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Sensory quality of low- fat ice cream developed with κ -carrageenan as a stabilizer

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Abstract
This research evaluates the development of low-fat ice cream using kappa carrageenan as stabilizer and investigated the sensory quality of the developed product. κ-carrageenan incorporated at three concentrations 0.03%, 0.04%, and 0.05% (TC_1, TC_2, TC_3) and compared with a control containing sodium alginate and glyceryl monostearate. Sensory attributes including body and texture, flavor, color and appearance, melting quality, and overall acceptability were assessed using a nine-point hedonic scale. The treatment TC_3 resulted in the highest scores for all sensory parameters, including overall acceptability, demonstrating its effectiveness in compensating for the textural and mouthfeel defects associated with fat reduction in ice cream. Thus, κ-carrageenan at 0.05% was found optimal for developing acceptable low-fat ice cream with desirable sensory and structural properties.

Keywords: Low-fat ice cream, κ carrageenan, hydrocolloid, stabilizer

Introduction

Milk and dairy products serve as vital sources of essential nutrients, including high-quality proteins, vitamins, and minerals, and play a significant role in human nutrition. Ice cream is one of the most popular dairy-based frozen desserts, appreciated for its unique texture, taste, and mouthfeel. Ice-cream is a frozen dairy product made by freezing a pasteurized mix with agitation to incorporate air and to ensure uniformity and consistency. Among dairy products, ice cream represents one of the fastest-growing and most popular categories, with universal appeal across all age groups and wide acceptance as a convenient, indulgent, and versatile food product.

The modern food landscape is increasingly driven by consumer demand for healthier options, leading to a significant market shift towards reduced-fat and low-fat frozen desserts (Samakradhamrongthai *et al*.,2021) [9]. While reducing milk fat content addresses public health concerns related to saturated fat intake, it poses a profound challenge to product quality. Milk fat plays a critical role by forming a crucial fat-globule network that stabilizes the air cells, imparts lubrication for a creamy mouthfeel, and limits the total free water available for ice crystal growth. The removal of this structural component typically results in undesirable textural defects, including increased perceived iciness, weaker body, faster meltdown rates, and an overall reduction in consumer acceptability (Mahdian and Karazhian, 2013) [5].

To mitigate these structural deficiencies, the food industry relies heavily on the strategic incorporation of functional additives, such as hydrocolloid stabilizers, which act as fat replacers and stabilizers. These stabilizers function primarily by increasing the viscosity of the continuous aqueous phase, thereby reducing water mobility and inhibiting the formation and growth of large, undesirable ice crystals during freezing and subsequent storage. (Sofjan and Hartel, 2004) [3].

Among the array of hydrocolloids available, carrageenan (κ-carrageenan) is a widely used linear sulfated polysaccharide extracted from red seaweed, noted for its powerful interaction with dairy proteins. Even at very low concentrations, -carrageenan interacts electrostatically with casein micelles in milk, forming a gel network. This unique property is essential for stabilizing the protein system, preventing syneresis and contributing significantly to the overall viscosity and rheological behavior of the ice cream mix (Muse and Harter,2004) [6]. Hence, the present investigation is planned to study the effect of varying concentrations of -carrageenan on the low-fat ice cream. The consumer preference for low-fat ice creams with kappa carrageenan had better texture, taste, and mouthfeel ratings than other hydrocolloids (Akbari *et al*.,2019) [1]. This indicates that carrageenan may be preferable from a sensory standpoint for those aiming to replicate the characteristics of traditional, higher-fat ice cream.

It effectively binds moisture, forms gels, and serves as a thickener and stabilizer in various food matrices. Its strong water-holding capacity enhances the viscosity, texture, and overall stability of products, contributing to improved appearance, consistency, and palatability. These properties make carrageenan an important additive in the formulation of dairy and other processed foods (Udo T., *et al*.,2023) [12].

In low-fat, non-fat, or plant-based dairy alternatives, carrageenan enhances viscosity and imparts a fatty 'mouthfeel,' compensating for the reduced fat content. This makes it a valuable ingredient in improving the sensory and structural qualities of reduced-fat dairy formulations (Noor. H. M., 2018) [8].

Materials and Methods

Materials

Milk: Milk was procured from the was procured from Modern Dairy Plant, College of Food and Dairy Technology, Koduveli, Alamathi (Post), Chennai-52

Skim milk powder: Spray dried skim powder was obtained from the local market, Chennai with 0.8% fat and 95% solids not fat.

Stabilizer and emulsifier: Food grade sodium alginate as stabilizer and glyceryl mono stearate (GMS) as emulsifier were used in the study.

K-carrageenan: Food grade κ-carrageenan was purchased from the local market, Chennai.

Sugar: Refined sugar from Parrys Sugar Pvt. Ltd was purchased from the local market of Chennai.

Vanilla essence: Food grade vanilla essence was purchased from iff International Flavors and Fragrances India Private Limited, Chennai.

Methods

Low fat ice cream was prepared using milk with 3% fat, 4.5% fat and 6% fat. Milk was heated to 45 °C followed by addition dry ingredients like sugar (15%), stabilizer and emulsifier (0.5%) and κ- carrageenan (0.03-0.05%) for treatments TC_1, TC_2, and TC_3 and sodium alginate for control low fat ice cream. Ice cream mix was prepared with maximum 2.5 percent fat, 26 percent total solids as per FSSAI (2020). In each treatment, the prepared ice cream mix was pasteurized at 85°C for 25 sec and cooled to 5C. Low fat ice cream mixes were kept overnight for ageing at 4C. Then the flavor was added. The prepared ice cream was frozen at a temperature of -1 to -9 °C along with the whipping of air into the mix by agitation in ice cream freezer (batch freezer). The ice cream was filled in 40 ml disposable cups and kept in the hardening unit at -23 C for 24 h. Then the prepared ice cream was stored at -18 °C.

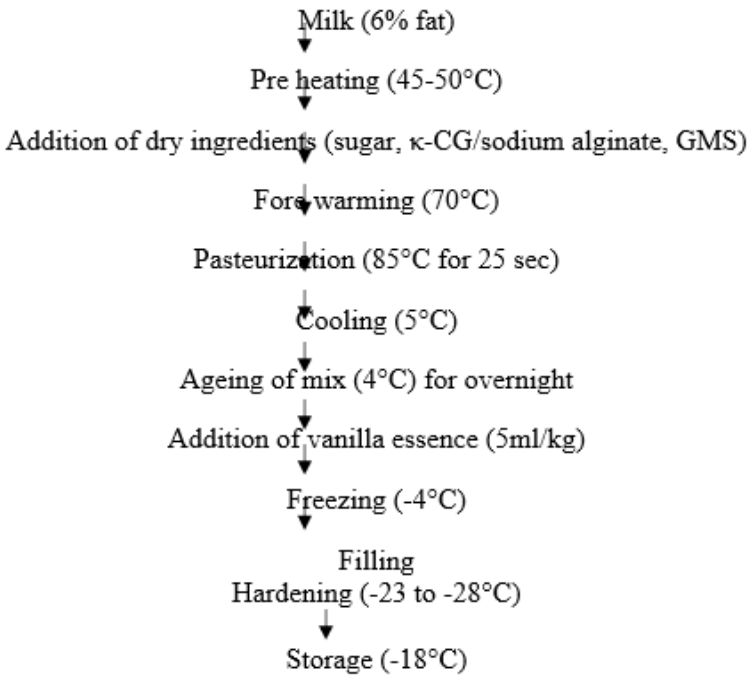

Fig 1: Flowchart for the preparation of low-fat ice cream

Proximate Analysis

Control and treatments of low-fat ice cream were analyzed formoisture, fat, protein, total ash, carbohydrates and energy values.

Sensory Analysis

Low fat ice cream samples were evaluated for their sensory quality using a nine-point hedonic scale. Attributes such as body and texture, flavor, color and appearance, melting quality and overall acceptability were assessed under controlled conditions.

Statistical Analysis

Statistical analysis was carried out to study the effect of different parameters on all the dependent variables. The data were tabulated and subjected to statistical analysis performed using IBM SPSS 20.0 for Windows® software as per the standard procedure of Snedecor and Cochran (1994) [10].

Results and Discussion

Proximate Analysis

Table 1 presents the proximate composition of control and treatments of low-fat ice cream. The proximate analysis gives the value in par with FSSAI standards 2020. There was highly significant ($p \leq 0.01$) difference observed between control and treatments in moisture and protein, significant difference($p<0.05$) between total ash, and energy value and non-significant difference for fat and carbohydrate. Moisture content was lowest in TC_3, indicating improved water retention in the bound form due to the hydrocolloid's stabilizing effect. Reduced free water contributes to minimized ice crystal formation and improved product

smoothness, as supported by Muse and Hartel (2004) [6]. Protein content showed slight variations, with marginally higher values recorded in TC_3 compared to TC_1 and TC_2. κ-carrageenan is known to interact with casein micelles, forming a weak gel network that enhances protein hydration and structural stability as reported by Thaiudom and Goff *et al.,* (2003). While κ carrageenan itself is a polysaccharide and thus a carbohydrate, it is typically added at very low concentration as observed by Soukoulis *et al.,* (2008) [11]. The small amount of carbohydrate added by the stabilizer is minute compared to the total sugar content. Therefore, the overall variation in the total carbohydrate measurement, which is often calculated by difference, is dominated by the small, non-significant fluctuations in the major components (fat, protein, and ash), leading to a statistically non-significant difference in the final carbohydrate percentage as stated by Nielsen (2017) [7].

Table 1: Proximate analysis of control and treatments of low-fat ice cream

Sample	Moisture (%)	Fat (%)	Protein (g) (TN*6.38)	Total ash (g)	Carbohydrate (g)	Energy value (kcal)
Control	63.42±0.204^{b}	2.34 ± 0.033^{b}	3.617 ±0.028^{c}	0.875 ± 0.014^{c}	29.693±0.247^{a}	154.51 ± 0.498^{c}
TC1	64.46±0.116^{c}	2.31 ± 0.023^{a}	3.51 ± 0.050^{a}	0.836 ± 0.007^{a}	29.438±0.247^{a}	152.71 ± 0.491^{a}
TC2	64.17±0.052^{c}	2.34 ± 0.037^{b}	3.47 ± 0.049^{a}	0.801 ± 0.012^{b}	29.385±0.078^{a}	151.97 ± 0.340^{b}
TC3	62.66±0.153^{a}	2.36 ± 0.017^{c}	3.534 ±0.053^{b}	0.861 ± 0.012^{c}	30.557±0.164^{b}	157.85 ± 0.380^{d}
F value	31.682**	18.755^{NS}	14.612**	29.181*	11.134^{NS}	43.183*

C– low fat ice cream with sodium alginate and glyceryl mono stearate; TC_1 – low fat ice cream with 0.03% κ- carrageenan and glyceryl mono stearate; TC_2 - low fat ice cream with 0.04 % κ- carrageenan and glyceryl mono stearate; TC_3 - low fat ice cream with 0.05 % κ-carrageenan and glyceryl mono stearate

@ Average of six trials, **Highly significant (P≤0.01); * - Significant (P<0.05); NS - Not significant (P>0.05)

Sensory Evaluation

The sensory quality of control and treatments of low- is presented in Table 2. The incorporation of κ-carrageenan significantly influenced all sensory attributes (P ≤0.01). Among the κ-carrageenan variants, low-fat ice cream containing 0.05% κ-carrageenan (TC_3) obtained the highest scores for body and texture, flavor, color and appearance, melting quality and overall acceptability. This finding correlates with study that κ-carrageenan improved body, texture, melting quality, and overall acceptability as reported by Soukalis *et al.,* (2008). The enhanced sensory quality in TC_3 may be attributed to the improved water-holding capacity and increased viscosity imparted by κ-carrageenan, reducing ice crystallization and promoting a smoother mouthfeel as reported by Kamińska-Dwórznicka *et al.,* (2020).

Table 2: Sensory scores for Control and Treatments of low-fat ice cream

Treatments	Body and texture	Flavor	Color and appearance	Melting quality	Overall acceptability
C	7.65 ± 0.24^{d}	7.45 ± .0368^{c}	7.5 ± 0.241^{c}	7.5 ± 0.2582^{c}	7.67 ± 0.102^{c}
TC_1	6.25 ± 0.26^{a}	6.25 ± 0.35^{a}	6.70 ± 0.3536^{a}	6.15 ± 0.2415^{a}	6.35 ± 0.184^{a}
TC_2	7.2 ± 0.25^{b}	7.1 ± 0.20^{b}	7.05 ± 0.2838^{b}	7.2 ± 0.2582^{b}	7.13 ± 0.124^{b}
TC3	7.85 ± 0.33^{c}	7.6 ± 0.31^{c}	7.6 ± 0.3162^{c}	7.7 ± 0.25^{c}	7.85 ± 0.141^{c}
F-value	61.745**	36.141**	27.733**	82.677**	191.013**

C– low fat ice cream with sodium alginate and glyceryl mono stearate; TC_1 – low fat ice cream with 0.03% κ- carrageenan and glyceryl mono stearate; TC_2 - low fat ice cream with 0.04 % κ- carrageenan and glyceryl mono stearate; TC_3 - low fat ice cream with 0.05 % κ-carrageenan and glyceryl mono stearate @ Average of six trials, **Highly significant (P≤0.01),

Conclusion

The incorporation of κ-carrageenan as a stabilizer significantly improved the sensory quality of low-fat ice cream. At a concentration of 0.05%, κ-carrageenan enhanced the body, texture, melting resistance, and overall acceptability of the product, resulting in sensory characteristics comparable to those of conventional full-fat ice cream. Its functional properties, particularly its water-binding capacity and gel network formation, played a crucial role in enhancing creaminess and texture. Therefore, κ-carrageenan can be considered an effective natural stabilizer for developing low-fat ice creams that meet consumer expectations for texture and taste while contributing to the formulation of healthier dairy products.

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