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RESEARCH ARTICLE

Preparation of Sandesh incorporated with Monk fruit (*Siraitia grosvenorii)* as natural sweetener

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Abstract: In this study, Sandesh was prepared using toned milk and monk fruit as a natural sweetener. Monk fruit powder was added at 0%,1%, 2%, and 3% by weight of chhana. Based on sensory evaluation, Sandesh containing 3% monk fruit powder was found acceptable in terms of sensorial quality. The Sandesh was further packed in different packaging materials such as High-density polyethylene (HDPE), Low-density polyethylene (LDPE), and Polystyrene (PS), and stored at ambient and refrigerated conditions. Under refrigerated conditions, the product was good in terms of physicochemical and microbial quality till the 14th day in the HDPE pouch. The Monk fruit Sandesh was also tested for DPPH radical scavenging, total phenolic content, color, texture, thermogravimetric analysis, X-ray diffraction (XRD), scanning electron microscopy, and storage stability.

Keywords: Sandesh, Monk fruit, Natural sweetener, Scanning electron microscopy

Abbreviations

AOAC-Association of Official Analytical Chemists, **DPPH-** 2,2-Diphenyl-1-picrylhydrazyl, **FTRI-** Fourier transform infrared spectroscopy, **GAE-** Gallic acid equivalents, **HDPE-** High-density polyethylene, **LDPE-** Low-density polyethylene, **PS-** Polystyrene, **SEM-** Scanning electron microscopy, **TGA-** Thermogravimetric analysis, **TPC-** Total phenolic content, **XRD-** X-ray diffraction.

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Introduction

India is the world's greatest milk producer, producing 230.6 million tonnes and consuming 459 grams per person daily (Anonymous, 2024). Approximately 45-50% of milk produced is used to make indigenous dairy products (Dhawade et al. 2024). Milk is a popular drink that contains nutrients (carbohydrates, protein, minerals, vitamins, and calcium) and is a staple in many people's diets (Pallathadka et al. 2022). Compositional heterogeneity has an important role in meeting specific requirements that can satisfy the needs of both processors and consumers. The product yield, composition, and quality are influenced by the milk components, particularly casein, fat, and calcium (Fox et al. 2017). Cow milk is recommended for chhana-based sweetmeats due to its soft coagulum which provides desirable physicochemical, rheological, and textural characteristics of the finished product (Singh et al. 2024).

Bengalis are known for their love of sweets, as the saying goes. In Bengal, sweets account for around 65% of total milk production (Asgar and Chauhan, 2023). Among them, Sandesh is very popular. Sandesh (chhana balls) is a delectable delicacy in eastern India (West Bengal, Assam, Bihar, Tripura). Sandesh is made by preparing good quality chhana. Cow milk produces better quality Sandesh than buffalo milk because it has more total solids, calcium, protein, and curd tension, which causes hard, chewy, rubbery, and irregular textured chhana, making it unsuitable for producing excellent-grade sweetmeats (Ammu et al. 2020). There are three varieties of Sandesh - Narampak (soft grade, medium moisture), Karapak (hard grade, medium moisture), and Kachagolla (extremely soft grade, high moisture). Narampak is the most popular variety (Giram et al. 2022). Sandesh is an excellent dessert famous for its sweet taste. It is also gaining popularity in other parts of the country and abroad because of its delicious flavour (Karpurapu et al. 2024) and sweet taste. Sweetness is the most palatable flavours in the human diet (McCain et al. 2018). Mostly table sugar is used as a sweetening agent known as sucrose. However, excessive sugar consumption has a detrimental impact on human health and may lead to obesity, diabetes, hypertriglyceridemia, cancer, renal disease, tooth decay, and cardiovascular illnesses (Carocho et al. 2017). At present

alternative sweeteners are used more and more to decrease the health issues caused by sugar (Buchilina and Aryana, 2021). Some artificial sweeteners are available in the market but repeated use of these manmade substances causes detrimental health issues**.** In dairy products, sugar functions as a bulking agent, influences texture and viscosity, enhances flavour and color, and can be used as a preservative (McCain et al. 2018).

Monk fruit is known as *Siraitia grosvenorii* and is commonly known as Luo Han Guo in China. Monk fruit sweetener is natural, and calorie-free with huge health advantages. This natural sweetener is 300 times sweeter than sucrose (Suri et al. 2021). This sweetener can protect the liver, control immunological response, lower blood glucose levels, asthma, guard against oxidation and cancer. The main antioxidant component in Monk fruit is mogrosides which have antioxidant properties. The main mogroside, mogroside V, accounts for 0.5 to 1.4% of the dried fruit of *S. grosvenorii*'s sweetness (Li et al. 2015). Mogroside is generally recognized as safe (GRAS) by the US Food and Drug Administration (FDA) (Mooradian et al. 2017). This makes monk fruit extract a viable alternative to table sugar for persons who want to cut their calorie consumption (Yeung, 2023).

Toned milk contains 3.0% fat, and 8.5% SNF. This milk is lower in cholesterol than full cream milk thus it can help to maintain the cholesterol in the body so it would be great for a healthy heart. So, toned cow milk chhana and monk fruit sweetener were used as sugar replacers to make Sandesh. Sandesh's properties may change by replacing the sugar with sweeteners. Monk fruit sweetener was used in camel milk yogurt (Buchilina and Aryana, 2021) to evaluate the physicochemical, rheological, microstructural, and antioxidant properties of yogurt (Ban et al. 2020) and skim chocolate milk (Li et al. 2015).

Erythritol, allulose, date sugar, coconut sugar, stevia, monk fruit are different commercially available sweeteners present in the market. It has been reported that Monk fruit sweetener is 300 times sweeter than sucrose (Suri et al. 2021). Since being granted GRAS (Generally Regarded as Safe) status in the USA, it has seen a notable increase in consumption as a tabletop sweetener and sugar-free food additive for industrial applications, following Stevia rebaudiana (Çiçek et al. 2020). Thus, incorporation of Monk fruit sweetener can be superior alternative to those already available in the market.

Keeping the above in view, the present study was undertaken with the objectives of preparing Sandesh from toned milk chhana using Monk fruit, analyzing the prepared Sandesh for physical, chemical, microbial, and sensory characteristics, and determining its shelflife using different packaging materials.

Materials and methods

Preparation of Monk fruit Sandesh

Toned milk was purchased from the local market of Varanasi, Uttar Pradesh. Monk fruit was bought from the world's leading monk fruit company "MonkFruit corp.". Sandesh was prepared using the procedure of (Rai et al. 2021) with some modifications. Chhana was prepared by heating milk at 90-95°C, followed by cooling to 70°C. After that, 1-2 % citric acid was added as a coagulating agent to previously heated milk for precipitation. Coagulation was done at 80-85°C and pH was 5.1-5.4. After coagulation whey was removed using a muslin cloth. The partly dewatered product obtained was chhana. Then solid mass was collected and kneaded into uniform dough and divided into two parts. After that one part of chhana was mixed with 0 %, 1%, 2%, and 3% monk fruit powder, and cooking was carried out at 70°C for 15 min with vigorous stirring and scraping. The second lot of chhana was added and the mixture was heated up to 60°C for about 10 min and the cardamom powder was added for flavour. The prepared Sandesh was cooled to 37°C and shaped like balls.

Yield of monk fruit Sandesh

The cooking yield was calculated using the following equation:

$$\text{Percent (\%) cooking yield} = \frac{\text{Cooked product weight}}{\text{Raw product weight}} \times 100$$

Packaging of Monk fruit Sandesh

Three types of packaging materials were selected i.e. high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polystyrene (PS) based on their physico-chemical properties, cost, and availability.

Sterilization of packages

The inner portion of HDPE, LDPE, and PS packets was cleaned with a teepol detergent solution and rinsed with hot water (Etaware et al. 2019). The packaging materials were then air-dried. The entire process was carried out under aseptic conditions in a packing room.

Storage of Monk fruit Sandesh

Freshly prepared Sandesh was filled into the packets which were sterilized and then sealed immediately. The sealed packages were stored at two different conditions, i.e. ambient temperature and refrigerated temperature. Sandesh samples stored at ambient temperature were analyzed at 0, 2, 4, and 6th days, and samples stored under refrigerated conditions were analyzed at intervals of 7, 14, and 28th days.

Analysis of Toned Milk and Monk Fruit Powder

Fat content, protein content, pH, and titratable acidity (TA) of milk were estimated using the AOAC method (AOAC, 2016). All measurements were performed in triplicate and the analytical grade

chemicals were used. Monk fruit powder was analyzed for ash, moisture, and pH (AOAC, 2016).

Sensory evaluation

The sensory evaluation was carried out after receiving permission from the Banaras Hindu University's Ethics Committee. All participants received written information about the study, including its purpose, procedures, and any potential risks or benefits. They signed informed consent forms to participate and were informed how the data would be used. The study was conducted under the Banaras Hindu University ethical guidelines. A group of thirty members (15 Males and 15 Females), comprising different age groups (20-55 Years) of the Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University were chosen to carry out the sensory evaluation of prepared Monk fruit Sandesh. The panelists evaluated the sensory attributes like colour& appearance, body and texture, aroma, flavour, and overall acceptability. The sensory analysis was conducted using a 9-point hedonic scale.

Physicochemical analysis of Monk fruit Sandesh

The prepared Sandesh's moisture, fat, ash, protein, titratable acidity, pH, and free fatty acid were determined with some modifications (AOAC, 2016). The Sandesh samples' water activity was measured using a water activity meter (AQUALAB 4TE, USA).

DPPH radical scavenging assay of Monk fruit Sandesh

DPPH radical scavenging assay was estimated for Sandesh according to the method of (Aparna et al. 2024) with some minor modifications. The absorbance was taken in a UV-VIS spectrophotometer at 517 nm against a blank solution.

Analysis of Total Phenolic Content of Monk Fruit Sandesh

The total phenolic content of the monk fruit Sandesh extract was determined using the Folin-Ciocalteau method (Aparna et al. 2024) with some modifications. The standard calibration curve of Gallic acid (0-800 mg/L) was produced and phenolic content was expressed in mg of Gallic acid equivalents (GAE)/g of extract.

Colour analysis

The colour of Sandesh was measured with a Hunter colour lab equipped with a measuring head (diameter 127 mm). The colour was analysed using the CIE L*a*b* scale and illuminant. Numerical values of a* and b* were converted into hue angle (h_) and Chroma (C*) that represent the hue and the saturation index. Results were expressed as L* (luminosity), hue angle (h_), and Chroma (C*). The L value for each scale therefore indicates the level of dark (0-50) or light (51-100), the a* value redness (positive value) or greenness (negative value), and the b value yellowness (positive value) or blueness (negative value).

Texture analysis

Textural parameters of Sandesh were analyzed using a Texture Analyzer (CT3 Texture Analyzer, BROOKFIELD AMETEK, Pennsylvania, U.S.) fitted with a 50000 g load cell. The product was subjected to the application of force to a depth of 10 mm by a TA 3/100 probe attached to the texture analyzer fitted with a 50000 g load cell. All the tests were carried out at room temperature. Texture parameters like hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness were measured using the instrument. Triplicate measurements were made for each sample. Test conditions for texture analysis of Sandesh were: pre-test speed- 2.0 mm/s, test speed- 5.00mm/s, return speed- 5.0 mm/s, trigger force auto -5 g, and data acquisition rate -15 points/ sec.

Fourier Transform Infrared (FTIR) Spectroscopy Analysis

The chemical information of Sandesh samples was studied by FTIR analysis (VERTEX 80V, Germany). The sample was mixed with the KBr (Potassium bromate) and pressed into a pallet. The mixture was scanned over a wavelength range of 400 cm-1 to 4000 cm-1. All FTIR spectra were subjected to noise reduction and baseline smoothing.

Thermogravimetric analysis (TGA)

A thermogravimetric 176 analyzer 117 (Pyris 1 TGA, Perkin-Elmer, USA) was used to measure Sandesh's thermal properties in a nitrogen atmosphere (20.0 ml/min) at a heating rate of 10°C/min over a temperature range of 30°C to 700°C.

X-ray diffraction (XRD) analysis

XRD study was carried out using an X-ray diffractometer (EMPYREAN, PANalytical, Netherlands). Half a gram of sample was scanned from 10° to 80° diffraction angle (2θ) with CuKα radiation at a voltage of 45 kV, current of 40 mA step-scan mode with a step size of 0.013° (2θ), and counting time of 18.87 s/step. The test was conducted at a temperature of 25°C.

Scanning electron microscopy (SEM) analysis

The morphology of the Sandesh sample was observed using a scanning electron microscope. The sample was placed on double adhesive tape, which was then stuck on an aluminium stub of SEM. Then, the sample was observed under a scanning electron microscope (JSM-6100, JEOL, Tokyo, Japan) at an accelerated voltage of 20 kV and magnification in the range of 1.0 – 500X (Kumari et al. 2023).

Storage stability of Monk fruit Sandesh

Sandesh was kept for 28 days in refrigeration with temperature (4±2°C) and 6 days at room temperature (25±2ÚC). At regular intervals, physicochemical and microbiological analysis was conducted. Standard plate count (SPC), Yeast and mold count, and coliform count were carried out according to the procedure of Giram et al. (2022).

Statistical Analysis

The data analysis was calculated by using Microsoft Office Excel 2019. All the tests were conducted in triplicate. Results are expressed in Mean ± SD values.

Results and Discussion

Yield of monk fruit Sandesh

The maximum cooking yield of Sandesh was estimated at 94% with increasing sugar substitute levels (Singh et al. 2019). In this study, the yield of monk fruit Sandesh was 95.5%.

Analysis of toned milk & monk fruit extract powder

The toned milk used for the Sandesh preparation was determined as fat (%) - 3.03 ± 0.06, protein (%) - 3.07 ± 0.06, pH - 6.46 ± 0.06, and titratable acidity (% LA) - 1.13 ± 0.01.

The ash content, moisture content, and pH were analyzed for monk fruit extract powder, and after this physicochemical analysis results were determined as 0.19%, 4.02%, and 4.47 respectively.

Sensory analysis of Monk fruit Sandesh

Conventional Sandesh is prepared from sugar (30% by weight of total chhana) (Singh et al.2019). In this study, a 3% monk fruit sample was found to have the highest sensory score by assuming monk fruit is 100 times sweeter than sugar. It was observed that the extract of monk fruit is 300 times sweeter than sucrose (Shivani *et al.* 2021). So, on concluding the sensory evaluation of Sandesh (chhana balls) with 0%, 1%, 2%, and 3% monk fruit extract powder, 3% was found more acceptable regarding sensory quality. Overall acceptability of Sandesh with 3% monk fruit scored 8.09 ± 0.16, which means likely very much according to a 9-point hedonic scale.

Physicochemical analysis of Monk fruit Sandesh

The ash, protein, and fat values of Monk fruit Sandesh were determined as 2.23 ± 0.006, 17.36 ± 0.03, and 10.38 ± 0.05 in percentage respectively. The results were partially similar to some works previously conducted by (Kaderee et al. 2021; Singh et al. 2019), respectively. Water activity of monk fruit Sandesh with 3% added monk fruit powder was calculated as 0.9778 ± 5.77. Singh et al. 2019 also reported quite the same value for low-calorie fiber-rich chhana balls.

Conventional Sandesh contains 30% sugar (by weight) of total chhana (Sen and Rajorhia, 1990). In this study 3% monk fruit was optimized as monk fruit is 100 times sweeter than sugar. Again, by comparative sensory evaluation of Sandesh (chhana balls) containing 0%, 1%, 2%, 3% monk fruit extract powder, 3% was optimized as it was superior than others. Though the beneficial effects on human health were not under the present study, but the literature showed that the incorporation of monk fruit extract might offer metabolic benefits over artificial sweeteners, which have been connected to dysbiosis and glucose intolerance, according to research on the effects of high-intensity sweeteners (Kaim and Labus, 2025). The scope of the present study did not allow us to further investigate.

DPPH free radical scavenging assay of Monk fruit Sandesh

The antioxidant activity of monk fruit Sandesh was detected as 14.43 ± 0.09 (average of 3 replicates; Mean ± SD). The result was somewhat similar to the report of pudina juice concentrated herbal Sandesh (Chakraborty et al. 2017). Monk fruit contains mogroside, which is a water-soluble compound having free radical scavenging activity.

Total phenolic content in Monk fruit Sandesh

The total phenolic compound in monk fruit sandesh was determined as 5.33 ± 0.40, which seemed quite similar to the total phenolic content of herbal Sandesh (Chakraborty et al. 2017). Monk fruit sweetener contains 3.45% phenolics and 2.24% total flavonoids (Ban et al. 2020). Phenolic compounds in the Monk fruit sweetener are reported to benefit chronic diseases such as coronary heart disease. The phenolics of plant extracts are health-beneficial because of their antiradical and antioxidant properties (Chakraborty et al. 2017).

Color analysis

Instrumental color analysis showed the high L* value was 83.35 for Sandesh. This might be due to the micelle aggregation phenomenon of casein micelles as they can scatter light (Chakraborty et al. 2021). a* and b*values of Monk fruit Sandesh were found to be -0.60 and 15.31. Thus, the color of Sandesh was defined as bright, the negative value of a* showed that the product was not red and the positive value of b* showed the product was slightly yellow.

Texture analysis

The texture analysis of monk fruit Sandesh was carried out in a cylinder-shaped sample with 19.28 mm length, 4 mm width, and 35 mm depth. Hardness, adhesiveness, cohesiveness,

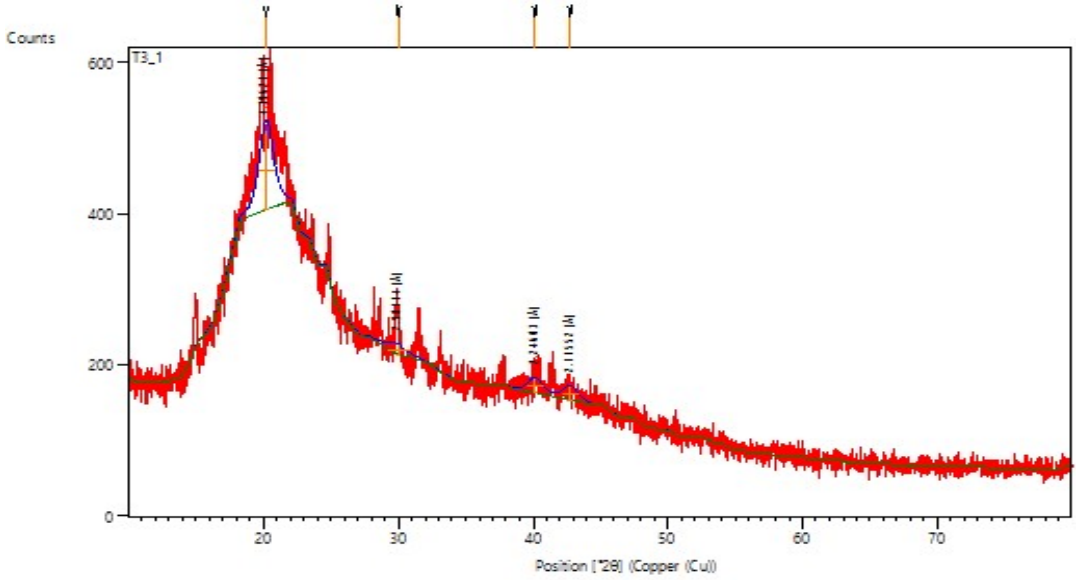


Fig. 1: FTIR graph of monk fruit Sandesh

springiness, gumminess, and chewiness were 1335.00 g, 1.00 mJ, 0.12, 3.90 mm, 160.00 g, and 6.10 MJ, respectively. The product was soft, smooth, and slightly chewy. The texture quality of the monk fruit Sandesh was desired and praiseworthy.

Fourier transform infrared spectroscopy (FTIR) analysis

In monk fruit Sandesh (Fig.1) the band of O-H stretching and asymmetric stretching of water, carbohydrates, carboxylic acids, and another hydroxylic group present in protein show bands in the region of 3200-3400 cm^{-1}, observed less broad and sharp peak because of little moisture loss. The 2840-2929 cm-1 IR peaks show medium C-H stretching. This may occur due to maintaining the structure of casein, whey protein, and with fat, mainly reorganization occurs (Chakraborty et al. 2021). As 2830-2695 cm-1 shows medium C-H stretching and 2600-2550 cm-1 represents weak S-H stretching (thiols). So, here in this study, the 2433- 2600 cm-1 peak shows the presence of a very small number of thiols. Heat treatment causes the denaturation of protein, which involves the unfolding of whey proteins, and by this, it exposes reactive functional groups such as thiol groups in β-lactoglobulin (Čurlej et al. 2022). The region 1800-1710 cm-1 showed C=O stretching of carbonyl group esters (Chakraborty et al. 2021). The FTIR graph of monk fruit Sandesh 1655-1745 cm-1 shows the presence of C=O stretching bands, and esters of fatty acids in the region. It means the Sandesh contains fat. The 1200-800 cm{ ¹ region corresponds to C-C to C=O stretches (Chakraborty et al. 2021). The 1249-1480 cm{ ¹ region represents O-C-H, C-CH, and C-O-H, while 1096, 1174, and 1249 cm{ ¹ indicate C-O bending from alcohols, ethers, and esters. These features may result from Sandesh's medium water and protein content, with stronger amide bonds and long-chain fatty acids.

Thermogravimetric analysis (TGA)

The thermal characterization of monk fruit Sandesh (chhana balls) was determined by thermogravimetric analysis by observing the decrease in mass of the sample against temperature. In the curve of Monk fruit Sandesh; there were three regions found (50 - 210°C, 210 - 430°C, and 430 - 690°C. Evaporation and dehydration of adsorbed and surface water caused a slow weight deprivation in the first region (50 - 210°C). The degradation of the polysaccharide resulted in a rapid weight reduction in the second region (210 - 430°C) and decomposition of the char resulted in a slow weight reduction in the third region (430 - 690°C).

X-ray diffraction (XRD) analysis

XRD analysis was used to understand the structure of monk fruit Sandesh (chhana balls). The peak of monk fruit Sandesh was shifted to a lower 2θ. In X-ray diffraction diffractograms, the crystalline material shows a series of sharp peaks, while the amorphous product produces a broad background pattern. Different peaks were found at 2θ equal to 20.19, 26, 30, 41, and 44° but after 35° peaks were not that much clear. Peaks disappeared towards the higher 2θ (Fig. 2). So, the diffraction pattern was amorphous because of the broad and diffuse line. Crystalline materials are more strong and rigid. X-ray diffraction of freeze-dried camel milk rennet (CC) and freeze-dried microbial coagulant (MC) showed the same kind of result which signifies the absence of a structural unit that would be duplicated exactly at periodic intervals in three dimensions (Bouras et al. 2025).

Scanning electron microscopic (SEM) analysis

The high-scanning images given by Scanning Electron Microscopy (SEM) (Fig. 3; a-d) showed the structure of monk fruit Sandesh. SEM images of different magnifications showed the morphology of tissue and surface modification. The monk

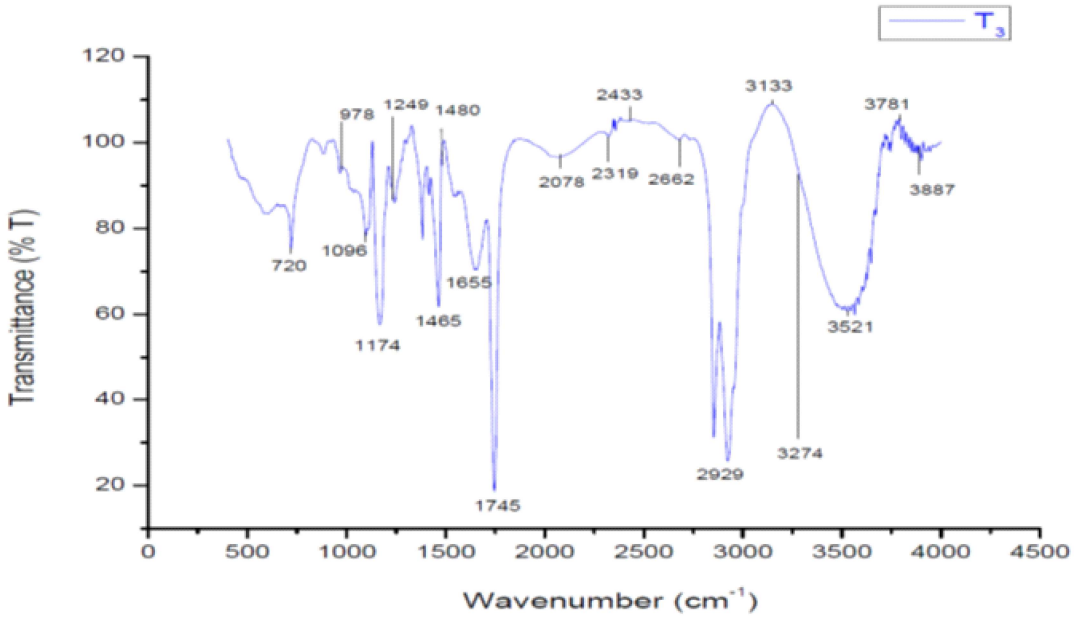
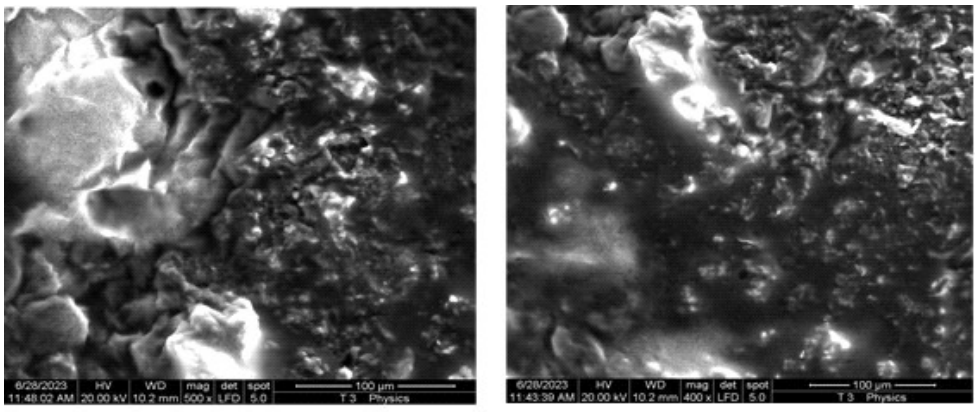
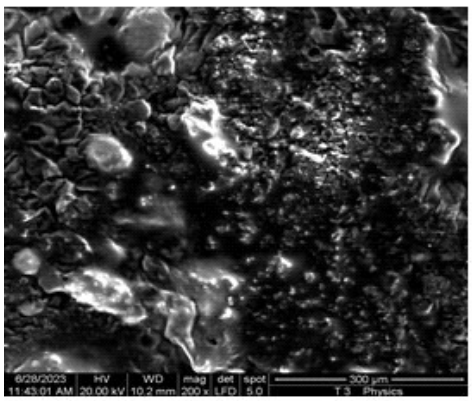


Fig. 2: XRD analysis graph of monk fruit Sandesh

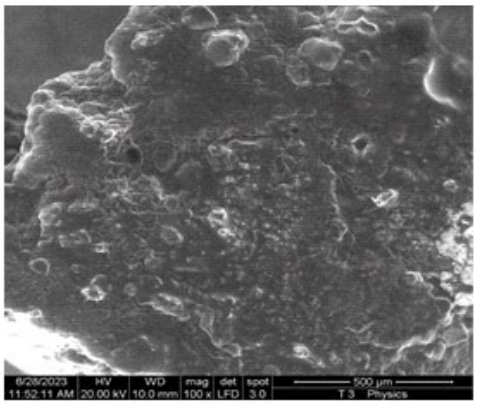


(a) SEM image of Sandesh in 500x magnification

(b) SEM image of Sandesh in 400x magnification



(c) SEM image of Sandesh in 200x magnification



(d) SEM image of Sandesh in 100x magnification

Fig. 3 (a-d): SEM images of Monk fruit Sandesh

fruit Sandesh surface was uneven and rough, which was also flaky, and this was maybe due to the fat globules being somewhat ruptured, which might be due to the cooking of Sandesh. The image of monk fruit Sandesh may show a loose protein matrix and many voids. The size of fat globules in cow milk is smaller than that in buffalo milk; thus, they are less vulnerable to heat treatment (Puri et al. 2017).

Table 1: Effect of packaging materials on the chemical quality of monk fruit Sandesh (chhana balls) at ambient (25 ±2°C) and refrigerated (7±2°C) storage conditions

Storage conditions	Packaging type	Storage period (days)	Moisture (%)	TA (%)	pH	FFA (%)	TPC (mg of Gallic acid equivalents (GAE)/g of extract)	%DI Inhib
Ambient	HDPE	0	57.62 ± 0.06	0.18 ± 0.01	6.42 ± 0.01	0.15 ± 0.01	5.33± 0.40	14.43
		2	57.61 ± 0.07	0.18 ± 0.01	6.42 ± 0.02	0.18 ± 0.01	5.33± 0.40	14.38
		4	56.60 ± 0.06	0.21 ± 0.02	6.31 ± 0.01	0.23 ± 0.04	5.18± 0.41	14.35
		6	56.43 ± 0.35	0.27 ± 0.02	6.27 ± 0.06	0.26 ± 0.01	4.93± 0.40	13.50
Refrigerated	HDPE	0	57.42 ± 0.05	0.18 ± 0.01	6.34 ± 0.01	0.14 ± 0.01	5.33± 0.40	14.43
		7	56.96 ± 0.65	0.26 ± 0.03	6.35 ± 0.06	0.18 ± 0.01	5.18± 0.41	14.40
		14	56.37 ± 0.04	0.26 ± 0.02	6.29 ± 0.07	0.23 ± 0.04	5.28± 0.39	14.28
		28	56.43 ± 0.35	0.23 ± 0.05	6.25 ± 0.11	0.26 ± 0.01	4.43± 0.30	13.20
Ambient	LDPE	0	57.42 ± 0.04	0.18 ± 0.01	6.42 ± 0.02	0.15 ± 0.01	5.33± 0.40	14.43
		2	56.6 ± 0.64	0.20 ± 0.03	6.31 ± 0.10	0.20 ± 0.12	5.32± 0.36	14.40
		4	56.35 ± 0.41	0.21 ± 0.02	6.33 ± 0.04	0.24 ± 0.03	5.30± 0.35	14.30
		6	54.6 ± 0.82	0.29 ± 0.03	5.99 ± 0.01	0.27 ± 0.04	4.83± 0.37	14.28
Refrigerated	LDPE	0	56.42 ± 0.04	0.18 ± 0.01	6.43 ± 0.02	0.15 ± 0.01	5.33± 0.40	14.43
		7	56.15 ± 0.23	0.25 ± 0.02	6.28 ± 0.06	0.21 ± 0.01	5.23± 0.38	14.35
		14	55.89 ± 0.33	0.27 ± 0.01	6.25 ± 0.02	0.24 ± 0.04	5.03± 0.35	13.80
		28	55.8 ± 0.14	0.29 ± 0.03	6.03 ± 0.08	0.27 ± 0.03	4.53± 0.31	13.20
Ambient	PS	0	56.68 ± 0.06	0.18 ± 0.01	6.43 ± 0.01	0.15 ± 0.01	5.33± 0.40	14.43
		2	56.62 ± 0.79	0.19 ± 0.01	6.4 ± 0.01	0.19 ± 0.01	5.03± 0.35	14.40
		4	56.39 ± 0.49	0.19 ± 0.01	6.31 ± 0.09	0.21 ± 0.01	5.03± 0.35	14.35
		6	56.10 ± 0.70	0.28 ± 0.01	6.25 ± 0.14	0.27 ± 0.02	4.63± 0.32	13.32
Refrigerated	PS	0	57.64 ± 0.06	0.18 ± 0.01	6.42 ± 0.01	0.15 ± 0.01	5.33± 0.40	14.43
		7	56.75 ± 0.75	0.25 ± 0.02	6.4 ± 0.01	0.22 ± 0.04	5.23± 0.38	14.40
		14	56.36 ± 0.45	0.26 ± 0.01	6.31 ± 0.09	0.22 ± 0.01	5.18± 0.41	13.80
		28	55.77 ± 0.76	0.27 ± 0.01	6.31 ± 0.02	0.28 ± 0.01	4.43± 0.30	13.20

*TA -Titratable acidity, HDPE- High-density polyethylene, LDPE- Low-density polyethylene, PS- Polystyrene: All values were calculated in triplicates and results are expressed in Mean ± SD.

Storage stability of monk fruit Sandesh

Physico-chemical changes:

A slight increase in titratable acidity and free fatty acid content was observed in all the samples during storage under ambient as well as refrigerated conditions irrespective of their packaging type (Table 1). A slight decrease in moisture and pH content was observed with the increase in storage period under both conditions. The changes in their quality were considerable depending upon the packaging type and storage period. The spoilage rate was more pronounced at ambient storage conditions rather than refrigerated conditions. The chemical degradations were maximum under both conditions in the LDPE pouch followed by PS and HDPE pouches. During the storage of Sandesh, common deteriorating factors were lipolysis, oxidation, and acid development. At ambient condition product was acceptable for 6 days only but at refrigerated condition chemical parameters were still good above 28 days. Quite similar changes were observed in 15-days storage study for Rabri enriched with date syrup and makhana (Saxena et al. 2022).

Monk fruit extract powder had a slight dried fruit taste, a distinct sweetness that stays on the tongue. After incorporation into the product, there was no bitter taste. Slightly bitter taste of monk fruit Sandesh was observed during the last period of storage at ambient as well as refrigerated temperature. Sugar creates typical flavor of Sandesh that was missing but the overall acceptability was good. Thus, monk fruit is becoming a famous sweetener to use in dairy product.

Under refrigerated conditions, the product was good in terms of physicochemical and microbial quality till the 14th day in the HDPE pouch. Mogroside is the major bioactive compound in monk fruit known for its antioxidant property and its effect on the FFA content, which is a shelf-life limiting factor in dairy products. Monk fruit added Sandesh, having FFA (% oleic acid) content at the 6th days of storage was 0.26 ± 0.01, and at 28th days of storage it was 0.26 ± 0.01 at ambient and refrigerated condition respectively in HDPE pouches. Quite similar result has been reported by Sen and Rajorhia (1990). But the typical taste of Sandesh started degrading during the last storage period. DPPH free radical scavenging assay and total phenolic content of Monk fruit Sandesh were decreasing slightly during storage. Yadav *et al.* (2017) evaluated of total phenol content and antioxidant properties of encapsulated grape seed extract in yoghurt. total phenolic content and antioxidant potential of the encapsulated grape seed extract yoghurt remained unaffected as compared to nonencapsulated grape seed extract yoghurt during a storage period of three weeks.

Table 2: Effect of packaging materials on the microbiological quality of monk fruit Sandesh (chhana balls) at ambient (25±2° C) and refrigerated (7±2°C) storage conditions

Storage conditions	Packaging type	Storage period (days)	SPC (counts/g of sample)	Yeast & Mold (counts/g of sample)	Coliform (counts/g of sample)
Ambient	HDPE	0	0	0	0
		2	0	0	0
		4	1.2×10^2	1.3×10^3	0
Refrigerated	HDPE	0	0	0	0
		7	0	0	0
		14	1.2×10^3	1.3×10^3	0
Ambient	LDPE	0	0	0	0
		2	1.2×10^1	1.2×10^2	0
		4	1.4×10^4	1.9×10^3	0
Refrigerated	LDPE	0	0	0	0
		7	1.5×10^2	1.5×10^2	0
		14	1.5×10^3	1.9×10^5	0
Ambient	PS	0	0	0	0
		2	0	1.2×10^2	0
		4	1.2×10^2	1.3×10^2	0
Refrigerated	PS	0	0	0	0
		7	1.2×10^2	1.3×10^2	0
		14	1.4×10^2	1.5×10^4	0

Where, HDPE: High-density polyethylene; LDPE: Low-density polyethylene; PS: Polystyrene pouch; All the values are calculated in triplicates; *SPC- Standard Plant Count.

Microbiological changes:

The growth of micro-organisms in Sandesh was faster in ambient than in the refrigerated condition (Table. 2). Maximum microbial growth was shown in LDPE package than in PS and HDPE. Microbial growth in the HDPE package was less. The standard plate count increased at both storage conditions. Yeast and mold count also increased but coliform was absent. This indicates that the production and packaging of monk fruit Sandesh was done in hygienic condition. On the sixth day at ambient temperature, the microbial count was high and the product was discarded, but at refrigerated temperature, the growth was less. Similar kind of results were found by Giram et al. (2022).

Conclusion

In this study, Sandesh was prepared by using toned milk, monk fruit extract powder as a natural sweetener, and cardamom as a flavoring agent. Monk fruit can be successfully incorporated up to 3% in Sandesh preparation. Zero-calorie natural sweetener monk fruit was found to provide a good body, flavor, and texture to Sandesh. The analysis which was conducted revealed that the product had good physico-chemical and antioxidant properties. Monk fruit has many health-beneficial properties such as preventing asthma, diabetes, and cancers, liver protection properties, regulating immune function, and lowering the levels of glucose in blood. Thus, monk fruit is becoming a famous sweetener to be used in dairy products. Many previous researches on the application of monk fruit sweeteners were focused on yoghurt, and chocolate milk. Being a low-calorie sweetener and having so many health benefits, monk fruit Sandesh also would have a great application in food for people who are suffering from diabetes.

Similarly, the future studies may be undertaken on instrumental analysis like high-performance liquid chromatography (HPLC) can be conducted in Sandesh to analyze the amino acid profile and organic acids present. A comparative study may be undertaken to evaluate the nutritional quality of monk fruit Sandesh against Sandesh prepared with other sweeteners, with particular emphasis on glycaemic response, metabolic health markers, and overall consumer acceptability, to determine which offers superior quality and potential health benefits.

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Conflict of interest

The authors declare no conflict of interest.

Ethical approval

The experiments on the sensory evaluation in this study have been strictly adhere to the ethical practices. The authors confirm that the rights and privacy of all the participants were protected during the execution of the research.

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