptable range as per FSSAI (2009) regulations. Lee and White (1991) also observed a decrease in SPC of ice cream samples during storage. The growth of psychrophiles was not detected in all ice cream samples during the first 30 days of storage period. Thereafter, a few colonies were observed. With further progress in the storage, its count increased from 3.91 to 4.00 $\log_{10}$ CFU/ml in control being higher than *amla* samples. Yeasts and molds

Table 4 Microbial quality during storage of ice cream incorporating processed *amla*

Processed <i>amla</i> [@]	Storage period, days				
	0	15	30	45	60
Standard plate count, log ₁₀ CFU/ml					
Control	5.39 ^a ± 0.082	5.29 ^a ± 0.062	5.08 ^a ± 0.075	4.92 ^{ab} ± 0.056	4.77 ^b ± 0.066
Shred	4.99 ^a ± 0.066	4.87 ^a ± 0.026	4.78 ^a ± 0.087	4.68 ^a ± 0.066	4.58 ^a ± 0.066
Pulp	5.11 ^a ± 0.072	5.07 ^a ± 0.030	4.99 ^a ± 0.122	4.89 ^a ± 0.053	4.78 ^a ± 0.056
Candy	5.29 ^a ± 0.062	5.22 ^a ± 0.056	5.11 ^a ± 0.072	5.05 ^a ± 0.046	4.94 ^a ± 0.010
Preserve	5.34 ^a ± 0.030	5.24 ^a ± 0.026	5.13 ^a ± 0.056	5.05 ^a ± 0.017	4.98 ^a ± 0.066
Powder	5.18 ^a ± 0.087	5.09 ^a ± 0.056	4.99 ^a ± 0.082	4.89 ^a ± 0.082	4.80 ^a ± 0.082
Psychrophiles, log ₁₀ CFU/ml					
Control	ND	ND	ND	3.91 ± 0.044	4.00 ± 0.010
Shred	ND	ND	ND	3.70 ± 0.036	3.87 ± 0.044
Pulp	ND	ND	ND	3.83 ± 0.036	3.90 ± 0.056
Candy	ND	ND	ND	3.88 ± 0.087	3.97 ± 0.030
Preserve	ND	ND	ND	3.85 ± 0.036	3.95 ± 0.026
Powder	ND	ND	ND	3.78 ± 0.050	3.89 ± 0.104

ND non-detectable, n = 3, values are ± standard deviation. Values with superscripts (a and b) in a column differ significantly at $p < 0.05$. @ 5% shreds, 5% pulp, 10% preserve, 10% candy and 0.5% powder

were not detected during 60 days of frozen storage. The results are in agreement with Singh et al. (2014).

Conclusion

The ice cream was manufactured by incorporation of *amla* fruit in the form of shreds, pulp, candy, preserve and powder into the mix during the freezing step. Such ice creams were packaged and stored frozen for 60 days. Storage influenced the functional and chemical constituents and melting properties of ice cream. The functional components i.e. ascorbic acid, antioxidant activity, total phenols and tannins declined significantly. The overrun of ice cream was also lowered due to shrinkage. The melting resistance increased with the inclusion of processed *amla*. The overall acceptability scores were found to decline slightly with progress in storage. However, all ice cream samples incorporating processed *amla* preparations remained highly acceptable and retained their functional properties viz. antioxidant activity, tannins and total phenols. Also, *amla* incorporated ice creams were microbiologically safe throughout the storage.

References

- Abdullah M, Rehman S, Zubair H, Saeed HM, Kousar S, Shahid M (2003) Effect of skim milk in soymilk blend on the quality of ice cream. *Pak J Nutr* 2:305–311
- AOAC (2000) Official methods of analysis. Association of Official Analytical Chemists, Washington
- APHA (1992) Compendium of methods for the microbiological examination of foods. American Public Health Association, Washington
- Arbuckle WS (1997) Ice cream. AVI Publishing Company Inc, New York
- Bajwa UA, Huma N, Ehsan B, Jabbar K, Khurrama A (2003) Effect of different concentration of strawberry pulp on the properties of ice cream. *Int J Agric Biol* 15:635–637
- Bhattacharjee AK, Tondon DK, Dikshit A (2014) Antioxidant activity and quality of spray dried aonla powder as affected by storage behavior of juice. *J Sci Ind Res* 73:607–612
- Bureau of Indian Standards (1981) ISI Handbook of food analysis. IS: SP: 18 part XI dairy products. Manak Bhawan, New Delhi
- Butt MS, Ahmad I, Mahmood S, Shahzadi N (1999) Effect of different combinations of stabilizers/emulsifiers on the quality of ice cream. *Pak J Agric Sci* 360:70–73
- Corstjens M, Doyle P (1981) Model for optimizing retail space allocations. <http://pubsonline.informs.org/doi/pdf/10.1287/mnsc.27.7.822>. Accessed 11 Aug 2016
- Davidson RH, Duncan SE, Hackney CR, Eigel WN, Boling JW (2000) Probiotic culture survival and implications in fermented frozen yogurt characteristics. *J Dairy Sci* 83:666–673
- Dolan KD, Singly RP, Wells JH (1985) Evaluation of time temperature related quality changes in ice cream during storage. *J Food Proc Pres* 9:253–271
- FSSAI (2009) Food safety and standards regulations. <http://www.fssai.gov.in/Portals/0/FSSAI%20regulations.pdf>. Accessed 31 Aug 2016
- García-Alonso FJ, Periago MJ, Vidal-Guevara ML, Cantos E, Ros G, Ferreres F, Abellán P (2003) Assessment of the antioxidant properties during storage of a dessert made from grape, cherry, and berries. *J Food Sci* 68:1525–1530
- Goff HD, Hartel RW (eds) (2013) Shelf life. In: Ice cream. Springer, New York, pp 353–378
- Goraya RK, Bajwa U (2015) Enhancing the functional properties and nutritional quality of ice cream with processed *amla* (Indian gooseberry). *J Food Sci Technol* 52:7861–7871

- Guzeler N, Kacar A, Say D (2011) Effect of milk powder, maltodextrin and polydextrose use on physical and sensory properties of low calorie ice cream during storage. *Acad Food J* 9:6–12
- Guzeler N, Kacar A, Keceli T, Say D (2012) Effect of different stabilizers, emulsifiers and storage time on some properties of ice cream. *Acad Food J* 10:26–30
- Hegenbart S (1991) Flavors levels. A logical approach. *Food Product Des* 1:33–42
- Lee FY, White CH (1991) Effect of ultra filtration retentates and whey protein concentrates on ice cream quality during storage. *J Dairy Sci* 74:1170–1180
- Mahran GA, El-Alomy HA, El-Bagoury EH, Sayed AF (1987) Effect of storage temperature of milk fat on ice cream quality. *Egypt J Food Sci* 15:65–73
- Murtaza MA, Huma GN, Din MU, Shabbir MA, Mahmood SD (2004) Effect of fat replacement by fig addition on ice cream quality. *Int J Agric Biol* 6:68–70
- Muse MR, Hartel RW (2004) Ice cream structural elements that affect melting rate and hardness. *J Dairy Sci* 87:1–10
- Nayak P, Bhatt DK, Shukla DK, Tondon DK (2011) Evaluation of aonla (*Phyllanthus Emblica* G.) segments in syrup prepared from stored fruit. *Res J Agric Sci* 43:252–257
- Palich P (1994) Study of changes in the quality of ice cream during storage. *Chlodnictwo* 29:21–25
- Poste LM, Mackie DA, Buller G, Larmond E (1991) Laboratory methods for sensory analysis of food. Research Branch Agriculture Canada Publication 1864/E, Ottawa
- Potter NN, Hotchkiss JH (1995) Food science, 5th edn. CBS Publishers, New Delhi
- Qayyum A, Huma N, Sameen A, Siddiq A, Munir M (2017) Impact of watermelon seed flour on the physico-chemical and sensory characteristics of ice cream. *J Food Process Preser.* <https://doi.org/10.1111/jfpp.13297>
- Ranganna S (2001) Handbook of analysis and quality control for fruit and vegetable products. TataMcGraw Hill Pub Co. Ltd, New Delhi
- Reddy AH, Chikkasubbanna V (2008) Standardization of recipe and storage behavior of lime blended aonla squash. *Asian J Hort* 3:203–207
- Rehmacha TE, Ibarza A, Ginot J (1992) Evaluation of color and effect of temperature on fruit pulp. *Rev Aliment* 56:59–68
- Reynold TM (1965) Chemistry of non-enzymatic browning. *Adv Fundam Res* 14:168–268
- Singh J, Minhas KS, Bajwa U (2006) studies on the preparation and shelf-life of yoghurt ice cream. *J Food Sci Technol* 43:656–661
- Singh A, Bajwa U, Goraya RK (2014) Effect of storage period on the physicochemical, sensory and microbiological quality of bakery flavoured ice cream. *Int J Eng Res Appl* 4:80–90
- Sze-Tao KWC, Schrimpf JE, Teuber SS, Roux KH, Sathe SK (2001) Effects of processing and storage on walnut (*Juglans regia* L.) Tannins. *J Sci Food Agric* 81:1215–1222
- Tripathi VK, Singh MB, Singh S (1988) Studies on comparative compositional changes in different preserved products of *aml*a (*Embl*ica *officinalis* G.) var. Banarsi. *Indian Food Packer* 42:61–66
- Waterhouse SD, Edmonds L, Wadhwa SS, Wibisono R (2013) Producing ice cream using a substantial amount of juice from kiwifruit with green, gold or red flesh. *Food Res Int* 50:647–656