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Aloe vera and carrageenan based edible film improves storage stability of ice-cream

Kanika Mahajan[a], Sunil Kumar[a], Zuhaib F. Bhat[a,*], Maninder Singh[b], Hina F. Bhat[c], Muhammad A. Bhatti[d], Alaa El-Din A. Bekhit[e]

[a] Division of Livestock Products Technology, SKUAST-J, India
[b] Division of Veterinary Public Health, GADVASU, India
[c] Division of Animal Biotechnology, SKUAST-K, India
[d] Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences (NMBU), Norway
[e] Department of Food Sciences, University of Otago, New Zealand

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ABSTRACT

The study was aimed at developing a bioactive edible film for improving the lipid-stability of ice-cream and frozen dairy products during storage using *Aloe* vera as a bioactive ingredient. Kulfi, a popular Indian ice-cream, was used as a food model system. The optimized film (1.5% w/v carrageenan and 14% w/v glycerol) was incorporated with different levels of *A. vera* (9, 12 and 15% w/v) and used to pack the kulfi samples during six-month frozen storage (-18°C). While density (g/mL) and thickness (mm) of the film increased, the transmittance (%), water-vapour transmission rate (mg/m^2t) and lightness (L^*) values decreased with concentration of *A. vera.* The *A. vera* films showed antimicrobial properties against *Escherichia coli*. The kulfi samples packaged in *A. vera* films showed significantly lower values for lipid-oxidation [thiobarbituric acid reacting substances (TBARS), free-fatty acids (FFA) and peroxide values (PV)] and microbial counts (psychrophilic and yeast/moulds) which were reflected in their sensory quality during entire storage period. The highest values for TBARS, FFA and PV were observed for control samples (1.0 mg malondialdehyde/kg, 0.80% and 1.99 meg/kg, respectively) and lowest for samples packaged in films containing 15% *A. vera* (0.61 mg malondialdehyde/kg, 0.47% and 1.34 meg/kg, respectively) on day 180.

1. Introduction

Increased consumer awareness has led to an increased interest of food manufacturers and processors to develop biopreservative systems using natural antimicrobials and antioxidants to ensure quality and safety of foods (Kaur et al., 2021). Numerous phytochemicals, bioactive molecules and plant extracts have been used in different food matrices (Dua et al., 2015a, b; Para et al., 2015; Singh et al., 2015a, b) with significant results in terms of improved lipid, microbial and colour stability (Kumar et al., 2016a; Jamwal et al., 2015; Kaur et al., 2015a). However, direct inclusion of plant extracts may have some negative effects on sensory attributes (such as colour and flavour) and acceptability of the foods (Sharma et al., 2021a, Bhat et al., 2010a, b). To avoid these undesirable effects, researchers have added plant extracts to the packaging itself to develop bioactive films (Sharma et al., 2021b; Bhat & Bhat, 2011a). One of the recent developments in the field of packaging is the use of edible and food grade biodegradable materials for development of packaging films which act as carrier of bioactive molecules and inherit antimicrobial and antioxidant properties to the packaging systems to improve consumer safety and storage quality of foods (Noor et al., 2018a). It is important to mention that the development of bioactive edible films is currently at a research stage and has not been fully commercialized.

Having the potential to reduce the use of conventional packaging materials (Panchal et al., 2022), bioactive edible films is one of the potential vehicles for plant extracts for improving the storage quality without reducing the sensory quality and efficacy of the extracts (Kalem et al., 2018a, b). Development of edible films with antimicrobial properties using natural bioactive ingredients has become a significant research area in food packaging and is associated with higher consumer acceptance due to higher food safety (Sharma et al., 2021b). Several edible films have been developed recently using ingredients such as whey proteins, starch, sodium alginate, maltodextrin and inulin for different food products (Sert et al., 2021; Orozco-Parra et al., 2020). Extracts from different plant sources and agricultural wastes, such as lemon peel, *T. cordifolia, T. arjuna, R. cordifolia* and *A. racemosus,* have been used as bioactive ingredients for development of edible films (Sharma et al., 2021a; Kalem et al., 2018a, b). However, use of *A. vera* as a bioactive

* Corresponding author.
E-mail address: zuhaibbhatvet@gmail.com (Z.F. Bhat).

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ingredient and development of bioactive packaging for improving the storage quality and lipid stability of ice-cream has received a very little scientific attention. Ice-cream and other frozen dairy products are susceptible to lipid oxidation during storage due to their higher fat content (Mahajan et al., 2021a, b). Therefore, the present study was designed with an aim to develop a bioactive edible film using *Aloe vera* gel as a bioactive ingredient for improving the lipid oxidative stability of ice-cream using kulfi as a model of study. Kulfi is a traditional Indian ice-cream that is popular in South Asian and Middle Eastern countries and is readily available in overseas restaurants where Indian cuisine is served (Susngi et al., 2019). A well-established biochemical profile and strong antimicrobial and antioxidant properties makes *A. vera* gel a good candidate for development of bioactive edible films (Waithaka et al., 2018). Carrageenan based film was developed using different levels of *A. vera* gel and used to pack the kulfi samples during six-month frozen storage (-18±1 ˚C). The film was characterized and its efficacy was evaluated on lipid oxidation, microbial stability, physicochemical characteristics and sensory quality of the products.

2. Material and methods

2.1. A. vera *extract and preparation of the film*

Preliminary trials were conducted to optimise the concentration of different ingredients used for development of the bioactive edible film. Different concentrations of carrageenan (1.0, 1.5 and 2.0% w/v) and glycerol (10, 14 and 18% w/v) were used. The optimized film with desirable characteristics contained 14% glycerol and 1.5% carrageenan. The 1.5% carrageenan solution were prepared in water and stirred (@350 rpm) at 80 ^{0}C for 20 min. This was followed by the addition of glycerol (14%) and the solution was continuously stirred for 10 min on a magnetic stirrer (Glassco Laboratory Pvt. Ltd., India), cooled at room temperature (60˚C) and used to cast the films on glass plates (10 × 20 cm). The casted films were dried in hot air oven (Narang Scientific Works, India) for 5 h at 55˚C and were peeled off and used to pack the kulfi samples.

The leaves were harvested from the *A. vera* plants (*Aloe barbadensis Miller*) grown in the agricultural university farm (SKUAST-Jammu, India) and were thoroughly washed with distilled water. The *A. vera* gel (inner parenchymatous tissue) was obtained by removing the gel fillet from the leaves after removing the rind with a sterilized knife and allowing drainage of *A. vera* latex (yellow exudate). The gel was homogenized using a domestic blender (11,000 rpm) and three different aqueous solutions (9, 12 and 15% w/v) were developed which were stirred for 72 h (@350 rpm) and filtered through Whatman filter paper no. 42. To avoid any loss of antioxidant and antimicrobial activity, the solutions were not pasteurized. The solutions were evaluated for microbial quality (total plate and coliforms) to ensure the safety before use. The *A. vera* based bioactive edible films were developed using these solutions, glycerol (14%) and carrageenan (1.5%). The results of minimum inhibitory concentration test were used to determine the minimum concentration of the *A. vera* solutions. The study did not include the chemical characterization of the *A. barbadensis Miller* gel since it has already been reported by several studies such as Ahmed & Hussain (2013) and Radha & Laxmipriya (2015). The developed films were characterized for various physico-mechanical, colour and antimicrobial properties.

2.2. Preparation of the kulfi

The mix for the kulfi was developed using 87.70% milk, 10% sugar (for sweetness), 2% arrowroot powder (for consistency) and 0.3% sodium alginate (as a stabilizer) (Mahajan et al., 2021a). The milk (8.5% solids not fat and 3% fat) was continuously stirred at 100˚C till it concentrated to a ratio of 2:1 (w/w). This was followed by the addition of sugar, arrowroot powder and sodium alginate. The mix was constantly stirred at the boiling temperature till all ingredients were dissolved completely and was allowed to cool at room temperature (30˚C) and filled into the cone shaped moulds. The product is traditionally prepared by heat-cum-stirring method at this temperature and is responsible for its peculiar texture and flavour and higher iron content. The products were hardened at -18˚C for 5,6 h and were removed from the moulds and packaged in the *A. vera* based edible films [9% (T_1), 12% (T_2) and 15% (T_3)] and stored for six months at -18˚C. The samples were taken on day 0, 45, 90, 135 and 180 and evaluated for lipid oxidative stability, microbial stability, physicochemical and proximate parameters, and sensory quality.

2.3. Physico-mechanical characteristics and colour analysis

The thickness of the film and water vapor transmission rate were determined using a micrometre (0–10 mm) (Swastik Scientific Company, Mumbai, India) and a test cell sealed with film (containing 15 mL distilled water in a desiccator for 24 h), respectively (Mahajan et al., 2021a). The moisture content and density of the film was determined by the gravimetric method (105±1 ˚C for 24 h) and floatation method (using carbon tetrachloride and heptane as solvents), respectively (Mahajan et al., 2021a). Transmittance was measured at a wavelength of 660 nm using strips of film (3 × 1 cm) placed in a cuvette (Mahajan et al., 2021b). The method described by Bhat et al. (2020a) was used to determine the colour of the film (L^*, a^*, b^*) using a colorflex colorimeter (Hunter Lab Colorimeter D-25, Hunter Associated laboratory Inc., VA, USA) at a 0˚ viewing angle. The colourimeter was calibrated using black and white tiles. Samples of the film were placed in the transmission port of optical unit and the results were obtained in terms of L^* (lightness) ranging from 0 (black) to 100 (white), a^* (Redness) from +60 (red) to -60 (green) and b^* (yellowness) from +60 (yellow) to -60 (blue).

2.4. Microbiological analysis

The methods described by Mahajan et al. (2021a) were used for performing disc agar diffusion and minimum inhibitory concentration tests using Muller Hinton agar and Muller Hinton broth, respectively, inoculated with culture of *E. coli* (10^6 cfu/mL) and incubated at 37 ˚C for 24 h. The methods described by Bukhari et al. (2012), Bhat & Pathak (2011) and Kumar et al. (2011) were used to determine the microbial counts (coliforms, psychrophiles and yeast/moulds) near flame under laminar flow (Thermo Electron Corporation D-63505 Langenselbold, Robert Boschstr. 1, Germany) and the results were expressed as $\log_{10}$ cfu/g (Bhat & Pathak, 2013).

2.5. Lipid oxidation, physicochemical parameters and proximate composition

A digital pH meter (Product code 35613424, Oakton instruments, Singapore) and a tissue homogenizer (Janke and Kenkel, IKA labor Technik, Germany) were used to measure the pH of the samples (Bhat et al., 2018a, b). Peroxide value (meq/kg) and free fatty acids (% oleic acid) of the samples were determined using the methods described by Mahajan et al. (2016, 2015a), respectively. Thiobarbituric acid reacting substances (mg malonaldehyde/kg) of the stored samples were determined following the method described by Kumar et al. (2016b). After homogenizing the samples (10 g) with 25 mL of trichloroacetic acid (20%) in orthophosphoric acid (2 M), double distilled water (25 mL) was added and the homogenates were filtered through Whatman filter paper (No. 1). The filtrate (3 mL) was mixed with 2-TBA reagent (0.005 M, 3 mL) in test tubes and stored for 16 h in dark before the absorbance was measured at 532 nm using a UV-Vis spectrophotometer (Systronics, India) and the values were expressed as mg malondialdehyde/kg. 1,1,3,3 tetra-ethoxypropane was used as a standard. The methods followed by Bhat et al. (2020b, 2019a, 2019b) were used to determine the proximate composition (moisture, crude protein and crude fat) of

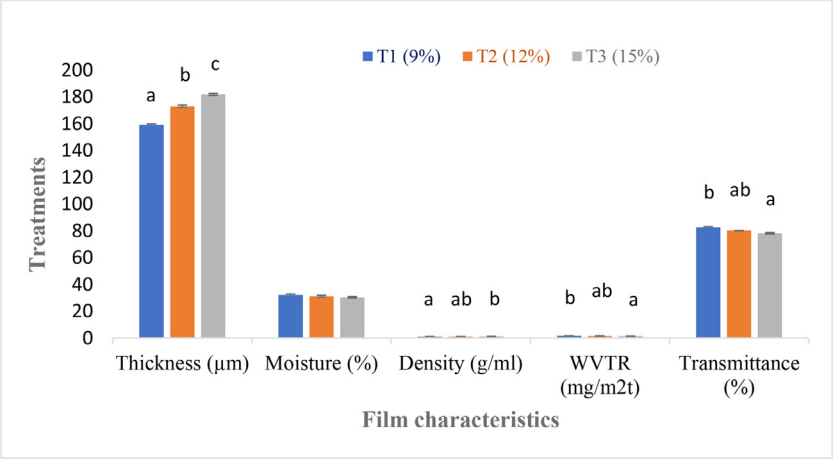

Figure 1. Effect of *Aloe vera* extract on the characteristics of edible film.

Different superscripts on columns for a parameter differ significantly ($P<0.05$)
T_1 (edible film containing 9% *Aloe vera* extract)
T_2 (edible film containing 12% *Aloe vera* extract)
T_3 (edible film containing 15% *Aloe vera* extract)
WVTR = Water vapour transmission rate (mg/m^2t)

the samples using a hot air oven (Narang Scientific Works, India), Soxhlet extraction apparatus (JSJW, Haryana, India) and a Micro-Kjeldahl digester distillation unit (JSJW, Haryana, India).

2.6. Sensory analysis

A panel of ten trained panellists [a mixed gender panel (male: female = 1:1) of an age group ranging from 25 to 45 years] performed the sensory analysis of the samples thrice (3 replications) for various sensory attributes on different storage intervals (Bhat et al., 2012). The Indian standards for sensory evaluation of foods specifies a requirement of 5–10 panellists for a trained panel (Standard IS 6273-1, 2012). The three-digit coded samples (50 g of kulfi) were presented in a random order and a 9-point descriptive scale was used (Ahmed et al., 2014). Sensory evaluation was carried out in the laboratory for all the batches and to avoid the carry over effect, drinking water was provided between the samples.

2.7. Statistical analysis

The data obtained for various parameters (replicated six times) were statistically analysed using one-way ANOVA (film characteristics, colour analysis, inhibition halos), repeated measurements ANOVA (sensory analysis) and a two-way ANOVA (storage parameters) using SPSS version 20 and the results were presented as means ± standard errors. Duncan's multiple range tests were applied to evaluate the effect of storage time and treatments at 0.05 level of significance.

3. Results and discussion

3.1. Physico-mechanical and colour properties

The mean results of the parameters related to various physico-mechanical and colour properties of the *A. vera* based films [T_1 (9%), T_2 (12%) and T_3 (15%)] are shown in Figs. 1 and 2. Both thickness (mm) and density (g/mL) of the film showed an increasing trend with concentration of *A. vera* and as expected this caused a decrease in the transmittance (%) and water vapour transmission rate (WVTR, mg/m^2t) of the film (Sharma et al., 2021b). Addition of polyphenolic compounds and bioactive molecules have been reported to form cross linkages with macromolecules, such as carrageenan and starch, and also induce changes in rheological properties causing an increase in thickness of the films (Sharma et al., 2021a; Darmawati & Fadhila, 2020). Both thickness and density of the films are affected by processing and compositional changes and have potential to affect other physico-mechanical properties of the films (Zhang et al., 2020). The WVTR of the edible films determines their potential to retain the moisture content of the stored products and is highly influenced by the density of the films. Previous studies have reported a decrease in transmittance and WVTR of the films on addition of different phytochemicals and plant extracts to the film matrices (Darmawati & Fadhila, 2020; Sharma et al., 2021a, b).

Addition of the transparent and turbid *A. vera* gel affected the colour and decreased ($P<0.05$) the lightness (L^*) values of the film. Such a decline in the colour values has been observed on addition of plant extracts to the film matrix (Darmawati & Fadhila, 2020). No significant effect of the addition of *A. vera* was observed on the moisture content, yellowness (b^*) and redness (a^*) values of the films.

3.2. Lipid stability

The mean values of the parameters related to lipid oxidative stability of the kulfi samples stored under frozen conditions viz. thiobarbituric acid reacting substances (TBARS), peroxide value (PV) and free fatty acids (FFA) are presented in Table 1. A significant effect of *A. vera* was found on the lipid oxidation of the products and significantly ($P<0.05$) lower values were observed for the products packaged in *A. vera* based films [T_1 (9%), T_2 (12%) and T_3 (15%)] compared to control samples for all the three lipid stability parameters over the entire period of storage beyond day 0. These results might be attributed to various bioactive molecules, such as phenolic compounds, organic acids, carotenoids, vitamins E and C, responsible for strong antioxidant properties of the *A. vera* extract (Hęś et al., 2019; Bhat et al., 2015a). Used to determine the freshness of the food products (Bhat & Pathak, 2012, 2009) and as a marker for oxidative damage (Singh et al., 2014a, b), TBARS assay is the most common method used for oxidative stability of the lipids of the food products (Sharma et al., 2021a; Bhat et al., 2019c). Both free fatty acids and peroxides are oxidation products of PUFA and provide an important information about the lipid stability of the foods (Dilnawaz et al., 2017a, b; Bhat et al., 2014) and are affected by several factors such as storage time, presence of metal ions, moisture and lipases (Kumar et al., 2015; Noor et al., 2018b, 2017). The present research and previous studies indicate a positive impact of the plant ex-

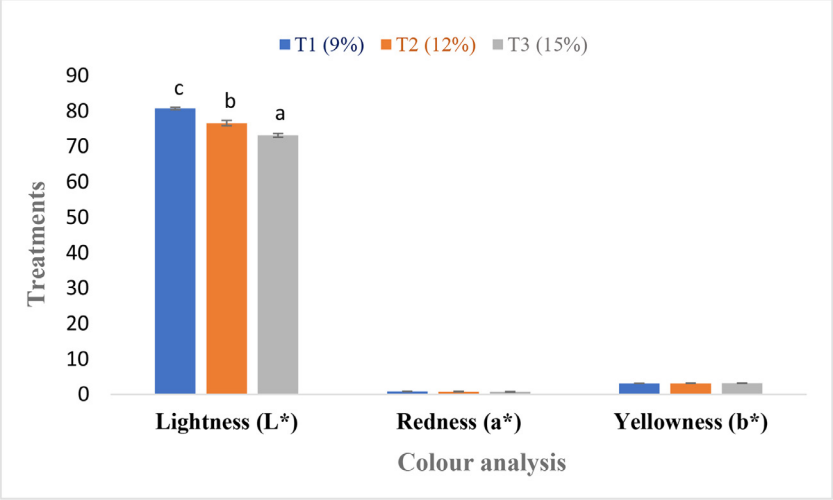

Figure 2. Effect of *Aloe vera* extract on the colour of edible film.

Different superscripts on the columns for a parameter differ significantly (P<0.05)
Instrumental colour analysis
T_1 (edible film containing 9% *Aloe vera* extract)
T_2 (edible film containing 12% *Aloe vera* extract)
T_3 (edible film containing 15% *Aloe vera* extract)

Table 1
Effect of *Aloe vera* based film on the lipid stability of kulfi during frozen storage (-18±1 °C).

Samples	Storage period (days)				
	0	45	90	135	180
TBARS value (mg malondialdehyde/kg)					
C	0.182±0.010^{Aa}	0.421±0.023^{Bc}	0.586±0.013^{Cc}	0.829±0.078^{Dc}	1.00±0.049^{Ec}
T_1	0.181±0.013^{Aa}	0.316±0.011^{Bb}	0.430±0.019^{Cb}	0.612±0.012^{Db}	0.804±0.031^{Eb}
T_2	0.176±0.012^{Aa}	0.212±0.016^{Aa}	0.322±0.020^{Ba}	0.466±0.036^{Ca}	0.658±0.027^{Da}
T_3	0.175±0.016^{Aa}	0.189±0.011^{Aa}	0.314±0.051^{Ba}	0.436±0.022^{Ca}	0.618±0.018^{Da}
Peroxide value (meq/kg)					
C	0.418±0.010^{Aa}	1.09±0.021^{Bc}	1.35±0.016^{Cc}	1.66±0.016^{Dc}	1.99±0.020^{Ec}
T_1	0.409±0.005^{Aa}	0.73±0.014^{Bb}	1.09±0.014^{Cb}	1.37±0.024^{Db}	1.68±0.031^{Eb}
T_2	0.403±0.022^{Aa}	0.42±0.010^{Aa}	0.73±0.021^{Ba}	1.05±0.034^{Ca}	1.38±0.023^{Da}
T_3	0.401±0.020^{Aa}	0.40±0.018^{Aa}	0.71±0.015^{Ba}	1.02±0.021^{Ca}	1.34±0.017^{Da}
Free fatty acids (% oleic acid)					
C	0.146±0.016^{Aa}	0.365±0.023^{Bc}	0.491±0.014^{Cc}	0.633±0.034^{Dc}	0.806±0.028^{Ec}
T_1	0.146±0.008^{Aa}	0.254±0.010^{Bb}	0.364±0.012^{Cb}	0.521±0.010^{Db}	0.668±0.023^{Eb}
T_2	0.143±0.006^{Aa}	0.161±0.009^{Aa}	0.277±0.012^{Ba}	0.377±0.014^{Ca}	0.514±0.027^{Da}
T_3	0.143±0.010^{Aa}	0.155±0.011^{Aa}	0.251±0.017^{Ba}	0.352±0.015^{Ca}	0.478±0.038^{Da}

Mean ± SE with different superscripts in a row (upper case alphabet) and column (lower case alphabet) differ significantly ($P<0.05$), $n = 6$ for each treatment.
C (kulfi stored without any edible film).
T_1 (kulfi with edible film containing 9% *Aloe vera* extract).
T_2 (kulfi with edible film containing 12% *Aloe vera* extract).
T_3 (kulfi with edible film containing 15% *Aloe vera* extract).

tracts on lipid oxidative stability whether added directly to the food matrices (Kaur et al., 2015b, c; Bhat et al., 2015b; Kumar et al., 2013a, b) or to the edible films (Sharma et al., 2021b; Noor et al., 2018a). Such a positive effect of bioactive edible films containing catechin and gallic acid has been reported on lipid oxidative stability of dairy products such as cheese (Unalan et al., 2013).

3.3. Microbiological characteristics

The mean values of various microbiological characteristics viz. minimum inhibitory concentration, disc agar diffusion test and microbial counts are presented in Fig. 3 and Table 2. In agreement with previous studies (Adzitey et al., 2019), a significant effect of the extract was observed and the size of inhibitory halos against *E. coli* showed an increasing trend with increasing concentration of *A. vera.* A minimum inhibitory concentration (MIC) of 1.87% was found for the extract (15%) against *E. coli,* confirming the results of Prasad et al. (2016) who has reported antimicrobial properties of *A. vera* extract against *E. faecalis* and found an MIC value of 1.80%. The psychrophilic counts were detected on 135th and 180th day and significantly ($P<0.05$) lower values were found for the samples packed in the *A. vera* based films. Strong antimicrobial properties have been reported for *A. vera* gel against several microbes including *P. aeruginosa, S. aureus, K. pneumoniae, S. flexneri, S. pyogenes, E. coli, E. faecalis, Klebsiella sp., Enterobacter sp.,* and *Citrobacter sp.* (Kumar et al., 2017).

Each kulfi was packaged separately within an edible film and taken out of the frozen conditions on different time points to take the subsamples for microbial evaluation. The samples were thereafter thawed in a refrigerator to ease the dilution making process for microbial assessment. The edible film and the plant extract used in the study were not sterilized. All these factors might have contributed to the microbial growth observed during the study. The microbial counts of the products

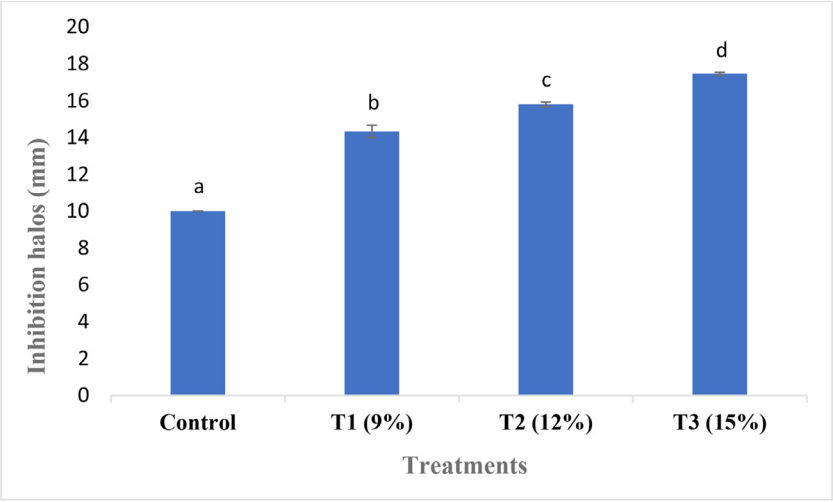

Figure 3. Antimicrobial potential of *Aloe vera* based edible film against *Escherichia coli.*

Different superscripts on columns differ significantly ($P<0.05$)
Control (edible film containing 0% *Aloe vera* extract)
T_1 (edible film containing 9% *Aloe vera* extract)
T_2 (edible film containing 12% *Aloe vera* extract)
T_3 (edible film containing 15% *Aloe vera* extract)

Table 2
Effect of *Aloe vera* based film on the microbial stability of kulfi during frozen storage (-18±1 °C).

Samples	Storage period (days)				
	0	45	90	135	180
Psychrophilic count (log_{10} cfu/g)					
C	ND	ND	ND	1.56 ± 0.039^{Ad}	2.08 ± 0.034^{Bd}
T_1	ND	ND	ND	1.32 ± 0.029^{Ac}	1.70 ± 0.010^{Bc}
T_2	ND	ND	ND	1.19 ± 0.039^{Ab}	1.52 ± 0.040^{Bb}
T_3	ND	ND	ND	1.04 ± 0.036^{Aa}	1.39 ± 0.038^{Ba}
Yeast and mould count (log_{10} cfu/g)					
C	ND	ND	ND	1.82 ± 0.021^{Ad}	2.39 ± 0.021^{Bd}
T_1	ND	ND	ND	1.56 ± 0.007^{Ac}	2.02 ± 0.041^{Bc}
T_2	ND	ND	ND	1.40 ± 0.030^{Ab}	1.83 ± 0.034^{Bb}
T_3	ND	ND	ND	1.28 ± 0.035^{Aa}	1.64 ± 0.036^{Ba}
Coliform count (log_{10} cfu/g)					
All samples	Not detected throughout the period of storage				

Mean ± SE with different superscripts in a row (upper case alphabet) and column (lower case alphabet) differ significantly ($P<0.05$).
$n = 6$ for each treatment.
ND = Not detected.
C (kulfi stored without any edible film).
T_1 (kulfi with edible film containing 9% *Aloe vera* extract).
T_2 (kulfi with edible film containing 12% *Aloe vera* extract).
T_3 (kulfi with edible film containing 15% *Aloe vera* extract).

were within the acceptable limits during entire frozen storage and were safe for consumption. No coliforms were detected in the samples during entire storage time and the yeast/moulds were detected on 135th and 180th day and significantly ($P<0.05$) lower values were found for the samples packed in the *A. vera* based films. Strong fungicidal properties have been reported for *A. vera* gel against several fungi including *Fusarium oxysporum, Aspergillus niger, Cladosporium herbarum, Fusarium moniliforme* and *Candida albicans* (Waithaka et al., 2018; Kumar et al., 2017). The Bureau of Indian Standards allows a maximum of 25×10^5 cfu/g for total microbial count and 90 cfu/g for coliforms for frozen kulfi (Robinson, 2002). Storage studies of different food products have reported absence of coliforms indicating the absence of pathogens in the samples (Dua et al., 2015c). Numerous studies have highlighted the importance of plant extracts in reducing the microbial counts either by direct addition to food matrices (Zargar et al., 2017, 2016; Bhat et al., 2011a, b, c; Pathak et al., 2008) or through addition to edible and bioactive packaging (Xiong et al., 2020; Kalem et al., 2018c).

3.4. pH and proximate composition

The mean pH and proximate composition values of the kulfi samples stored under frozen conditions and packaged within the *A. vera* based edible films are presented in Table 3. No significant effect of the film was recorded on the protein and fat contents of the products during storage. The moisture content of the samples packaged within the films was significantly ($P<0.05$) higher than control samples indicating the effectiveness of the films in reducing the moisture loss from the product surfaces during storage (Sharma et al., 2021a; Noor et al., 2018a). The edible films act as a physical barrier and avoid an unimpeded evaporation from the product surfaces. Higher moisture retention of the samples stored within T_2 and T_3 films might be attributed to relatively higher thickness and density of the films due to a higher concentration of polyphenolic and bioactive molecules which are known to form cross linkages with macromolecules, such as carrageenan, and also induce changes in rheological properties and water vapour transmission rate (Sharma et al., 2021a; Darmawati & Fadhila, 2020). Both thickness and density of the films can affect moisture retention capacity of the films (Sharma et al., 2021b). In addition, the significantly lower pH values of the samples packaged within T_2 and T_3 films might be attributed to the diffusion of phenolic and acidic compounds from *A. vera* extract to the product surface. *A. vera* gel contains various organic acids and compounds with acidic properties such as caffeic acid, cinnamic acids, feruloylquinic acid and chlorogenic acids which can reduce the pH of the samples (Bhat et al., 2015a). Effect of plant extract based edible films on the pH of the food samples has been reported (Xiong et al., 2020).

3.5. Sensory analysis

The mean scores of various sensory characteristics of the kulfi samples stored under frozen conditions and packaged within the *A. vera* based edible films are presented in Table 4. The kulfi samples packaged

Table 3
Effect of *Aloe vera* based film on the physicochemical and proximate composition of kulfi during frozen storage (-18±1 °C).

Samples	Storage period (days)				
	0	45	90	135	180
pH					
C	6.41±0.024^{ABa}	6.35±0.033^{Ab}	6.47±0.018^{Bc}	6.62±0.022^{Cc}	6.67±0.017^{Cc}
T_1	6.40±0.023^{Ba}	6.31±0.005^{Aab}	6.43±0.007^{Bbc}	6.57±0.019^{Cbc}	6.64±0.008^{Dbc}
T_2	6.40±0.018^{Ba}	6.28±0.015^{Aa}	6.40±0.012^{Bab}	6.54±0.019^{Cab}	6.59±0.019^{Dab}
T_3	6.38±0.017^{Ba}	6.24±0.017^{Aa}	6.36±0.023^{Ba}	6.50±0.012^{Ca}	6.55±0.023^{Ca}
Moisture (%)					
C	63.18±0.34^{Da}	62.58±0.028^{Ca}	62.09±0.023^{Ba}	61.61±0.027^{Aa}	61.17±0.033^{Aa}
T_1	63.19±0.25^{Da}	62.90±0.053^{CDb}	62.57±0.041^{Cb}	62.09±0.042^{Bb}	61.69±0.026^{Ab}
T_2	63.21±0.33^{Ca}	62.97±0.039^{BCbc}	62.64±0.021^{Bbc}	62.16±0.033^{Abc}	61.78±0.044^{Abc}
T_3	63.22±0.25^{Da}	63.02±0.024^{CDc}	62.71±0.017^{Cc}	62.22±0.027^{Bc}	61.84±0.052^{Ac}
Protein (%)					
C	5.87±0.018^{D}	5.83±0.016^{DC}	5.80±0.013^{BC}	5.77±0.019^{AB}	5.73±0.018^{A}
T_1	5.88±0.020^{C}	5.84±0.021^{BC}	5.81±0.017^{AB}	5.78±0.016^{AB}	5.75±0.017^{A}
T_2	5.89±0.029^{B}	5.87±0.018^{B}	5.84±0.023^{AB}	5.82±0.015^{AB}	5.78±0.019^{A}
T_3	5.91±0.019^{C}	5.89±0.018^{BC}	5.86±0.017^{ABC}	5.85±0.019^{AB}	5.82±0.017^{A}
Fat (%)					
C	5.43±0.015^{E}	5.29±0.023^{D}	5.14±0.027^{C}	4.97±0.033^{B}	4.85±0.028^{A}
T_1	5.43±0.014^{E}	5.34±0.026^{D}	5.20±0.029^{C}	5.04±0.024^{B}	4.92±0.029^{A}
T_2	5.45±0.015^{D}	5.39±0.025^{D}	5.27±0.028^{C}	5.10±0.028^{B}	4.98±0.030^{A}
T_3	5.47±0.017^{D}	5.43±0.024^{D}	5.33±0.027^{C}	5.15±0.031^{B}	5.04±0.028^{A}

Mean ± SE with different superscripts in a row (upper case alphabet) and column (lower case alphabet) differ significantly ($P<0.05$), $n = 6$ for each treatment.
C (kulfi stored without any edible film).
T_1 (kulfi with edible film containing 9% *Aloe vera* extract).
T_2 (kulfi with edible film containing 12% *Aloe vera* extract).
T_3 (kulfi with edible film containing 15% *Aloe vera* extract).

Table 4
Effect of *Aloe vera* based film on the sensory quality of kulfi during frozen storage (-18±1 °C).

Samples	Storage period (days)				
	0	45	90	135	180
Appearance and colour					
C	8.24±0.039^{Da}	7.65±0.038^{Ca}	7.35±0.037^{Ba}	6.94±0.035^{Aa}	NP
T_1	8.25±0.036^{Ea}	7.90±0.033^{Db}	7.61±0.040^{Cb}	7.29±0.041^{Bb}	6.87±0.043^{Aa}
T_2	8.27±0.035^{Ea}	7.99±0.045^{Dbc}	7.68±0.039^{Cbc}	7.38±0.039^{Bbc}	7.01±0.052^{Abc}
T_3	8.29±0.041^{Ea}	8.06±0.046^{Dc}	7.75±0.041^{Cc}	7.48±0.039^{Bc}	7.14±0.050^{Ac}
Flavour					
C	8.09±0.043^{Da}	7.51±0.046^{Ca}	7.24±0.040^{Ba}	6.94±0.040^{Aa}	NP
T_1	8.10±0.044^{Ea}	7.79±0.040^{Db}	7.52±0.045^{Cb}	7.24±0.039^{Bb}	6.94±0.040^{Aa}
T_2	8.11±0.047^{Ea}	7.85±0.042^{Db}	7.61±0.047^{Cbc}	7.33±0.051^{Bbc}	7.04±0.046^{Ab}
T_3	8.11±0.049^{Ea}	7.90±0.040^{Db}	7.69±0.045^{Cc}	7.42±0.050^{Bc}	7.16±0.038^{Ac}
Body and texture					
C	8.04±0.038^{Da}	7.46±0.038^{Ca}	7.19±0.048^{Ba}	6.90±0.042^{Aa}	NP
T_1	8.05±0.043^{Ea}	7.77±0.049^{Db}	7.50±0.047^{Cb}	7.20±0.047^{Bb}	6.82±0.044^{Aa}
T_2	8.06±0.049^{Ea}	7.81±0.045^{Db}	7.54±0.043^{Cb}	7.28±0.048^{Bbc}	6.92±0.043^{Aab}
T_3	8.06±0.042^{Ea}	7.89±0.042^{Db}	7.61±0.037^{Cb}	7.35±0.05^{Bc}	7.04±0.043^{Ab}
Palatability					
C	8.15±0.066^{Da}	7.39±0.045^{Ca}	7.11±0.046^{Ba}	6.83±0.047^{Aa}	NP
T_1	8.16±0.041^{Ea}	7.72±0.045^{Db}	7.42±0.042^{Cb}	7.13±0.044^{Bb}	6.80±0.056^{Aa}
T_2	8.16±0.043^{Ea}	7.79±0.040^{Dbc}	7.53±0.045^{Cab}	7.21±0.050^{Bab}	6.89±0.049^{Aab}
T_3	8.17±0.049^{Ea}	7.89±0.052^{Dc}	7.62±0.045^{Cc}	7.32±0.049^{Bc}	7.02±0.041^{Ab}
Overall acceptability					
C	8.01±0.040^{Da}	7.36±0.040^{Ca}	7.06±0.047^{Ba}	6.73±0.045^{Aa}	NP
T_1	8.01±0.044^{Ea}	7.65±0.050^{Db}	7.36±0.043^{Cb}	7.06±0.043^{Bb}	6.71±0.047^{Aa}
T_2	8.02±0.044^{Ea}	7.72±0.046^{Db}	7.42±0.048^{Cbc}	7.15±0.040^{Bbc}	6.82±0.047^{Aab}
T_3	8.03±0.046^{Ea}	7.78±0.045^{Db}	7.50±0.046^{Cc}	7.21±0.050^{Bc}	6.89±0.041^{Ab}

Mean ± SE with different superscripts in a row (upper case alphabet) and column (lower case alphabet) differ significantly ($P<0.05$)
9-point descriptive scale, where 1 = liked extremely and 9 = disliked extremely.
$n = 30$ for each treatment.
NP = Not performed.
C (kulfi stored without any edible film).
T_1 (kulfi with edible film containing 9% *Aloe vera* extract).
T_2 (kulfi with edible film containing 12% *Aloe vera* extract).
T_3 (kulfi with edible film containing 15% *Aloe vera* extract).

within the edible films showed significantly higher scores for all the sensory attributes during entire six-month frozen storage beyond day 0. The significant improvement observed in lipid oxidative and microbial stability of the kulfi samples packaged in the edible films reflected in their sensory quality. Strong antioxidant and antimicrobial properties of *A. vera* reduced the rate of deterioration of the sensory quality of the kulfi samples during storage. Primary and secondary metabolites and off-flavour compounds produced during oxidation of lipids and proteins affect the flavour, texture and colour of the products during storage (Bekhit et al., 2019; Dua et al., 2016; Kalem et al., 2017). Significantly higher moisture content of the samples packaged within the edible films resulted in higher juiciness and textures scores (Saricaoglu et al., 2018). Significant improvements have been reported in the sensory quality of the food products packaged in the plant extract based edible films during storage (Sharma et al., 2021a, b; Mahajan et al., 2021a).

4. Conclusions

An attempt was made to improve the lipid oxidative stability of ice-cream using an *A. vera* based edible film during frozen storage. The film was developed using different levels of *A. vera* gel and was characterized and evaluated for efficacy using kulfi as a model of study. The developed film improved the lipid oxidative stability and significantly reduced the mean values of TBARS, FFA and PV of kulfi samples during six-month frozen storage. The highest values for TBARS, FFA and PV were observed for control samples (1.0 mg malondialdehyde/kg, 0.80% and 1.99 meg/kg, respectively) and lowest for samples packaged in films containing 15% *A. vera* (0.61 mg malondialdehyde/kg, 0.47% and 1.34 meg/kg, respectively) on day 180. It also significantly improved the microbial stability and sensory quality of the products during storage. Significantly lower values were observed for psychrophilic and yeast/mould counts for the samples packaged in the films containing 15% *A. vera* on day 180 (1.39 and 1.64, respectively) compared to control samples (2.03 and 2.39, respectively). The highest sensory scores were observed for the samples packaged in the films containing 15% *A. vera* (7.48, 7.42, 7.35, 7.32 and 7.21 for colour, flavour, texture, palatability and overall acceptability, respectively) on day 135 and lowest scores were observed for control samples (6.94, 6.94, 6.90, 6.83 and 6.73 for colour, flavour, texture, palatability and overall acceptability, respectively). The studies in future should focus on consumer perception and acceptance and evaluation of the efficacy in other variants of ice-cream and frozen dairy products for commercialization of the film. Development of *A. vera* based edible cones should be attempted.

Ethical statement

The study was not performed in animals or humans

Declaration of Competing Interest

There is no conflict of interest.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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