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Formulation and evaluation of functional attributes of low-fat mozzarella cheese using okra mucilage as a fat replacer

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Summary Mozzarella cheese is a fermented product comprised of 30–45% milk fat on a dry basis. The milk fat gives the mozzarella its desirable stretchable properties which are demanding in food processing industries. The current study was designed to use okra mucilage as a carbohydrate-based fat replacer to prepare low fat mozzarella cheese. For this purpose, the different concentrations of okra mucilage (0.25 to 1.0% (v/v)) were used. The fat contents were significantly reduced in all treatments and the addition of okra mucilage with a concentration of 0.25% (T_2) was considered best for its organoleptic properties and 1% (T_4) has a positive impact on the textural, functional attributes of low-fat mozzarella cheese.

Keywords Buffalo milk, cheese, fat replacer, mozzarella, mucilage, stretchability..

Introduction

Mozzarella cheese is preferred as a versatile food product that incorporates a variety of flavours and textures in processed foods. It comes under the category of soft, white, unripened cheeses, which can be used immediately after its manufacture. Mozzarella cheese comes under the pasta filata family and was originally reported in the Battipaglia region of Iran (Ah & Tagalpallewar, 2017). For many years, the starter culture was used for the preparation of cheese curds, but nowadays, the direct acidification technique is preferred for preparing cheese at the commercial level (Fox *et al*., 2017).

Mozzarella cheese prepared from buffalo milk is preferred over cow milk due to its whitish colour appeal and a higher concentration of solids (Sales *et al*., 2017; Ahmad & Saleem, 2020). The stretching of cheese curd provides an outstanding fibrous texture when used in food products prepared under high temperatures. The stretching is a thermo-mechanical treatment in which shear stress and heat are employed in the form of mechanical energy to the cheese curds (Banville *et al*., 2016). The reliability of the mozzarella is dependent on the fat content, amount of calcium, moisture, nitrogen fractions and pH of the final product (Martínez-Martínez & Vélez-Ruiz, 2019).

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Over time, the awareness regarding the use of healthy foods has increased, and people demand less caloric and low-fat (LF) cheeses. The LF content of mozzarella cheese can adversely affect its functionality, textural and sensorial attributes and ultimately results in the rubbery texture, hard, bitter taste and poor meltability (Chatli *et al*., 2019). Numerous techniques are employed to boost textural and flavour anomalies of LF cheese, and one of the most promising is the use of fat replacers. The use of three whey protein-based fat replacers (Dairy-Lo) (purity indices 35%), Simpless (53% sincerity) and LS1907 (90% purity indices) was reported for the successful preparation of the LF mozzarella cheese (Tahereh *et al*., 2017). In food processing industries, plant and microbial gums including alginate, guar gum, carrageenan, maltodextrins, pectin, mucilage and xanthan gum are widely used as polysaccharides stabilisers to restrict water mobility and impart fatty mouthfeel (Aziz *et al*., 2018; Dantas *et al*., 2021).

Okra (*Abelmoschus esculentus*) is palatable, dicotyledonous and annual cultivated herb that belongs to the Malvaceae family. The whole okra plant is edible and also used in medicines besides a variety of foods. The 100 g of okra pod was reported to have moisture (w/w) (9.63–13.33 g), crude protein (w/w) (10.25–26.16 g), carbohydrates (w/w) (36.66–50.97 g) and fats (w/w) (0.56–2.49 g) (Liu *et al*., 2021). The okra mucilage is usually comprised of galactose, rhamnose, galacturonic acid and amino

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acids and provides plasticity, elasticity and viscosity in different food commodities (Gemede *et al.*, 2015). The objective of this study was to investigate the outcomes of okra mucilage as a carbohydrate-based fat replacer in LF mozzarella cheese and to determine its effect on the chemical composition and functional properties of LF mozzarella cheese.

Material and methods

Sample and material collection

The unripened and tender okra pods and fresh buffalo milk samples were purchased from the local market. The ingredients used to prepare mozzarella cheese were fresh buffalo milk, vinegar (for acidification), dried rennet and distilled water. All the chemicals used for qualitative testing of mucilage and LF mozzarella cheese analysis were of analytical grade and used as such.

Extraction of mucilage from okra pods

The mucilage obtained from okra was extracted from okra pods following the method reported by Aziz *et al.* (2018) with slight modifications. The okra pods were cut into longitudinal slices to remove the seeds and overnight soaked in warm distilled water (60°C) in a ratio of 1:3 (okra slice:water). This practice proved beneficial for the effective extraction of mucilage. After extraction, the mucilage was filtered using a clean muslin cloth. The extracted mucilage was then covered and stored at a low temperature (<10°C) for further experiments.

Viscosity and solubility measurement of okra mucilage

The viscosity and solubility of extracted okra mucilage were measured following the method reported by Saju & Sivaraman (2021). To determine viscosity, 200 mL of (1%) homogenous okra mucilage was added to 250 mL of a pre-cleaned glass beaker. The viscosity readings were determined using a viscometer (Baoshishan Digital Rotary Viscometer, NDJ-9S, China). To determine its solubility, 10 mL of extracted okra mucilage was dissolved in 10 mL of polar and non-polar solvents (water, acetone, chloroform and ethanol) one after another at ambient temperature.

Total polysaccharide contents of okra mucilage

The total polysaccharides contents of the extracted okra mucilage were determined using the method of Sami *et al.* (2019) with slight modifications. The phenol–sulphuric acid colorimetric method was used by taking the glucose as a standard (Fig. S1 and Table S1). The optimum absorbance of the reacted solution was measured at 490 nm using a UV/Vis spectrophotometer.

Preparation of LF mozzarella cheese

Mozzarella cheese was prepared following the report by Arora *et al.* (2019) with slight modifications. The standardised (fat content of 3.5%) mozzarella cheese was termed as T_0 and served as control and the reduced fat content (1.5%) was termed as T_1. Further treatments of mozzarella cheese were prepared by using the three different concentrations of okra mucilage (0.25% (T_2), 0.5% (T_3) and 1.0% (T_4)). The low-temperature pasteurisation of all the milk treatments (T_0, T_1, T_2, T_3 and T_4) was performed at 62°C for 10 min. After pasteurisation, the temperature of all the treatments was dropped from 60 to 40°C by continuous stirring. Then, 5 mL of vinegar (4.5%) was added to each treatment, and rennet was added at this point at a concentration of 0.05 ppm. After 30 min of the rennet addition, the curd was obtained. At the desired level of firmness, the curd was cut into smaller square pieces that were allowed to stabilise for 10 min. Further cooking in whey was performed by gradually raising the temperature from 40 to 42°C for 30 to 40 min. After 40 min of scalding, the whey was drained with the help of a narrow-sized mesh and 1% (w/w) NaCl salt was added. After the addition of salt, the stretching of the curd was performed in hot water at 80°C. Later, all prepared mozzarella cheese treatments were moulded and stored at 4°C for further analysis.

Proximate analysis and pH determination of extracted okra mucilage and LF mozzarella cheese

The proximate analysis (moisture (%), crude fat (%), crude protein (%) and total ash (%)) of the extracted okra mucilage and LF mozzarella cheese treatments was carried out by using the AOAC official methods (AOAC, 1999). The fat content in cheese samples was determined by using the Gerber centrifuge method of fat extraction (Gonçalves & Cardarelli, 2020). The pH and acidic contents of the LF mozzarella cheese treatment were measured by using the methods reported by Mukhtar *et al.* (2020).

Functional properties of LF mozzarella cheese

The functionality of LF mozzarella cheese in varying concentrations (T_2, T_3 and T_4) was measured using the methods reported by AH and Tagalpallewar (2017). The functional properties include hardness, melting, stretchability and spreadability.

Texture profile analysis of the LF mozzarella cheese

The hardness of the LF mozzarella cheese was determined by using a texture analyser (Imada, Toyohashi, Japan) that can weigh approximately 3–7 g sample. To measure the texture, hardness, shear and puncture, probes were used following the method of Rolle *et al*. (2012) with slight modifications. For analysis, a piece of low-fat mozzarella cheese (64 × 32 cm) was cut and texture was measured on days 0,3, 5, 7 and 9.

Yield analysis of LF mozzarella cheese

The theoretical yield of the prepared LF mozzarella cheese was calculated using the Van Slyke yield equation with slight modifications. The calculated value of theoretical yield was converted into percentages (%).

$$\text{Theoretical yield (g)} = \frac{[\{(0.859 \times \%\text{milk fat}) + (\%\text{milk casein} - 0.1)\} \times 1.13]}{1 - \left(\%\text{cheese}\,\frac{\text{moisture}}{100}\right)} \quad (1)$$

The actual yield (%) was determined by weighing the curd after the proper pressing (Khan & Masud, 2013).

Organoleptic evaluation of LF cheese treatments

A panel of nine trained judges analysed all the treatments of mozzarella cheese prepared by using LF buffalo milk for sensorial properties including colour, appearance, texture, flavour and stringiness using a 9-point hedonic scale. The used hedonic scale was with a magnitude of 9 for maximum liking and 1 for maximum dislike as reported by Larmond (1997).

Statistical analysis

The obtained data were statistically analysed using the IBM SPSS Statistics 21 and findings were reported as mean values with standard deviations. Tukey's test was applied to determine the level of significance at 95% probability ($p \leq 0.05$). For accurate statistical analyses, all the trials were performed in triplicate in the batch flow method of production.

Results and discussion

Solubility and viscosity for the extracted okra mucilage

The solubility test of the okra mucilage was performed to determine whether the mucilage was easily soluble in water or any other organic solvent. For this purpose, the sample of extracted mucilage (1%) was dissolved in different polar and non-polar solvents including distilled water, acetone, chloroform and ethanol. The mucilage showed good solubility in water and get precipitated in chloroform, acetone and ethanol. The results of the current study show great compatibility with the results of a study performed in the past, that is, mucilage showed good solubility in warm water as compared to cold water, and is completely insoluble in organic solvents (Farooq *et al*., 2013). Moreover, 1% okra mucilage has a viscosity of 240 cP and was well compatible with previous findings of Palei *et al*. (2016), which reported okra mucilage viscosity of 247.34 cP.

Total polysaccharide contents of okra mucilage

The analysis showed total polysaccharide contents of 16.43/100 g. A similar study reported total polysaccharide contents in the range 11.22–17.35/100 g determined using phenol– sulphuric acid colorimetric method in okra pods. The major polysaccharide content that can be obtained from the standard glucose curve was starch, while phenyl–phenol procedures were not able to detect pectic polysaccharides (Sami *et al*., 2019).

Effect of mucilage on the chemical composition and pH values of the LF cheese treatments

Table 1 shows the proximate analysis of okra mucilage. The results of the proximate values of okra mucilage showed that it contains 66.3% moisture, 0.21% crude fat, 2.14% crude proteins and 0.15% ash. The value of total carbohydrates (NFE) determined by measuring the difference was 31.26%. A similar study also reported that extracted mucilage of okra contained 66.15% moisture content, 0.12% crude fat content, 2.13% crude proteins and 0.15% ash (Aziz *et al*., 2018). The pH of okra mucilage reported in the current study was 6.58 which relates to the pH value of 6.8–7.5 for okra mucilage reported in past research (Farooq *et al*., 2013).

The results of proximate analysis for standardised mozzarella cheese T_0 (3.5% fat) and LF mozzarella

Table 1 Results of the chemical analysis and pH value of the extracted okra mucilage

Parameter	Mean ± SD
Moisture (%)	66.33 ± 0.58
Crude fat (%)	0.12 ± 0.01
Crude protein (%)	2.14 ± 0.01
Ash (%)	0.15 ± 0.01
pH	6.58 ± 0.01

Table 2 Results for the proximate analysis, pH and acidity of all mozzarella cheese treatments

Parameters	T_o	T_1	T_2	T_3	T_4	Means
Moisture (%)	50.60 ± 1.15^{A*}	51.50 ± 0.50^{A}	52.20 ± 0.3^{A}	53.27 ± 0.16^{A}	53.17 ± 0.15^{A}	52.14 ± 0.40
Crude fat (%)	27.46 ± 0.61^{B}	13.13 ± 0.35^{B}	13.40 ± 0.6^{B}	13.22 ± 0.46^{B}	13.27 ± 0.32^{B}	16.09 ± 0.46
Crude protein (%)	21.86 ± 0.32^{C}	29.60 ± 0.29^{C}	26.52 ± 0.28^{C}	27.47 ± 0.40^{C}	27.46 ± 0.41^{C}	26.58 ± 0.34
Ash (%)	2.25 ± 0.01^{D}	2.85 ± 0.05^{D}	3.25 ± 0.05^{D}	3.53 ± 0.25^{D}	3.47 ± 0.10^{D}	3.07 ± 0.38
pH	5.44 ± 0.05^{D}	6.60 ± 0.01^{D}	5.34 ± 0.05^{D}	5.34 ± 0.03^{D}	5.32 ± 0.02^{D}	5.61 ± 0.03
Acidity	0.93 ± 0.01^{D}	0.89 ± 0.01^{D}	0.89 ± 0.01^{D}	0.91 ± 0.01^{D}	0.91 ± 0.01^{D}	0.91 ± 0.02

*The same letters show a non-significant difference at 95% probability level.

cheese treatments (T_1, T_2, T_3 and T_4) are presented in Table 2. The minimum moisture content (50.6%) was obtained in mozzarella cheese with 3.5% fat (T_0). The highest fat (%) of about 27.46% was obtained in mozzarella cheese with 3.5% fat (T_0), and the lowest fat (13.22%) in LF mozzarella cheese with 0.5% mucilage (T_2).

It was noticeable that the addition of fat replacer (okra mucilage) also had a significant ($P = 0.02$) effect on the pH values of the cheese samples. The current study reported the pH values for all the cheese treatments within the range 5.32–5.44. The possible reason for the change in the pH could be due to the decrease in fat levels and varying concentrations of mucilage content in different LF cheese treatments. The results of the present study showed that all LF mozzarella cheese treatments have 0.87% to 0.93% acidic contents. The T_0 has 0.93%, whereas T_4 has 0.91% acidity as compared to T_1, T_2 and T_3. According to paired t-test of T_2 and T_3, there was a non-significant ($P = 0.37$) difference observed between T_2 and T_3. The obtained results demonstrated that the lowering of the fat content in mozzarella cheese samples did not significantly impact the acidic contents.

The difference found in the moisture (%) of all the mozzarella cheese treatments was highly significant ($P = 0.01$). The moisture (%) results of the present study showed that mozzarella cheese samples contained moisture content in the range of 50.67 to 53.17%. However, compared to other treatments (T_1, T_2, T_3), T_0 has 50.67%, whereas T_4 reported 53.17% moisture, which might be due to a decrease in fat contents and the addition of the highest mucilage concentration (1%) that tends to increase the moisture level of cheese samples.

According to paired *t*-test of T_2 and T_3, there was a significant ($P = 0.05$) difference between moisture (%) of T_2 and T_3. The moisture content of cheese increased by decreasing the protein-to-fat ratio. In T_2, moisture content decreased because okra mucilage bound extra water and interfered with the shrunk protein matrix as it reduced the force required to expel water from the curd. The moisture content again increased in T_4 cheese due to the increased concentration of hydrocolloids because hydrocolloids proposed a water retention attribute (Fig. 2).

The difference between fat content (%) of all the treatments was highly significant ($P = 0.00$). The current study reported that all the mozzarella cheese treatments have fat content in the range 12–25.4%. The highest fat content (%) was recorded for T_0 as 25.47%, whereas T_4 had 12% as compared to others (T_1, T_2 and T_3). The use of okra mucilage increased the fat content of cheese at T_2 as compared to T_3, and T_4 because okra mucilage has the gelling ability and fat retained in curd despite it getting removed in whey. In T_3 and T_4, fat content decreased due to the increasing concentration of okra mucilage.

The difference found in the protein content of all the mozzarella cheese treatments was also highly significant ($P = 0.00$). The current study showed that cheese samples have protein content (%) ranging from 21.8 to 27.5%. The lower protein was recorded for T_0 (21.87%), whereas T_4 has (27.5%) higher protein content. According to paired *t*-test of T_2 and T_3, there was a significant ($P < 0.05$) difference observed between T_2 and T_3. Protein acted as a dominant factor in LF mozzarella cheese treatments. Bhat *et al.* (2022) studied the impact of different milk sources on mozzarella cheese and reported that mozzarella cheese from buffalo milk contained more protein content (%) as compared to mozzarella cheese made from cow milk. The difference between all the mozzarella cheese treatments was non-significant ($P = 0.25$) among all treatments. The current study showed that cheese samples have 3.23% (T_o) to 3.4% (T_4). The obtained results demonstrated that ash content did not significantly increase or decrease due to a reduction in fat content. As ash contents represented the overall mineral contents in the final products and it mainly depends upon the bringing strength used in the preparation of cheese. In the current treatment plan, the same concentration of salt was used at 1% (NaCl); therefore, it showed non-significant results.

Functional characteristics of LF mozzarella cheese samples with okra mucilage

The meltability of the mozzarella cheese was directly linked with the fat content present in milk samples. The increase in the fat content of the mozzarella improves its meltability and softness. The LF milk tends to produce low-quality mozzarella cheese with poor colour and rubbery texture (Ah & Tagalpallewar, 2017). The addition of fat replacer (okra mucilage) directly impacted the meltability of LF mozzarella cheese samples in the current study. The difference between all the treatments was highly significant ($P = 0.00$). The present study recorded the meltability in the range 42–55 mm for all the mozzarella cheese treatments. The T_0 has 55 mm meltability, whereas T_4 has 49.10 mm. The meltability of LF mozzarella cheese improved with the increase in the concentration of fat replacers.

The stretchability of the mozzarella cheese is dealt with by the formation of elongated, non-breakable, fibrous strands at high temperatures (hot conditions). The stretching quality of cheese plays a significant role in the determination of the end-use of mozzarella cheese in different food products. As per the United States Department of Agriculture (USDA), the mozzarella cheese when topped on pizza and baked at 425 °F for 12 min in a conventional oven should be able to extend or stretch to a minimum range of 3 inches without breaking. For this study, the stretchability results in all prepared mozzarella cheese samples stored on the 3rd day were obtained in hot conditions (Fig. 1). The difference between treatments was highly significant ($P = 0.00$). The mozzarella cheese samples showed stretchability in the range 33.83–38.57 mm. The T_0 has 38.57 mm, whereas T_4 has 33.83 mm stretchability. According to paired *t*-test of T_1 and T_4, there was a significant ($P = 0.04$) difference observed between T_1 and T_4. The T_1 indicated a higher stretchability as compared to T_2, and T_3. The possible reason is that T_1 has more fat natural as compared to T_2 and T_3. Stretchability increased in T_4 as compared to T_2 and T_4 due to increased concentration of okra mucilage. The results for the stretchability of the cheese samples are presented in Table 3a and the pictorial representation of the stretchability test is presented in Fig. 1.

Texture profile analysis of the LF mozzarella cheese with okra mucilage

The textural analysis of LF mozzarella cheese samples with okra mucilage is presented in Table S2. The hardness (N) of the LF mozzarella cheese samples was measured on different days (0, 3, 5, 7 and 9) during its ripening at 4°C. The shear and puncture forces are used to measure the hardness which was found to be increased with the increase in the storage days. For all LF mozzarella cheese treatments, the hardness was found to be changed regularly during storage. During the textural analysis, the results showed that hardness was significantly higher ($P = 0.043$) in T_1 on the 9th day of storage as compared to T_0. The mozzarella cheese prepared with skim milk showed significantly higher hardness as compared to the cheese prepared with sodium alginate as a fat replacer (Chatli *et al.*, 2017).

Effect of okra mucilage on sensorial properties of LF mozzarella cheese treatments

The mozzarella cheese samples were presented in front of the trained panel for sensorial evaluation using the 9-point hedonic scale. Based on appearance, among all the treatments T_0 get the highest score while T_4 was the least liked by the panel. This showed that fat content imparts the desirable physical appeal of the mozzarella cheese; therefore, with lowering the fat content, the appearance of the cheese samples was impaired. The cheese sample scores ranged between 4.6 and 8.4 points, and T_2 and T_3 were more acceptable as compared to T_4 on the scale of colour, appearance, texture, flavour and stringiness. An organoleptic score of colour for LF cheese samples ranged from 5 to 7.6 as compared to T_0. Okra mucilage was able to repay the similar sensory attributes of actual cheese, especially in T_2 and T_3. Cheese colour is reported to be influenced by several factors including the type of milk, fat content, cheese packaging and its storage conditions (Bekele *et al.*, 2018). In cheese, the scattering of light was due to fat and casein micelles as these contribute to milk colour. The colour variation in LF cheese samples was due to light scattering as T_2 has the best colour profile because light scattering increased due to increased okra polysaccharides concentration.

The difference in the texture of all treatments was observed and the obtained results showed that T_o has the highest scoring in appearance while T_4 was the least liked by the panel. The T_0 has the highest score of 8.8 as compared to T_1, T_2, T_3 and T_4 in appearance. The current study indicates that the hardness of LF mozzarella cheese decreased with an increase in okra mucilage concentrations (Table S2). Like other hydrocolloids, okra mucilage as a fat replacer trapped the extra water as they provided lubricity and softness in LF products. The difference in flavour among T_0, T_1, T_2, T_3 and T_4 was observed and the obtained results showed that T_0 has the highest scoring in the flavour profile while T_4 was the least liked by the panel. The scores were ranging from 5.2 to 7.4 as T_0 has the highest score of 8 as compared to others. T_2

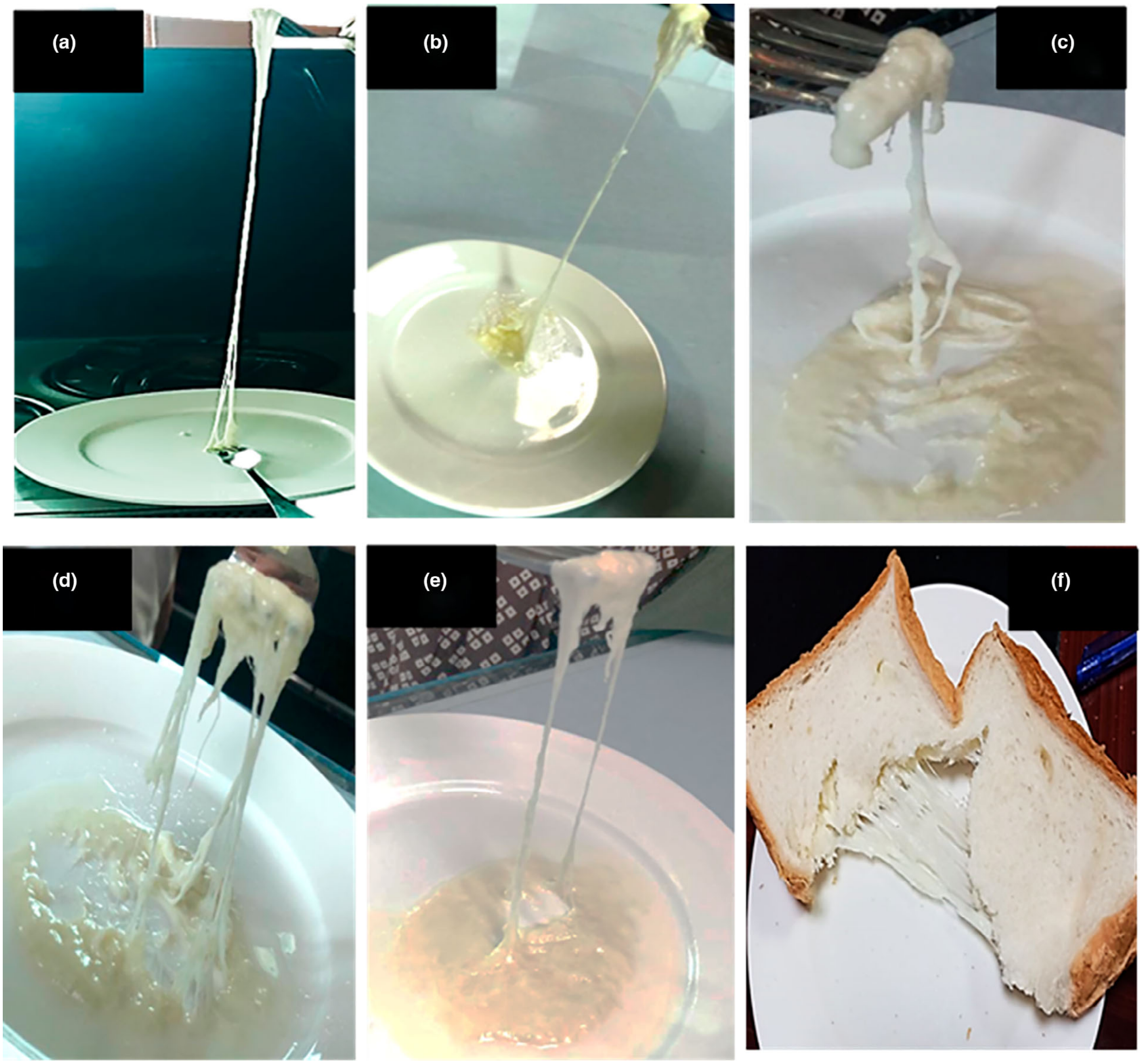

Figure 1 The effect of okra mucilage on stretchability of LF mozzarella cheese samples. (a) Stretchability, T_0; (b) Stretchability, T_1; (c) Stretchability, T_2; (d) stretchability, T_3; (e) Stretchability, T_4; and (f) meltability, T_4.

has the best score among LF mozzarella cheese samples due to the thickening ability of okra mucilage as it bound flavours and contribute to viscosity in T_2. The current study showed that the taste profile of LF mozzarella cheese was affected due to a reduction in the fat level and the addition of a high concentration of okra mucilage (T_4). Sattar *et al.* (2015) also reported that xanthan and guar gum did not provide the same flavour profile in LF mozzarella cheese that cheese claims. The results are also in agreement with those reported by Tammam *et al.* (2019) that okra mucilage in concentration (0.01%) produced the same organoleptic properties in yogurt made from skimmed cow milk.

The results for the difference in stringiness showed that T_0 has the highest scoring in stringiness while T_4 was the least liked by the panel. The scores ranged from 5.6 to 7.8 and T_2 has the highest score as compared to T_1, T_3 and T_4. The stringiness of mozzarella cheese decreased due to a decrease in fat level. The effect of okra mucilage on organoleptic analysis of mozzarella cheese is presented in Fig. 2.

Table 3 The Functional attributes and yields of LF mozzarella cheese. (a) Functional properties and (b) theoretical and actual yield (%)

(a)

Parameter	Mean ± SD	t-value
Meltability (mm)	2.63 ± 0.30	0.004
Stretchability (mm)	3.13 ± 0.25	0.002

(b)

Parameter	Mean ± SD	t-test
Theoretical yield	9.27 ± 2.398	0.22
Actual yield	7.29 ± 1.559	0.025
Recovery data	1.98 ± 1.156	0.422

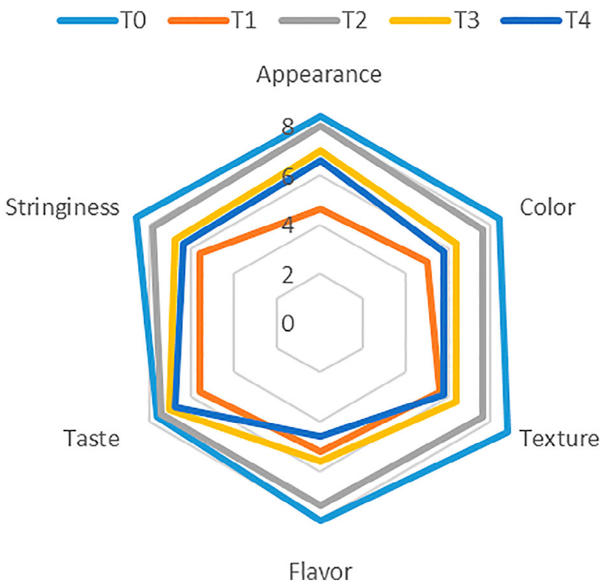

Figure 2 The organoleptic evaluation of LF mozzarella cheese prepared by using okra mucilage as a potential fat replacer.

Yield (%) analysis of LF mozzarella cheese treatments

The (%) yield has great importance since it determined the number of recovered solids and profit estimation for the cheese manufacturing companies. The overall yield estimation is shown in Table 3b. The milk fat level was reduced from 3.5% to 1.5% as it exerted a significant impact on % of the yield. The study indicated that all mozzarella cheese samples yielded between 5.5 and 10%. The results showed that T_2, T_3 and T_4 yielded higher as compared to T_1. T_2 showed more yield in comparison to T_3 and T_4. Sattar *et al.* (2015) studied and reported that water-dispersible fat replacers (gums) tend to mimic the properties of fat in low-fat mozzarella cheese. These fat replacers have the ability to mechanically entrap water molecules that imparts lubricity and produce a soft textured cheese.

Conclusion

The varying concentrations of the okra mucilage (as fat replacer) were used to prepare the LF mozzarella cheese using buffalo milk. The results of this study showed that the addition of okra mucilage as a carbohydrate-based fat replacer was very effective in concentrations between 0.25 and 1.0%. The concentration of 1% (T_4) okra mucilage exerted a significant impact on the functional and textural attributes as compared to T_2 and T_3. The organoleptic analysis indicated that T_2 has a higher score as compared to T_3 and T_4. The study showed the best results at lower concentrations in organoleptic analysis and was able to produce approximately the same textual and functional at a concentration (1%) in comparison to the market-available LF mozzarella cheese. It can be concluded that organoleptic properties can be improved by adding certain flavours and colours (food conditioners) while adding (1%) okra mucilage as a fat replacer.

Author contributions

Aqsa Akhtar: Formal analysis (equal); investigation (equal); methodology (equal); visualization (equal); writing – original draft (equal). **Rabbia Khan:** Formal analysis (equal); methodology (equal); writing – original draft (equal). **Nauman Khalid:** Project administration (equal); supervision (equal); validation (equal); writing – review and editing (equal).

Ethical guidelines

Ethics approval was not required for this research.

Peer review

The peer review history for this article is available at https://publons.com/publon/10.1111/ijfs.15952.

Data availability statement

The research data will be available upon request from the corresponding author.

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Annotated References

Tammam, A. A., Mohran, M. A., Khodea, M. M. & Zayan, A. F. (2019). Influence of Adding Mucilage as a Fat Replacer on the Characteristics of Yoghurt. *Assiut J of Agricult Sci* 50(2): 26-37.

The reference was selected since it contain all information regarding mucilage importance as fat replacer in dairy based products.

Tahereh, J., Mahin, A. & Mojtaba, R. (2017). Determinative Effects of Fat Replacement and Homogenization on the Sensory and Rheological Properties of Low-Fat Mozzarella. *J of Food Process Preserv*, 41, e12753.

The reference was selected due to vital information regarding rheological assessment of low fat mozzeralla cheese, and moreover different processing conditions are well presented.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Glucose standard curve used for the determination of the total polysaccharide contents in the okra mucilage.

Table S1. Results of the absorbance readings of standard (glucose) and okra mucilage for total polysaccharide content.

Table S2. Comparison of the hardness (N) of LF mozzarella cheese samples treated with okra mucilage on different days of storage.