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Development and evaluation of prebiotic enhanced Ragi Kulfi

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Abstract

The present study was undertaken to develop and evaluate a prebiotic-rich Ragi Kulfi by incorporating Ragi (Finger millet) and banana into a traditional Kulfi formulation. Conventional Kulfi, though popular, lacks functional health benefits and is generally high in sugar and fat. Ragi is nutritionally rich in dietary fiber, calcium, and bioactive compounds, while banana is a natural source of resistant starch and soluble fiber with prebiotic potential. The developed Kulfi was analyzed for physico-chemical properties including moisture, fat, protein, total solids, ash, titratable acidity, and pH, along with rheological parameters such as melting rate, viscosity, and hardness. Sensory evaluation was carried out using a 9-point hedonic scale, and statistical analysis was performed using paired Student's t-test. Results showed that the prebiotic Ragi Kulfi possessed acceptable physico-chemical and rheological characteristics with good structural stability. Sensory scores indicated no significant difference between the control and experimental samples, confirming good consumer acceptability. The study demonstrates that incorporation of Ragi and banana enhances the nutritional and functional value of Kulfi without compromising quality, indicating strong potential for its use as a functional frozen dairy dessert.

Keywords: Prebiotic, Ragi, banana, Kulfi, functional food, frozen dairy dessert

Introduction

Kulfi also known as Malai Kulfi/Malai-ka-burf is an Indian frozen dairy product, which closely resembles ice cream. In recent years, the consumption of ice cream in India has increased considerably especially in urban areas which has in turn increased the viability and scale of the Indian frozen market range especially of Kulfi and similar products. (Siddhu *et al.*, 2017) ^[13] Even though Kulfi has nutritional significance, it possesses no reported therapeutic properties and is considered rather high in sugars and cholesterol. The growing interest of consumers towards therapeutic products with improved health benefits gives considerable basis for enrichment of Kulfi in a variety of different yet accessible ways. (Khan *et al.*, 2013) ^[10]

The goal of the current study is to develop and formulate an innovative and health beneficial product, prebiotic Banana Ragi Kulfi, which is a traditional frozen dessert enriched with the nutritional aspects of Ragi (Finger millet) and green banana as a prebiotic.

Sensory evaluation to affirm the palatability and consumer acceptance was done using 9-point Hedonic scale followed by paired Students' t-test. Nutritional analysis was also done for dietary fibre and calcium. This study also presents the physico-chemical analysis of prebiotic Ragi Kulfi fortified with Ragi and banana, focusing on parameters such as moisture content, fat, protein, acidity, total solids (T.S), ash, pH, melting point, viscosity, and hardness so as to optimize the product for maximal acceptance. Structure development in ice cream often is attributed to the macromolecules present in the Kulfi mix—milk fat, protein, and complex carbohydrates. (Adapa *et al.*, 2000) ^[1]. Thereby the structure-function relational aspects were evaluated in the study not only for the basis of the current product but future research and technological development.

Rationale for incorporation of Ragi (Finger Millet) flour

Millets are also good sources of nutraceutical and functional food ingredients in health promotion, mainly due to their antioxidant, antimicrobial, anti-inflammatory, antiviral,

anticancer, antiplatelet aggregation, and cataractogenesis inhibitory activities. (Adebiyi *et al.*, 2016; Chethan & Malleshi, 2007; Rawat *et al.*, 2023) [2, 5, 12]

Ragi provides the highest level of calcium, antioxidant properties, phytochemicals, which makes it easily and slowly digestible. Hence it helps to control blood glucose levels in diabetic patients very efficiently. The bulkiness of the fibres and the slower digestion rate makes us feel fuller on fewer calories and therefore may help to prevent us from eating excess calories. Therefore, Ragi is considered to be an ideal food for diabetic individuals due to its low sugar

content and slow release of glucose/sugar in the body. (Chethan & Malleshi, 2007; Desai *et al.*, 2010) [5, 6]

Furthermore, cultivation of Ragi, being a hardy crop with little requirements for fertilizers and irrigation, greatly hedges the risks of crop failure and bankruptcy in Indian farmers. The statewide production of Ragi is given in Table 1 below. It must be noted that most produced Ragi is consumed domestically and is technologies for making of products with Ragi as a component is rather a new concept. (Desai *et al.*, 2010) [6]

Table 1: Statewise production of Ragi in India of the last few years (Directorate of Millets development, Jaipur, Note: A = Area, P = Production and Y = Yield)

Crop/State	2017-18 A	2017-18 P	2017-18 Y	2018-19 A	2018-19 P	2018-19 Y	2019-20 A	2019-20 P	2019-20 Y	2020-21 A	2020-21 P	2020-21 Y	2021-22* A	2021-22* P	2021-22* Y	Normal A	Normal P	Normal Y
Andhra Pradesh	0.35	0.45	1277	0.32	0.43	1348	0.34	0.45	1320	0.33	0.41	1197	0.30	0.30	1000	0.33	0.40	1233
Bihar	0.04	0.04	994	0.03	0.03	1071	0.03	0.02	760	0.03	0.03	934	0.02	0.02	779	0.03	0.03	927
Chhattisgarh	0.05	0.01	250	0.08	0.02	214	0.06	0.01	253	0.05	0.02	382	0.03	0.01	300	0.05	0.01	257
Gujarat	0.12	0.11	896	0.12	0.10	804	0.12	0.10	862	0.11	0.13	1205	0.10	0.19	1899	0.11	0.12	1106
Himachal Pradesh	0.02	0.02	1056	0.02	0.02	1060	0.02	0.02	1170	0.01	0.01	842	0.01	0.01	842	0.01	0.02	1056
Jammu & Kashmir	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
Jharkhand	0.19	0.18	972	0.14	0.11	805	0.15	0.13	875	0.19	0.16	874	0.19	0.17	878	0.17	0.15	885
Karnataka	7.78	12.86	1653	5.27	6.78	1285	6.41	11.64	1816	7.85	13.20	1745	8.49	11.33	1334	7.16	11.26	1573
Kerala	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
Madhya Pradesh	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0
Maharashtra	0.93	1.06	1145	0.80	0.93	1164	0.82	0.87	1061	0.82	0.94	1151	0.74	0.93	1264	0.82	0.95	1154
Odisha	0.43	0.33	767	0.37	0.26	705	0.33	0.21	721	0.41	0.33	796	0.38	0.44	798	0.41	0.32	786
Tamil Nadu	0.87	3.21	3714	0.79	2.56	3257	0.85	2.75	3247	0.83	2.39	3451	0.74	2.21	2972	0.81	2.72	3346
Telangana	0.01	0.01	1137	0.01	0.01	977	0.02	0.03	1581	0.01	0.01	1343	0.01	0.02	1853	0.01	0.02	1412
Uttarakhand	0.05	0.14	1387	0.02	0.10	1194	0.04	0.09	1395	0.09	0.09	1459	0.06	0.12	1478	0.11	0.13	1333
West Bengal	0.12	0.14	1130	0.03	0.03	895	0.03	0.04	1454	0.06	0.06	1073	0.05	0.06	1176	0.06	0.07	1146
Others	0.02	0.03	1634	0.01	0.02	1345	0.01	0.02	1503	0.01	0.02	1458	0.01	0.02	1899	0.01	0.02	1450
All India	11.58	19.87	1462	8.91	12.59	1404	10.04	17.85	1779	11.59	19.58	1724	12.11	16.96	1401	10.92	17.53	1459

Prebiotics and the prebiotic capability of banana

The human gastrointestinal tract contains a diverse collection of microorganisms, the majority of which reside in the colon. The human gut contains around 1014 bacterial cells and up to 1000 species, which exceeds the largest microbial community associated with the human body. (Cani & Delzenne, 2007) [4] These bacterial cells are called “intestinal symbiotic bacteria” because they show symbiosis. This means that microflora present in the human gut are beneficial because they represent an individual's energy, metabolic activity, and immune system. Not only does dietary fibre help evade hydrolysis, digestion and absorption in the human small intestine, but it achieves at least one of these functions: increases the faecal bulk, stimulates colonic fermentation, reduces postprandial blood glucose (reduces insulin responses) and reduces pre-prandial cholesterol levels. (Elleuch *et al.*, 2011; Rawat *et al.*, 2023) [7, 12].

Prebiotics are one in a group of nutraceutical and functional food and their health-benefiting effects have been widely studied. (Synytsya *et al.*, 2009) [14] By definition, a prebiotic is ‘a substrate that is selectively utilised by host microorganisms, conferring a health benefit’. In this context, the word ‘substrate’ implies a substance used for growth through nourishment, with ‘selectively utilised’ indicating that the effects must extend only to some microbial groups, and not all. (Lockyer & Stanner, 2019) Furthermore, to be classed as a prebiotic, a substrate must not confer negative consequences for the host, such as abdominal distension due

to excess gas production or the growth of pathogenic microorganisms. (Gibson *et al.*, 2017) [9]

Bananas, especially Raw Bananas and Plantains have a significant amount of Resistant Starch, much of which is lost during ripening. In a peer reviewed study, Raw Banana Powder significantly promoted the growth of *Lactobacillus acidophilus in vitro*. Daily administration of raw BPF to male Wistar rats modulated intestinal environment via stimulating the growth of beneficial species and inhibiting the growth of pathogens (Gajananrao Mahore & Shirolkar, 2018) [8]. In another study, mice fed with green banana flour significantly ($p < 0.05$) decreased body weight and metabolic markers, glucose, triglyceride, total cholesterol and blood pressure measurements. (Alvarado-Jasso *et al.*, 2020) [3]

Materials and Methodology

Materials

Raw Banana, Ragi Flour, Milk and Condensed Milk were purchased locally from Vadodara, Gujarat. For the purpose of Blending, a Philips HL7756/00 750-Watt Mixer Grinder from Philips India Ltd was used. For determination of Fat, protein and fibre content, Petroleum ether AR grade from Sigma Aldrich, Sulfuric acid 99.5% pure from Merck Life Science Pvt. Ltd., India, Potassium sulfate from Loba Chemie Pvt. Ltd., Mumbai, Sodium Hydroxide from Finar Chemicals, Ahmedabad, Methyl red from HiMedia Laboratories Pvt. Ltd., Mumbai was used. Soxhlet extractor was from Borosil Scientific Ltd., India, Digestion Apparatus

from Remi Instruments, Mumbai, Hot Air oven from Tempo Instruments & Equipments, Mumbai and pH meter used was M. Tronoic digital-255 from Systronics India Ltd., Ahmedabad. For paired sample comparison, Amul Kulfi (plain) was used as the control sample, procured locally from Vadodara.

Preparation of Sample and determination of total solids, fat, protein, ash and titratable acidity

Sample preparation and subsequent testing was done as per IS 2802-1964 Specification for Ice cream/Bureau of Indian Standards, New Delhi/A.O.A.C 17edn, 2000, Official method 969.20. The prepared Kulfi samples were analyzed for total solids, fat, protein, ash, and titratable acidity using standard analytical procedures. Fat content was determined using the Soxhlet extraction method, protein content was estimated by the Kjeldahl method, moisture and total solids were measured by oven-drying technique, ash content was determined by incineration in a muffle furnace, and titratable acidity was estimated by titration against standard alkali. All analyses were performed in triplicate to ensure accuracy and reproducibility of results.

Determination of rheological parameters (Melting, Viscosity, Hardness) and pH

Rheological properties of the developed prebiotic Ragi Kulfi, including melting rate, viscosity, and hardness, were determined using standard laboratory procedures. The melting rate was assessed by measuring the time required for a fixed volume of Kulfi to melt at room temperature. Viscosity of the Kulfi mix was measured using a viscometer under controlled conditions, while hardness was determined using a texture analyzer.

The pH of the Kulfi sample was measured using a calibrated digital pH meter at room temperature. All measurements were carried out in triplicate, and mean values were recorded.

Statistical Analysis

Statistical Analysis was carried out using Stat Ease 360™ Design Expert Software and R studio v. 4.3.1. The results were expressed as mean $\pm$ standard deviation. Significant differences among samples were evaluated at a 5% level of significance ($p \leq 0.05$).

Preparation of product (Methodology)

Prebiotic Ragi Kulfi was prepared by blending milk, condensed milk, sugar, Ragi paste, banana pulp, and cardamom powder in appropriate proportions. Milk was heated and concentrated, followed by the addition of Ragi paste and banana pulp with continuous stirring to obtain a uniform mixture. The prepared mix was allowed to cool, poured into Kulfi molds, and frozen under controlled conditions until complete solidification. The frozen samples were then stored at sub-zero temperature for further analysis.

Results and Discussion

Physico-chemical analysis of prebiotic Ragi Kulfi

The physico-chemical characteristics of the developed prebiotic Ragi Kulfi were analyzed to evaluate its quality, stability, and suitability as a functional frozen dairy product. The results obtained are presented in Table 2. The moisture content of the Kulfi sample was recorded as 57.52%, indicating appropriate water retention and contributing to a

smooth and creamy texture. The total solids content was found to be 42.30%, which reflects the concentration of milk solids, Ragi constituents, and banana pulp, contributing to the dense body characteristic of Kulfi.

The fat content of the developed Kulfi was 10.006%, which is comparable to traditional Kulfi formulations and plays a crucial role in enhancing mouthfeel, richness, and flavor. The protein content was recorded as 3.516%, indicating nutritional enrichment due to the incorporation of Ragi and milk proteins.

The ash content was found to be 0.51%, reflecting the mineral contribution from Ragi, milk, and banana, particularly calcium and iron. The titratable acidity of the Kulfi was 0.192%, which falls within acceptable limits for frozen dairy products and indicates good product stability without excessive sourness.

The pH value of the Kulfi sample was 6.428, confirming that the product remained near neutral pH, which is desirable for maintaining sensory quality and shelf stability.

Table 2: Physico-chemical properties of prebiotic Ragi Kulfi

Sr. No.	Parameter	Value (Mean $\pm$ SD)
1	Moisture (%)	57.52 $\pm$ 0.02
2	Fat (%)	10.006 $\pm$ 0.01
3	Protein (%)	3.516 $\pm$ 0.01
4	Titratable Acidity (%)	0.192 $\pm$ 0.01
5	Total Solids (%)	42.30 $\pm$ 0.02
6	Ash (%)	0.51 $\pm$ 0.01
7	pH	6.428 $\pm$ 0.01
8	Melting Rate (min)	6.016 $\pm$ 0.02
9	Viscosity	25.65 $\pm$ 0.03
10	Hardness	9.856 $\pm$ 0.02

Rheological properties

Rheological analysis showed that the Kulfi possessed desirable textural characteristics. The melting value was recorded as 6.016, indicating adequate resistance to melting at ambient conditions. This property is important for consumer acceptance and handling during serving. The viscosity of the Kulfi mix was found to be 25.65, suggesting proper thickness and flow behavior, which can be attributed to the presence of Ragi starch and banana pulp. These components enhance water-binding capacity and contribute to improved body and texture. The hardness value of the Kulfi was measured as 9.856, indicating firm structure and good freeze stability. The hardness observed ensures that the Kulfi maintains its shape while providing a pleasant bite during consumption.

Table 3: Sensory evaluation scores of prebiotic Ragi Kulfi

Sensory Attribute	Control Kulfi	Prebiotic Ragi Kulfi	Significance ($p \leq 0.05$)
Color & Appearance	Acceptable	Acceptable	NS
Flavor	Acceptable	Acceptable	NS
Body & Texture	Acceptable	Acceptable	NS
Melting Resistance	Acceptable	Acceptable	NS
Overall Acceptability	Acceptable	Acceptable	NS

Sensory acceptability

Sensory evaluation using a 9-point hedonic scale revealed that the prebiotic Ragi Kulfi was well accepted by panelists. The incorporation of banana contributed natural sweetness and flavor, while Ragi enhanced the body and texture without imparting undesirable taste. Overall acceptability scores indicated that the developed Kulfi was comparable to conventional Kulfi products.

Statistical analyses and interpretation

All experimental analyses were carried out in triplicate, and the results were expressed as mean $\pm$ standard deviation. Statistical evaluation of the sensory and physico-chemical data was performed using Stat-Ease 360™ Design-Expert software and R Studio version 4.3.1.

For sensory evaluation, data obtained from the 9-point hedonic scale were statistically analyzed to determine consumer acceptability of the developed prebiotic Ragi Kulfi in comparison with the control sample. A paired Student's t-test was applied to identify significant differences between control and experimental samples. The level of significance was set at $p \leq 0.05$.

The statistical analysis revealed that there was no significant negative difference ($p > 0.05$) between the control Kulfi and the prebiotic Ragi Kulfi in terms of color and appearance, flavor, body and texture, melting resistance, and overall acceptability. This indicates that incorporation of Ragi and banana did not adversely affect sensory quality.

Physico-chemical parameters including moisture, fat, protein, acidity, total solids, ash, pH, melting rate, viscosity, and hardness were also subjected to statistical evaluation. The consistency of results across replicates confirmed the reliability and reproducibility of the experimental data.

Overall, statistical findings support that the developed prebiotic Ragi Kulfi is comparable to conventional Kulfi in quality while offering enhanced nutritional and functional benefits.

Table 4: Statistical summary

Parameter Group	Statistical Tool Used	Observation
Sensory Data	Paired Student's t-test	No significant difference between control and experimental Kulfi
Physico-Chemical Data	Mean $\pm$ SD	Results consistent across triplicates
Software Used	Stat-Ease 360™, R Studio v4.3.1	Reliable data processing
Level of Significance	$p \leq 0.05$	Accepted

Conclusion

The present study successfully developed a prebiotic-rich Ragi Kulfi by incorporating Ragi (Finger millet) and banana into a traditional Kulfi formulation. The developed product exhibited acceptable physico-chemical, rheological, and sensory characteristics, confirming that the inclusion of functional ingredients did not adversely affect product quality. Physico-chemical analysis indicated appropriate levels of moisture, fat, protein, total solids, ash, acidity, and pH, reflecting good product stability and nutritional enhancement. Rheological properties such as melting rate, viscosity, and hardness demonstrated that the Kulfi possessed desirable texture, structural integrity, and resistance to melting. Sensory evaluation showed that the prebiotic Ragi Kulfi was well accepted by panelists and was comparable to the control sample, with no significant differences observed.

Overall, the incorporation of Ragi and banana improved the nutritional and functional value of Kulfi by enhancing dietary fiber and prebiotic potential while maintaining consumer acceptability. The developed product shows strong potential as a functional frozen dairy dessert and offers scope for commercialization. Further studies may focus on shelf-life evaluation and *in-vivo* assessment of prebiotic effects.

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