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RESEARCH ARTICLE

Process optimization, characterization, and formulation of ragi-based functional ice cream with the addition of natural sweetener

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Abstract: Ice cream is identified as a convenient and wholesome product with significant commercial potential. Contemporary trends and evolving consumer preferences indicate that the development of cereal-based, value-added dairy products has substantial potential for entrepreneurs. Incorporating ragi into ice cream might enhance its useful properties and nutritional value. This study aimed to develop functional ice cream, whereby optimization revealed that vanilla-flavoured ice cream was made better with roasted, gelatinised ragi flour (6% per litre of mix), sugar, and stevia in a 50:50 ratio. The optimization was founded on sensory evaluation of body, texture, colour, flavour, and overall acceptability, which received a score of 8.41 ± 0.14. The item that was produced had 9.9% fat and 4.05% protein, with an estimated cost of Rs. 1050 for 10 kg of the product. The total phenolic content was determined to be 62.83 mg GAE/g, representing an additional advantage. It can be used within 15 days of storage at a refrigeration temperature of 4°C.

Keywords: Functional, Ice cream, Optimization, Ragi, Stevia

Introduction

Milk is said to be an ideal and complete food that can be considered perfect, and India is the largest producer of milk, with a production of 239.3 million tonnes of milk (NDDB, 2023-24). The Indian subcontinent serves as a demand centre for milk and milk products, in which frozen desserts are meeting its demand, which is recognized for its unique taste. Ice cream is globally favoured, particularly among the youth, as it satisfies thirst and induces pleasure through many sensory sensations while eating. Across generations, a shift in spending behaviour is emerging among both young and elderly individuals due to its cooling nature (Sarkar et al. 2024) .The sales are steadily increasing across the region, particularly in locales characterized by hot, humid conditions (Kanse et al. 2020). Compared to the global average of 2.3 litres per year, India's per capita ice cream consumption is notably low, at around 300 millilitres (Clarke et al. 2024). Being a frozen dessert, it can be added with numerous healthy agents, providing a beneficial amount of nutrition and thus contributing to a positive sense of consumption. Nowadays, advanced ice cream compositions are the subject of several ice cream studies in which various ice cream formulations are innovated with useful properties such as probiotics and yoghurt. Ice cream; symbiotic yoghurt ice cream; ice cream with dietary fiber and ice cream with natural antioxidants (Arslaner et al. 2020).

In India, people often consume cereal-based milk products, utilizing cereals to address lysine deficiencies and for value-added applications. Modified cereal starches, recognized for their significant water-binding properties, are commonly used in ice creams either alone or in conjunction with other stabilizers to improve texture and quality (Chakraborty et al. 2022; Patel et al.2015). Ragi, also known as finger millet (Eleusine coracana), is an important agricultural product in India and Africa. It is abundant in vitamins A and B, protein, phosphorus, fiber, and essential amino acids; it possesses hypoglycaemic, antibacterial, and antioxidant qualities attributed to its polyphenolic composition, thereby enhancing its market demand (Somarajan et al. 2022).Stevia (*Stevia rebaudiana*), a natural, non-nutritive sweetener, serves as a safe substitute for sugar without associated health hazards. It has steviol glycosides, like stevioside and rebaudioside, which are 250–300 times sweeter than sucrose and are commonly used to add sweetness to food in Japan, China, and South America (Schiatti-Sisó et al. 2022). In addition to its sweetness, stevia has health advantages, including antihyperglycemic, anticancer, hepatoprotective, and antioxidant effects (Gardana et al. 2018). The FAO/WHO has classified steviol glycosides as safe for consumption in food and drinks, with a recommended daily dose of 0–4 mg/kg body weight. In 2015, the FSSAI sanctioned the use of steviol glycosides in a range of

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goods, including carbonated beverages, dairy confections, jams, and yoghurts.

The increasing interest in dessert options in the contemporary health-conscious market has led academics to explore creative methods for developing functional food. Ragi (finger millet), a nutrient-dense grain abundant in fiber, vital amino acids, and minerals, has significant health advantages, including hypoglycaemic and antioxidant effects, making it an ideal foundation for functional sweets. Adding a natural sweetener like stevia makes the product more appealing by lowering the amount of refined sugar while keeping the sweetness. This makes it suitable for diabetics and others looking for low-calorie options to improve their health. The increasing incidence of diabetes in India underscores the necessity for alternatives, with stevia and ragi providing dual advantages as hypoglycaemic components (Jagati et al. 2021). The objective of this study is to create a cereal-based, low-calorie, functional ice cream enriched with ragi and sweetened with stevia leaf powder. Ragi flour, used in both roasted and unroasted forms, was included in the formulation with several flavours, while optimization was conducted via sensory evaluation, texture analysis, and physicochemical assessment. This research aims to develop a dairy product that fulfils taste demands while providing health benefits that exceed those of conventional ice cream formulations.

Materials and methods

Fresh milk was acquired from the dairy farm of Banaras Hindu University, Varanasi. The cream (25% milk fat) was obtained from a local store in Varanasi. Skim milk powder of the "Sagar brand, manufactured and marketed by Gujarat Cooperative Milk Marketing Federation, Anand. Commercial-grade sugar from a local market in Varanasi is added to the powder. Stevia leaves were procured from the local nursery in Varanasi. BAKERSVILLE India Pvt. Ltd.'s sodium alginate is used as a stabilizer, and BAKERSVILLE India Pvt. Ltd. markets GMS Powder (Glycerol Monostearate) as an emulsifier. Bakefrillz Vanilla Essence, cocoa powder from Cadbury India Ltd., and Kool Rose Food Essence, manufactured by Amrut International, Ahmedabad, were the different flavours that were used to provide the vanilla, cocoa, and rose flavours, respectively. A mechanical flour mill processed the ragi seeds into flour. The flours are sieved using a 20-mesh sieve and stored in airtight containers.

Preparation and processing of Ragi

Cereals undergo multiple processing treatments to achieve acceptable sensory quality and nutritional characteristics. These changes affect flavour, nutritional value, macro- and microstructure, and starch digestibility. Preliminary investigations show that adding gelatinized ragi flour to a mixture can increase its viscosity, making it difficult to manage (Saldivar et al. 2016). The two types of ragi flour, i.e., gelatinized ragi flour (GRF) and roasted-gelatinized ragi flour (RRF), were used for the formulation of functional ice cream. Gelatinized roasted ragi flour in butter with whole milk is cast-off to prevent dilution issues. Evaluation of the combination of ragi flour and whole milk at several concentrations (10%, 15%, and 20% w/w)was done (Table I). It was observed that when 15% ragi flour was used and heated to 90°C for no hold, the resulting mixture had good gel properties, while a concentration of more than 15% resulted in a sticky gel that was difficult to handle and integrate into the mix. Roasting of ragi flour is done to enhance its appearance, color, flavour, and aroma in the processed raw material. It was roasted for 10-12 minutes in a stainless steel deep open pan at a temperature of 125°C (Srivastava et al. 2019). The study indicated that the roasting period for ragi flour had been chosen based on the development of its particular aroma and flavour. Prior to use, the roasted ragi flour underwent gelatinisation as previously explained.

Preparation of powder from stevia leaves

Stevia leaves were dried in sunlight and pulverized into a fine powder. The pulverized powder is sifted through a sieve, and the fine powder of dried stevia leaves is collected and used directly in the ice cream as a substitute for sugar. The quantity of stevia included was determined according to the previous research which indicates that 1 g of stevia is similar to 130 g of sugar in terms of sweetness(Halder et al. 2018).

Preparation of the control Ice cream

The control composition consisted of 25% fat, 11% milk solids-not-fat (MSNF), 15% sucrose, 0.25% sodium alginate, and 0.15% glycerol monostearate (GMS). The measured amounts of liquid components for each treatment were weighed, combined, and properly blended in a stainless-steel vessel before heating commenced. At a temperature of around 60°C, SMP with a specific amount of sugar is incorporated into the mixture. The measured quantity of stabilizer and emulsifier with sugar is combined and incorporated into the preheated mixture at 65°C. Sert et al. (2021) outlined the process of pasteurizing the ice cream mixture at 72°C for 30 minutes to eliminate pathogens and homogenize the mix in an electric homogenizer after pasteurization. The mixture must be homogenized in a pre-cleaned and sterilized homogenizer in two stages after being heated to 70°C. The ice cream mixture is subsequently aged overnight in an aging vat (Sert et al. 2021).

Preparation of Ragi-based functional ice cream

The production of ragi-enriched functional ice cream included two phases. In the initial phase, gelatinised ragi flour (GRF) and roasted gelatinised ragi flour (RRF) were integrated into the mixture at concentrations of 2%, 4%, 6%, and 8% (G1–G4 and R1–R4) and assessed against a control to ascertain the appropriate amount by sensory assessment. A certain amount of whole milk was combined with gelatinised ragi flour, while skim milk powder, sugar, and stevia were included to avert lump formation prior to heating to 60°C. The ragi variations were subsequently included, the mixture was heated to 80°C, and homogenised with a double-stage homogeniser. Figure 1 represents the prepared samples, whereas Figure 2 illustrates the process.

Physicochemical examination

Ice cream mixtures were tested for fat content, total solids content, titratable acidity, pH, protein content, viscosity, specific gravity, overrun, melting properties, and hardness. The fat content was determined using the ISI Handbook of Food Analysis (2015); total solids content was assessed using the standard approach for milk; titratable acidity was assessed using the standard method outlined in the ISI Handbook of Food Analysis (2015); pH was measured using a digital pH meter; protein content was assessed using the Kjeldahl technique. The protein percentage was determined by multiplying the total nitrogen content by a factor of 6.38 for both milk and ice cream.

The viscosity of the ice cream mixture was measured using the viscometer, while the specific gravity was measured at 20°C (Khider et al. 2021). The overrun was assessed using Eq. 1, utilizing a standard 100 mL cup(Zheng H. 2019). The initial dripping and total melting durations of samples were quantified in seconds. The melting rate was determined by putting 50 g of ice cream on a wire mesh (4 pores per 2.5 square inches) situated above a funnel and measuring cylinder. The volume of melted ice cream was measured after 30 minutes. The melting rate of ice cream was expressed in millilitres per 30 minutes.

$$\text{Overrun} = \frac{\text{Volume of ice cream} \times \text{Volume of mix}}{\text{Volume of mix}} \times 100 \qquad \text{Eq. (1)}$$

Sensory analysis: The ragi-based functional ice cream was evaluated by a sensory panel consisting of semi-trained panellists taken from the faculty and students of the Dairy Science and Food Technology Department at the Institute of Agricultural Sciences, BHU, Varanasi. The samples were evaluated using a

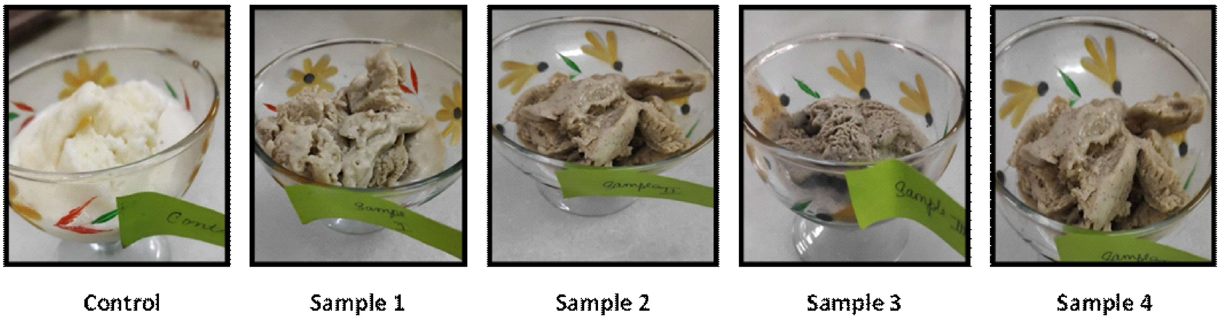

Fig. 1 Prepared sample of Ice cream

Part of whole milk (mixed) + cream (25% milk fat)

↓

Heating to 65 °C and then Mixing dry ingredients (SMP, sugar, stabilizer, emulsifier,

Ragi@2%,4%,6%

Stevia extract @25%,50%,75%,100%)

↓

Heat to 80° C

↓

2 stage homogenization (1st stage at 2500 psi and 2nd stage at 500 psi)

↓

Pasteurization at 80 °C for 5 min

↓

Cooling immediately to 3-4°C and Ageing (3-4° C for 4-12 h)

↓

Addition of vanilla essence @ 1 ml/ kg mix

↓

Aging the mix at 4 °C for 6-12 hours

↓

Freezing the mix (-15 to -25 °C)

↓

Packaging of Ragi added functional ice cream

↓

Hardening and storage of Ragi added functional ice cream (-18 to -23 °C)

Fig. 2 Process flow chart for the manufacture of ragi added functional ice cream nine-point hedonic scale (ranging from 9-extremely like to 1-extremely dislike) for several attributes, including colour and appearance, flavour, body and texture, taste, and overall acceptability.

Antioxidant activity. The antioxidant activity has been evaluated using the DPPH technique. The DPPH radical scavenging assay is frequently employed to evaluate the efficacy of natural antioxidants in neutralising free radicals (Gulcin & Alwasel, 2023). The absorbance was measured at at 517 nm. The scavenging activity was quantified as a fraction of the scavenging effect using the formula:

$$\% \text{ RS activity} = \frac{Ab - As}{Ab}$$

Were,

RS = Radical scavenging activity or % inhibition of DPPH

Ab = Absorbance of blank.

As = Absorbance of sample

Texture profile analysis (TPA)

Profile analyser (Brookfield TA. XT Plus, UK) has been used to evaluate the hardness, cohesiveness, adhesiveness, springiness, gumminess, and chewiness of ice cream. The textural parameters were determined using the force-time curve obtained for each sample, with probe force represented on the Y-axis and time on the X-axis. The sample was crushed by the plunger twice, analogous to two bites, and the force produced by the sample on the plunger was detected by the machine, resulting in a two-peak force-time curve. Each assessment utilised a sample weighing between 100 and 150 g for texture analysis. The materials temperature was maintained at 25°C during the textural analysis.

Statistical analysis

All experiments were performed in triplicate. Data is expressed as the mean value ± standard deviation (SD). Statistical significance was tested by employing analysis of variance (ANOVA) was applied to determine the significance of differences among treatments at $p < 0.05$.. For the computation of data, software application programs like Microsoft Excel and SPSS are used.

Results and Discussion

The ragi-based functional ice cream followed many phases, beginning with the selection of ragi flour form (gelatinised ragi flour and gelatinised roasted ragi flour). This was followed by the substitution of sugar with stevia in different ratios (75:25, 50:50, 25:75, and 100:0), concluding in the selection of flavours. Ragi-based functional ice cream was subjected to Physico-chemical examination, antioxidant activity assessment, textural profile analysis (TPA), microbiological analysis, and sensory evaluation.

Physicochemical analysis of sugar-substituted ragi-based functional ice cream

Optimized ragi-based ice cream with 6% roasted cum gelatinized ragi and different levels of sugar and stevia was evaluated for physiochemical characteristics. Different level of ragi was added, in which 6% of ragi was decided based on its geletanization properties seen during the experimental trial of ice cream production. The data regarding fat, protein, total solids, acidity, and pH, viscosity are mentioned in Table 2. The study analyzed the fat level of different experimental ice cream samples, revealing that the control sample carried a greater fat percentage than the other samples. The result shows that there was a significant difference in fat content among all trial samples ($p<0.05$). S2 shows the highest fat content, and S1 shows the lowest fat content. The incorporation of ragi and stevia into the ice cream did not significantly influence the fat level, despite a large variation being observed. The fat percentage in plain ice cream mixed with sucrose was lower fat content than that in plain ice cream mixed with stevia (Ozdemir et al. 2020). Sulejmani and Demiri (2020) reported that the use of stevia significantly affected fat destabilization in ice cream formulations. The protein composition of the control and experimental ice cream samples was comparable, with no significant change detected. The protein% of control, S1, S2, S3, and S4 were 3.5±0.1, 4.05±0.05, 4.22±0.25, 4.4±0.1, 4.64±0.04, respectively. The protein content had not changed much, i.e., there is no significant difference between them ($p>0.05$). Sample S4 had the greatest protein content when entirely replaced with stevia in a 0:100 ratio. The incorporation of roasted ragi into the ice cream did not significantly alter protein levels. Sukhmani et al. (2018) observed a significant increase in protein content in kulfi samples upon the incorporation of stevia. Mayangsari et al. (2019) found no significant difference between the control ice cream and the low-calorie stevia ice cream.

The total solids content of the ice cream altered significantly due to varying ratios of sugar and stevia. The control sample and

Table 1: The ratio of sugar and stevia used in the substitution

Samples	Substitution	Amount of Sugar	Amount of Stevia
C	100:0	120g	0 g
S1	75:25	90g	0.3g
S2	50:50	60g	0.6g
S3	25:75	30g	0.8g
S4	0:100	0 g	1.2g

optimized sample S2 exhibited increased solids content, i.e., 36.30 and 36.74% respectively. The minimum total solid content was seen in S4, which entirely substituted sugar with stevia. Robins et al. (2019) found that Stevia-sweetened low-calorie goat milk ice cream showed a lower total solids percentage than the control due to its lower sugar content. An elevation in stevia concentration markedly reduced the total soluble solids in ice cream, resulting in a substantial drop in total solids as stevia levels increased(Patel et al. 2020; Pon et al. 2015). Thus, the total solids declined significantly (p<0.05) with the rise in stevia concentration.

Viscosity: The study analyzed the impact of sugar and stevia on the viscosity of ice cream formulations. The viscosity of the mixes was shown to rise with the addition of stevia. The control sample had a viscosity of 290.49 cp at 4°C, whereas the experimental samples exhibited viscosities of 328.560 cp (S4), 318.01 cp (S3), 313.23 cp (S2), and 303.75 cp (S1). The samples exhibited no statistical significance (p>0.05). The use of ragi in different forms often enhanced the viscosity of mixtures. Ragi is an excellent source of starch and fiber. The water absorption capacity, swelling power, and solubility of starches and fibers depend upon temperature and the extent of intermolecular bonding, whereas starch depolymerization results from heat treatment. The rise in temperature demonstrates a greater swelling pattern compared to that observed at lower temperatures, which is ascribed to the elevated thermal treatment that results in a complete rupture of the granular structure of the starches. A notable growing trend in the viscosity of experimental mixtures was noticed in conjunction with a gradual rise in the amount of MRB. These findings are consistent with Pon et al. (2015), who found that when stevia was used instead of sugar, the ice cream became thick, means the consistency indexes increased due to variances in molecular size in the sweeteners used. Mayangsari et al. (2019) discovered that substituting sugar with stevia leaf powder significantly influenced the viscosity of ice cream; when substituted for sugar, the ice cream attains a thicker consistency.

Overrun, directly correlated with the air content in ice cream, is significant as it affects product quality, profitability, and compliance with regulatory criteria. Excessive overflow results in a light, airy ice cream, whereas little overrun yields a dense, mushy product. The overrun of the optimized ice cream (S2) and the control sample was 48.72% and 52.06%, respectively, on day zero. In comparison to the control, this was due to the incorporation of ragi, as in a study, it was reported that the addition of carbohydrate-based materials influences the total solid content, which further affects the overrun of the product as well. The disparity between the values of control overrun and optimized was considerable (P<0.05). This depletion may be attributed to the loss of oxygen and moisture from the ice cream. An increase in the concentration of milk substitutes will increase viscosity, increase the melting rate, and decrease the overrun content of the product (Romulo et al. 2021).

The melting rate of ice cream, Meltdown, is a significant characteristic of ice cream that influences its sensory quality. Ice cream should liquefy into a smooth consistency, indicative of a luxurious ice cream. The ice cream must be neither too firm nor prone to rapid melting. The control and experimental samples (S1, S2, S3, S4) was quantified in milliliters per 50 grams. The elevated melting resistance of S4 (40 ml) may be attributed to the increased starch content from the integration of greater quantities of ragi and stevia, which, while without statistical significance (p > 0.05), might have contributed to the over-stabilization of the

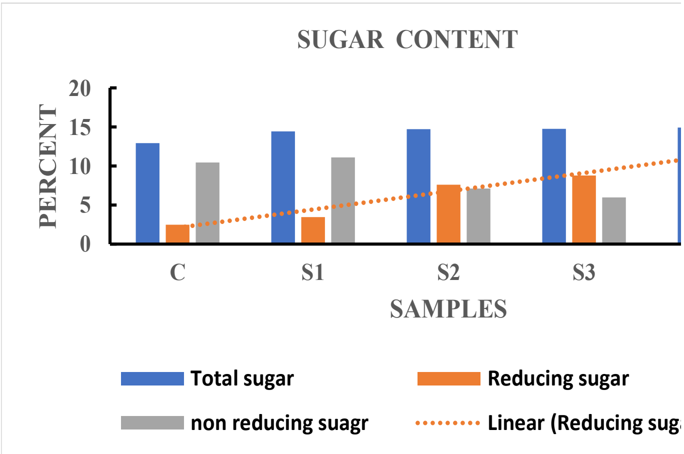

Fig. 3 The effect of stevia on total sugar, reducing sugar and non-reducing sugar%

Table 2: Physicochemical analysis of sugar substituted ragi based functional ice cream

Sample	Fat (%)	Protein (%)	Total Solids (%)	Acidity (% LA)	pH	Viscosity (cp at 4°C)
C	10.08 ± 0.14*	3.5 ± 0.1*	36.30 ± 0.19*	0.18 ± 0.01^{NS}	6.31 ± 0.02*	290.49± 0.51*
S1	9.9 ± 0.70*	4.05 ± 0.05^{NS}	37.52± 0.27*	0.20± 0.05^{NS}	6.35 ± 0.15*	303.75 ± 0.75*
S2	9.9 ± 0.14*	4.22 ± 0.25^{NS}	36.74 ± 0.29*	0.21 ± 0.01^{NS}	6.33 ± 0.01*	313.23± 0.78*
S3	9.9 ± 0.07*	4.4 ± 0.1^{NS}	36.43 ± 0.15*	0.21± 0.01^{NS}	6.33 ± 0.05*	318.01± 0.25*
S4	9.8 ± 0.07*	4.64 ± 0.04^{NS}	36.22 ± 0.22*	0.21± 0.05^{NS}	6.35 ± 0.05*	328.56 ± 0.45*

*=0.05 Level of significance NS= non-significance, S.D. = Standard Deviation, Values are means of triplicate ± S.D. C- Control Sample; S1-(75:25); S2-(50:50); S3-(25:75); S4-(100:0).

ice cream mixture. Sobana et al. (2021) indicated that substituting sugar with stevia led to an increase in free moisture content, resulting in the formation of larger ice crystals, which may have reduced the melting rate of the ice cream mixture . Patel et al. (2020) reported in their research that the use of stevia in low-calorie ice cream significantly increased both melting time and protein content compared to the control ice cream. Mayangsari et al. (2019) Reported that substituting sugar with stevia leaf powder significantly affected the melting rate of ice cream ($p < 0.05$).

Total sugar, reducing sugar, non-reducing sugar of control, and developed Ice cream

Figure 3 highlight the sugar content of ice cream with the substitution of stevia leaf powder. Statistical analysis indicated that varying amounts of stevia leaf powder did not significantly affect ($p > 0.05$) total sugar and non-reducing sugar but significantly affected ($p < 0.05$) reducing sugar levels. Nikhitha et al. (2022) showed that the amount of reducing sugar went up significantly as the concentration of stevia went up. The T0, T1, T2, T3, and T4 nectars had measurements of 2.78, 1.70, 1.26, 0.85, and 0.63, respectively. Sameen et al. (2016) Reported that the use of Phoenix dactylifera syrup as a sugar substitute significantly reduced the total sugar concentration in ice cream. Mayangsari et al. (2019) Found that the incorporation of stevia leaf powder in varying amounts had a highly significant effect ($p < 0.05$) on the overall sugar content of the ice cream produced.

TPC and Antioxidant

The ice cream samples, ragi flour, and stevia all had a total phenolic content (TPC) of 91.06 mg GAE/g, 45.48 mg GAE/g, and 62.83 mg GAE/g, respectively, as shown in Table III. Gull et al. (2015) showed that the total phenolic content (TPC) of ragi was 39.96 mg GAE/100g, whereas Tripathi et al. (2015) determined that the TPC of stevia leaves was 56.74 mg GAE/g. The DPPH values for ragi flour, Stevia leaves powder, and the optimized ice cream sample were analyzed to be 12.27%, 29.49%, and 50.49%, respectively . Hidar et al. (2021) reported a DPPH value of 93.46% for stevia, Gull et al. (2015) reported a DPPH value of 26.04% for ragi flour.

Texture Profile Analysis

The analyzed ice cream was measured for texture, which included hardness, cohesiveness, chewiness, and springiness. The outcome showed that the optimized sample (S2) had a hardness of 360.00 ± 20.01, a cohesiveness of 0.17 ± 0.80, a springiness index of about 0.79 ± 0.03, and a chewiness index of about 48.00 ± 0.50 g (Figure 4). The control sample, on the other hand, had a hardness of 400.00 ± 0.23, a cohesiveness of 0.80 ± 46, a springiness index of about 0.96 ± 0.06, and a chewiness index of about 31.00 ± 0.30 g. The consistency of the ice cream was affected when sugar was substituted with stevia in different amounts. Pon et al. (2015) indicated that alterations in the microstructure of ice cream, including phase volume, ice crystal size, and fat stability, result from the substitution of stevia at varying percentages. Tondare et al. (2021) observed that a reduction in sugar quantity leads to a decrease in the product's cohesiveness value. Pon et al. (2015) observed that the use of stevia in ice cream improved its hardness, adhesiveness, and cohesiveness. Consequently, they determined that substituting sugar with stevia at different ratios enhanced the cohesiveness of ice cream.

Shelf-life study during a storage period of 30 days at 5-day intervals. The study aimed to analyze the impact of stevia on the shelf life of an optimized ice cream sample. The ice cream had a shelf life of 15 days at 4°C in an airtight container, and the use of stevia extended its shelf life.

The titratable acidity content of the control sample was 0.20% at 0 days and slightly increased after 15 days (0.22%), while the optimized product (S2) with stevia had a pH range of 6.33–6.32 during 30 days of storage. As shown in Figure 5**,** the results showed that there is no statistical significance ($p>0.05$) between the samples. In contrast, Patel et al. (2020) reported that the acidity values of each experimental and control Kulfi were statistically and significantly similar ($p<0.05$). Sulejmani and Demiri (2020) reported that the titratable acidity (%) of the freshly made ice creams prepared with milk powder and stevia powder was not statistically significant($p>0.05$).

The pH value of dairy products has a direct impact on taste perception, which is affected by changes in content and biochemistry that occur during storage shown in Figure 6. The pH values for the control sample ranged from 6.30 to 6.32, whereas those for the optimized product (S2) ranged from 6.33 to 6.32 during 30-day storage periods. It was found that the pH value lowered when the samples were stored for longer periods. Many studies have explained that the pH value of dairy products has a direct impact on taste perception. Studies have found that the pH value of dairy products has a significant influence on treatments and storage. Ice cream produced with stevia lowers the pH .Sameen et al. (2016) found the statistical data of pH and acidity have a significant ($p<0.05$) influence on treatments and storage owing to different concentrations of date syrup. Ice cream produced with stevia lowers the pH(Treciokiene et al. 2020). Roselle extract is added to ice cream, the pH of the ice cream lowers as the concentration of roselle extract is increased (Singo et al. 2019). Ozdemir et al. (2020) reported a pH range of 6.50 to 6.52 for stevia ice cream; however, Sulejmani et al. (2020) reported a pH range of 5.82 to 6.62 for stevia ice cream.

The total bacterial count values were within the recommended limit of 2,50,000 (cfu/g) for the first 15 days. However, after the 20th day, the number of colonies began to slightly increase based on the visual examination shown in Figure 7. There was no growth or negligible growth in coliform plates, yeast, and mould plates during the storage period. Similar studies have reported no significant impact on the product's physicochemical and microbiological properties. Robins et al. (2019) reported in their study that no significant difference in the coliform count and total viable count was observed between the control and

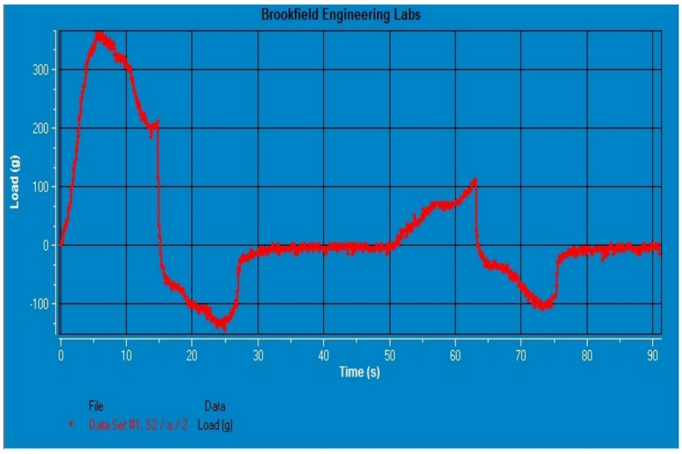

Fig. 4 Graphical illustration of texture analysis of the optimized sample (S2)

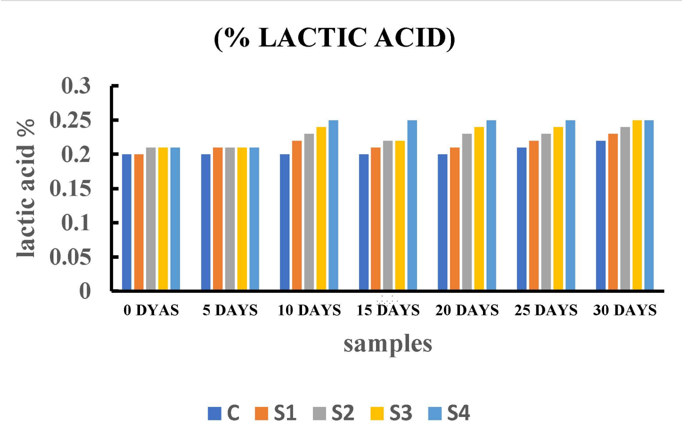

Fig.5 Effect of storage on Titrable acidity of ice cream

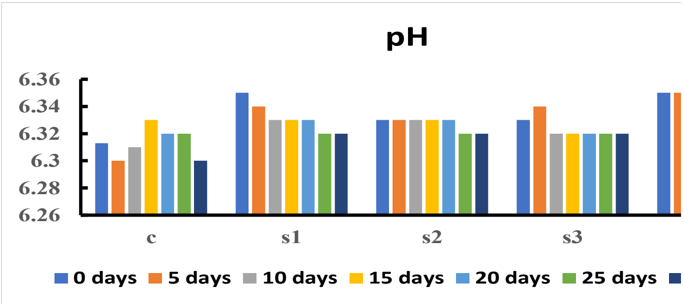

Fig.6 Graphical illustration of the effect of storage on pH

treatment groups. Schiatti-Sisó et al. (2022) found that the production of low-calorie yoghurt and ice cream with stevia had no significant impact on the product's physicochemical and microbiological properties; the culture maintains a useful level after 28 Days of storage.

Sensory analysis

The study aimed to enhance the sensory attributes of ice cream formulated through gelatinized ragi flour and roasted gelatinized ragi flour, focusing on the replacement of sugar with stevia in different ratios and finding the best ratio among them. A batch of ice cream made with gelatinized ragi Flour (G1, G2, G3, G4) and another batch of ice cream made with Roasted cum gelatinized ragi flour (R1, R2, R3, R4). The findings indicated significant differences in color, flavour, body, and texture between the batches. Treatment R3 was selected according to sensory assessment. Patel et al. (2015) found in the study that the greatest acceptance of ragi ice cream produced using roasted and malted ragi flour is similar Taynath et al. (2018) the sensory acceptability of ragi flour cake diminished with a 25% increase compared to 20%.

Ice cream with roasted and gelatinized ragi flour was prepared using various proportions of sugar and stevia and evaluated by semi-trained judges. The highest sensory score was recorded in sample SS2, at 8.23. The SS2 sample, including a 50:50 mix of sugar and stevia, exhibited good color, appearance, taste, flavor, texture, and sweetness. The aftertaste of stevia was more pronounced in SS4 and SS3. Significant changes ($p<0.05$) were also noted in color, flavour, and sweetness. Patel et al. (2020) indicated that kulfi prepared with Amaranthus and skim milk powder in a 25:75 ratio exhibited significantly ($p<0.05$) higher rankings for flavour, body, texture, color, and appearance. Akesowan et al. (2020) discovered that substituting sugar with stevia resulted in progressively lower flavour scores as stevia concentrations grew, hence diminishing the flavour of the fruit bars.

A semi-trained panellist evaluated the ice cream with various flavours, where C is the control, which has no flavour, SF1 is vanilla flavoured, SF2 is rose flavoured, SF3 is chocolate flavoured, and SF4 is mixed fruit-flavoured ice cream, determining SF1 (i.e., ice cream with vanilla flavour) as the superior option based on sensory evaluation scores. The vanilla-flavoured ice cream was rated highest in sensory evaluation, effectively concealing the off-flavour of stevia, with an overall acceptance score of 8.41, and followed a trend of SF1>SF3>SF2>SF4. Ice cream was analyzed for flavour, body and texture, color and

Table 3 TPC and DPPH Assay of ragi flour, stevia leaves powder, and optimized sample

Sample	Total Phenolic Content (mg GAE/g)	DPPH(%)
Ragi flour	45.48±5.09	29.49±2.8
Stevia leaf powder	91.06±4.68	50.49±2.3
Optimized product	62.83±5.67	12.27±2.3

S.D. = Standard Deviation, Values are means of triplicate ± S.D.

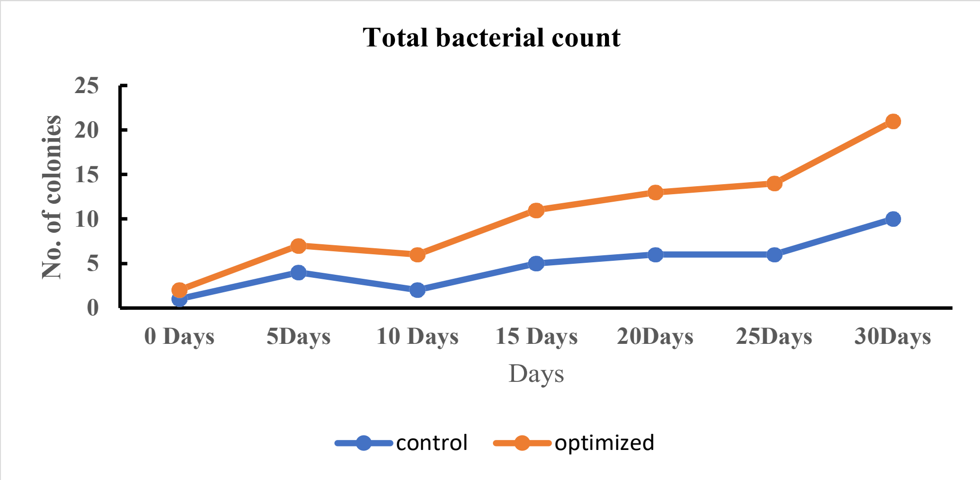

Fig. 7 Shelf-life study during a storage period of 30 days

appearance, melting quality, and overall acceptability using the 9-point hedonic scale. Many research studies have shown that replacing some sugar with the natural sweetener stevia may leave a bitter taste in the mouth. Peres et al. (2018) found in his study that the partial replacement of sugar with natural sweetener stevia, gave an aftertaste and bitter flavour of stevia, because of the steviol glycoside present in it, which causes an undesirable taste with the addition of sweetness. Ahmad et al. (2020) also reported in their study the effect of sugar substitution with stevia, which gave an aftertaste, and it was observed that the vanilla and cocoa flavours masked the aftertaste of stevia. Li and Dando (2019) also found in their study that the aftertaste of stevia in their product was masked by vanilla flavour.

Commercial Recommendation

The functional ice cream made with ragi-stevia has a high potential to be commercially viable because of its healthier nature of products since most people need products that are nutritionally balanced with low sugar content. Further studies are needed to increase the marketability of the company, and in this regard, large-scale consumer acceptance researches involving various demographic profiles should be conducted to capture the taste preferences and consumer buying behaviour. It is also suggested that pilot-scale production tests and cost-benefit analysis should be done to determine scalability and economic viability of its industrial use. Further research on ingredient optimization, shelf-life extension and development of sustainable packaging may also enhance competitiveness in the market, as well as product permanence in the functional dairy industry. Currently, consumers across the globe and in India are moving toward health-giving and indulgent desserts, with low-sugar, clean-label, high-fiber, and high-protein foods being preferred. The increase in the use of natural sweeteners such as stevia also promotes the formulation of healthier products. Within this dynamic environment, the ragi-stevia functional ice cream would be in a good position to address the nutritional voids by increasing the amount of fiber, minerals, and antioxidants in it, as well as serving the needs of the current market, which is health-conscious yet wants to indulge itself. Further research should thus proceed on the large-scale consumer testing, standardization of processes, optimization of costs and strategic placement of product as a high-quality and affordable functional dairy innovation.

Conclusion

It may be concluded that ragi and stevia may be effectively used for the formulation of functional ice cream. The optimized ice cream with 6% ragi flour, a 50:50 ratio of sugar to stevia, and vanilla flavouring. The product falls under the growing health-conscious dessert market, filling the nutritional gaps in the traditional ice cream and satisfying the consumer demands rich in nutritional properties, who are low in calories and rich in antioxidants and Protein. It was determined that optimized goods were suitable for consumption for up to 15 days of storage, at 4 degrees Celsius. They met acceptable standards for pH, titratable acidity, and total bacterial count within the required limits.

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