

## QUALITY OF LOW-FAT MOZZARELLA CHEESE WITH DIFFERENT FAT REPLACERS

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(Received: 10 February 2019; accepted: 4 April 2019)

The comparative efficacy of 0.4% carboxymethyl cellulose (CMC) and 0.3% sodium alginate (SA) was evaluated as fat replacer in low-fat (<0.5% milk fat) mozzarella pre-cheese on the basis of physico-chemical, processing, textural, and colour profile, nutritional and sensory attributes. High-fat mozzarella cheese (prepared from milk with 6.0% fat) was taken as control (FFMC), whereas low-fat mozzarella cheese (prepared from milk with <0.5% fat) without any fat replacer (LFMC) taken as negative control. The per cent yield was lower in low fat cheese with CMC (LFMC-CMC), whereas in low fat cheese with SA (LFMC-SA) it was comparable with FFMC. The moisture and protein contents were higher ( $P<0.05$ ) in low-fat mozzarella cheese (LFMC-CMC, LFMC-SA) than in FFMC. The energy content in LFMC-CMC and LFMC-SA was 44 percent lower than in FFMC. The meltability decreased, whereas melt time increased in LFMC-CMC and LFMC-SA compared to FFMC. The processing and nutritional attributes were comparable in both treatments. Hardness increased, whereas chewiness decreased in low-fat cheese. However, type of fat replacer did not affect hardness of the product. Gumminess was higher ( $P<0.05$ ) in LFMC-CMC than in LFMC-SA. The sensory panellists rated LFMC-SA better for flavour and overall acceptability than LFMC-CMC. The appearance, texture, and juiciness were comparable in low-fat and high-fat mozzarella cheese. Results indicated that 0.3 per cent SA can be successfully used for processing of low-fat cheese.

**Keywords:** carboxymethyl cellulose, full-fat cheese, low-fat cheese, mozzarella cheese, physico-chemical quality, sodium alginate

Mozzarella cheese is a fresh soft cheese of “Pasta Filata” family, originated from Italy, with a characteristic “chicken breast” fibrous structure with unique melting and stretching properties (SANDROU & ARVANITOYANNIS, 2000). Rheological, sensory, and nutritional qualities of the cheese are determined by milk fat. However, the increased awareness of people on fitness and healthy life style has resulted in an increased demand for low-calorie foods, i.e. low and reduced fat cheeses. A study conducted by Dairy Management Inc. and Taylor Nelson Sofres found that 16% of adults aged 20–54 are restricting cheese in their diet (‘cheese restrictors’), and 29% of ‘cheese restrictors’ would be willing to incorporate cheese into their diet, if low-fat cheese were available without compromising flavour and texture (RASHIDI et al., 2015). Low-fat cheese has bland taste, firm and rubbery texture, and dull colour (SİPAHIOĞLU et al., 1999) attributed to loss of plasticizing property of the fat and increased cross-linking of proteins.

Various techniques developed to improve the texture of low and reduced fat cheeses included process modifications, use of special starter cultures and fat replacers. Fat replacers are water-dispersible substances, which improve the sensory and functional properties of

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low-fat cheese by bulking effect associated with moisture retention as well as provide a sense of lubricity and creaminess (RUDAN et al., 1999). Basically two types of fat replacers have been recommended in cheese products, microparticulated protein or carbohydrate based ones (ROMEIH et al., 2002). The selection of fat replacer depends on the composition and characteristics of the food (SANDROU & ARVANITOYANNIS, 2000). By trapping moisture, the fat replacers provide creamy and lubricated feel to the cheese, but cannot positively impact the flavour defects in cheese (CHATLI et al., 2017). The functional and processing quality of low-fat cheese depends on the innate characteristics of the fat replacer, especially its morphology (i.e. microparticulation and particle size), intermolecular interactions, and dispersal within the protein matrix and serum of the curd particles (MCMAHON et al., 1996).

Carboxymethyl cellulose (CMC) is a carbohydrate based fat replacer, which acts as thickening agent, stabilizer, and suspending agent, and is used in a variety of dairy products due to its technological and nutritional advantages. Alginates are polysaccharides, binary copolymer of  $\alpha$ -L-guluronic and  $\beta$ -D-mannuronic acids, extracted through anion exchange from red or brown seaweed (*Phaeophyceae*) and giant kelp (*Macrocystis pyrifera*). It possesses a number of properties in food systems viz. gelling including gel rigidity, water holding capacity, springiness and appearance characteristics (RASHIDI et al., 2015), thickening and binding, viscosifying and stabilizing, and suspending agent properties. Moreover, it is also useful as a dietary fibre source for the prevention of obesity, hypercholesterolemia, and diabetes.

In our previous studies, the level of fat replacers as carboxymethyl cellulose and sodium alginate were optimized as 0.4% and 0.3%, respectively, for the development of low-fat mozzarella cheese (CHATLI et al., 2016, 2017). The present study was envisaged to compare the efficacy of selected levels of carboxymethyl cellulose and sodium alginate as fat replacers in mozzarella cheese on the basis of processing, nutritional, textural, and sensory quality attributes, so that the recommendations can be provided to the industry.

## 1. Materials and methods

### 1.1. Raw materials

Fresh buffalo milk was procured from University Dairy Farm (GADVASU, Ludhiana). Citric acid (5%) was used as acidulant and freeze dried microbial rennet from *Mucor miehei* Type II as coagulant (Danlac, Canada). Carboxymethyl cellulose (sodium salt high viscosity carboxymethyl, S D Fine-Chem Ltd., Mumbai, India; Code No. 56095) and sodium alginate (Algin Central Drug House Pvt Ltd., New Delhi, India; Code No. 030105) were used as fat replacers.

### 1.2. Preparation of mozzarella cheese

Mozzarella cheese was prepared by direct acidification method standardized in our laboratory with 5% citric acid as acidulant and microbial rennet for coagulation (CHATLI et al., 2017). Two lots of milk were prepared – full-fat milk (6.0% fat; 8.5% non-fat solids) and skim milk (<0.5% fat; 8.5% non-fat solids). Buffalo milk was separated to cream and skim milk with cream separator. Four treatments of mozzarella cheese were prepared as follows: full-fat mozzarella from milk with 6.0% fat (FFMC), low-fat mozzarella cheese from milk with <0.5% fat without fat replacer (LFMC), low-fat cheese with 0.4% carboxymethyl cellulose

(LFMC-CMC), and low-fat cheese with 0.3% sodium alginate (LFMC-SA). The fat replacers were added to the milk at 30 °C, were mixed properly, then 5% citric acid was added to decrease milk pH to  $5.40 \pm 0.02$ . Then, microbial rennet (1% sol,  $1.5 \text{ ml l}^{-1}$ ) was added and the milk lots were incubated for 45 min at 35 °C. The settled curd was cut into  $1 \text{ cm}^3$  parts that were heated to a temperature of 42 °C using hot water. The whey was drained and the curd was scalded at 80 °C with hot water, and was shaped manually. Finally, cheese was packed in low density polyethylene bags, and was subjected to analyses for physico-chemical, proximate, texture, colour, and sensory parameters.

### 1.3. Characterization of mozzarella cheese

**1.3.1. Processing parameters.** The percent average yield of buffalo mozzarella cheese was calculated as ratio of weight of cheese (g) to weight of milk (g).

**1.3.2. Proximate composition.** Proximate composition was determined by methods described by AOAC (2000): moisture/dry matter AOAC 926.08; fat AOAC 935.05, protein AOAC 991.23, and ash AOAC 935.05. Moisture was determined using hot air oven (Macro Scientific Works MAC 10A/UA, India), fat by ether extraction using Socs Plus (SCS-6-AS, Pelican Industries, India), and protein with automatic digestion and distillation unit (Kel Plus-KES 12L, Pelican Industries, India). For ash estimation, moisture free sample was heated at 550 °C in muffle furnace for about 7 h. Estimates of total calories in the cheese were calculated on the basis of 100 g portion using Atwater values for fat ( $9 \text{ kcal g}^{-1}$ ), protein ( $4 \text{ kcal g}^{-1}$ ), and carbohydrate ( $4 \text{ kcal g}^{-1}$ ). Therefore, the calorie values were estimates and not actual values.

**1.3.3. Physico-chemical analyses.** Melt time of cheese was recorded as the time for melting 100 g of cheese over hot water bath maintained at temperature of 82 °C (McMAHON & OBERG, 1998). The pH was measured using digital pH meter (SAB 5000, Labindia).

**1.3.4. Texture profile.** Texture profile analysis was done with texture analyzer (TMS-PRO, Food Technology Corporation, USA). Sample size of  $10 \times 10 \times 10 \text{ mm}$  was subjected to pretest and test speed ( $30 \text{ mm sec}^{-1}$ ) and post-test speed ( $100 \text{ mm sec}^{-1}$ ) to a double compression cycle with a load cell of 100 N. Parameters as hardness (N), adhesiveness (mJ), springiness (mm), stringiness (mm), cohesiveness (ratio), chewiness (J), gumminess (N), and resilience (ratio) were calculated with the preloaded software using force-time plot.

**1.3.5. Colour profile.** Colour profile analysis, CIE  $L^*$  (lightness),  $a^*$  (redness), and  $b^*$  (yellowness) values were measured at three random locations of each cheese sample using Lovibond Tintometer (Lovibond RT-300, Reflectance Tintometer, United Kingdom) set at 2° of cool white light ( $D_{65}$ ) and 2.54 cm diameter aperture (CHATLI et al., 2017).

**1.3.6. Sensory evaluation.** A seven-member experienced panel of judges consisting of faculty and postgraduate students of university evaluated the samples for different attributes as appearance/colour, texture, flavour, juiciness, and overall acceptability using an 8-point descriptive scale (CHATLI et al., 2017), where 8=extremely desirable and 1=extremely undesirable. Two sessions were conducted, and all panellists were briefed on the descriptive scale and product characteristics. The panellists carried out evaluation in a room free of noise and odours, suitably illuminated with natural light. The coded samples were tempered at

room temperature, then presented to the panellists. Drinking water was provided to the panellists for rinsing the mouth intermittently.

#### 1.4. Statistical analysis

Data was analysed statistically using SPSS-16.0 (SPSS Inc. Chicago IL, USA) software package. The experiment was repeated thrice, and duplicate samples ( $n=6$ ) were drawn for each parameter except colour and texture profile ( $n=9$ ), which were carried out in triplicate. Sensory evaluation was performed by a panel of seven judges ( $n=21$ ). Data are presented in the form of mean  $\pm$  standard deviation and were subjected to one-way analysis of variance (ANOVA) for the comparison of different treatments. Duncan's Multiple range test was employed and statistical significance was expressed at  $P<0.05$ .

## 2. Results and discussion

### 2.1. Proximate composition and physico-chemical parameters

The addition of fat replacers in mozzarella cheese significantly ( $P<0.05$ ) influenced the proximate and physico-chemical parameters (Table 1). The pH of cheese milk was 6.66, which did not change with the incorporation of fat replacers (CMC, SA). The pH of whey was significantly lower ( $P<0.05$ ) in LFMC-CMC than FFMC, LFMC, and LFMC-SA, whereas the pH of the curd was comparable in all the samples. The average yield was lower ( $P<0.05$ ) in LFMC than FFMC, attributed to lower total solid content. In case of LFMC, the sum of the casein and fat contents of the milk, which are the principal components for determining cheese yield, were lower (KATSIARI & VOUTSINAS, 1994; ROMEIH et al., 2002). However, among treated samples, LFMC-SA had higher per cent yield than LFMC-CMC, which can be attributed to the water binding and moisture retention properties of sodium alginate.

Proximate compositions are shown in Table 1; moisture was the highest ( $P<0.05$ ) in LFMC-SA (61.99%) followed by LFMC-CMC (60.61%), LFMC (56.20%), and then FFMC (49.37%). Protein and ash contents were higher ( $P<0.05$ ) in all treatments compared to FFMC. Similar findings were reported by KATSIARI and VOUTSINAS (1994) in Feta cheese. The higher moisture in fat replacer treated products indicated that curd syneresis was depressed during cheese making. Since water can bind directly to fat replacers, they interfere with the shrinkage of casein matrix by lowering the driving force involved in expelling water from the curd particles (McMAHON et al., 1996). KAVAS and co-workers (2004) and SAMEEN and co-workers (2008) observed higher protein levels in low-fat mozzarella cheese and white pickled cheese. Low-fat cheese (LFMC-CMC and LFMC-SA) showed significantly higher protein (32.26–33.36%) and ash contents (1.46–1.67%) than FFMC, thus promoting nutritive value. Similar results were reported by YASIN and SHALABY (2013) in low-fat cottage cheese cakes. The higher ( $P<0.05$ ) fat and energy values in FFMC are rather attributed to higher fat (6%) milk used for the preparation than treatments. The total calorie content was reduced by more than 44% in the treated cheese compared to FFMC.

Among physico-chemical attributes, pH of LFMC-CMC was lower ( $P<0.05$ ) than of other samples. KATSIARI and VOUTSINAS (1994) and SAMEEN and co-workers (2008) also observed no significant difference in the pH values of high and low-fat mozzarella cheese and Feta cheese. On reduction of fat content, the melt time increased ( $P<0.05$ ) in low-fat cheese

compared to control (FFMC). McMAHON and OBERG (1998) also observed higher melt time in low-fat cheese than full-fat cheese. Meltability followed as FFMC>LFMC-SA>LFMC>LFMC-CMC. SATTAR and co-workers (2015) reported increase in meltability of low-fat mozzarella cheese with the addition of fat mimetics. The difference in the meltability between LFMC-SA and LFMC-CMC is attributed to the innate characteristics of fat replacer, their interactions with casein, dispersal in milk protein matrix, moisture content leading to varied cheese microstructure and ultimately functionality.

Table 1. Effect of fat replacers on the processing, proximate composition and physico-chemical parameters of mozzarella cheese

Parameters	FFMC	LFMC	LFMC-CMC	LFMC-SA
Processing parameters (n=3)				
pH of milk	6.66±0.06 <sup>a</sup>	6.66±0.04 <sup>a</sup>	6.66±0.04 <sup>a</sup>	6.67±0.04 <sup>a</sup>
pH after addition of fat replacer	6.66±0.06 <sup>a</sup>	6.66±0.04 <sup>a</sup>	6.72±0.04 <sup>a</sup>	6.79±0.05 <sup>a</sup>
pH of whey	5.43±0.06 <sup>b</sup>	5.38±0.04 <sup>b</sup>	5.09±0.01 <sup>a</sup>	5.40±0.02 <sup>b</sup>
pH of curd	5.42±0.01 <sup>a</sup>	5.41±0.05 <sup>a</sup>	5.30±0.04 <sup>a</sup>	5.33±0.12 <sup>a</sup>
Average yield (%)	13.81±1.04 <sup>b</sup>	8.90±0.81 <sup>a</sup>	9.44±0.72 <sup>b</sup>	9.83±0.60 <sup>b</sup>
Proximate composition (n=6)				
Moisture (%)	49.37±0.50 <sup>a</sup>	56.20±0.36 <sup>b</sup>	60.61±0.47 <sup>b</sup>	61.99±0.10 <sup>c</sup>
Protein (%)	27.63±1.37 <sup>a</sup>	34.17±0.66 <sup>b</sup>	32.26±1.08 <sup>b</sup>	33.36±0.48 <sup>b</sup>
Fat (%)	14.54±1.28 <sup>b</sup>	0.35±0.12 <sup>a</sup>	0.29±0.06 <sup>a</sup>	0.22±0.08 <sup>a</sup>
Ash (%)	0.86±0.21 <sup>a</sup>	1.51±0.10 <sup>b</sup>	1.67±0.12 <sup>b</sup>	1.46±0.07 <sup>b</sup>
Energy value (kcal/100g)	249.39±15.35 <sup>b</sup>	145.12±6.81 <sup>a</sup>	144.05±2.24 <sup>a</sup>	139.01±4.47 <sup>a</sup>
Physico-chemical parameters (n=6)				
pH of cheese	5.60±0.01 <sup>b</sup>	5.60±0.01 <sup>b</sup>	5.51±0.01 <sup>a</sup>	5.59±0.01 <sup>b</sup>
Melt time of cheese (min)	4.38±0.24 <sup>a</sup>	7.5±0.34 <sup>c</sup>	6.00±0.41 <sup>b</sup>	5.38±0.29 <sup>b</sup>
Meltability (cm)	1.18±0.18 <sup>c</sup>	0.31±0.06 <sup>b</sup>	0.18±0.04 <sup>a</sup>	0.36±0.02 <sup>b</sup>

Full-fat mozzarella cheese, FFMC: Milk with 6.0% MF (milk fat) and 8.5% SNF (non-fat solids), low-fat mozzarella cheese, LFMC: <0.5% MF and 8.5% SNF (skim milk), LFMC-CMC: skim milk+0.4% CMC, LFMC-SA: skim milk+0.3% SA. Mean ± SD, with different superscripts in the row differ significantly (P<0.05)

## 2.2. Instrumental texture and colour profile

Texture profile (Table 2) depicted higher (P<0.05) hardness in LFMC, whereas comparable in LFMC-SA, LFMC-CMC, and FFMC. This corresponds to their respective fat %, because fat breaks up the protein matrix and plays the role of lubricant to provide smoothness and a softer texture (ROMEIH et al., 2002). LFMC was hardest due to its highest protein content, followed by LFMC-SA, LFMC-CMC, and FFMC. Similar findings were reported by KOCA and METIN (2004) in low-fat fresh Kashar cheese. Adhesiveness was significantly lower (P<0.05) in LFMC, whereas comparable amongst FFMC and cheese with CMC and SA. All parameters except gumminess remained comparable amongst all treatments. However, gumminess was significantly lower (P<0.05) in LFMC-SA than LFMC-CMC, FFMC, and LFMC. There was non-significant decrease in cohesiveness, chewiness, gumminess, and

resilience of treatments (LFMC-CMC, LFMC-SA) compared to FFMC. KOCA and METIN (2004) observed decrease in gumminess and chewiness of low-fat fresh Kashar cheese, whereas RASHIDI and co-workers (2015) in low-fat UF Feta cheese with fat replacers.

Table 2. Effect of fat replacers on the texture and colour profile parameters of mozzarella cheese

Parameters	FFMC	LFMC	LFMC-CMC	LFMC-SA
Texture profile				
Hardness (N)	8.81±0.85 <sup>a</sup>	16.70±1.08 <sup>b</sup>	9.39±0.48 <sup>a</sup>	9.63±0.54 <sup>a</sup>
Adhesiveness (mJ)	0.22±0.03 <sup>b</sup>	0.15±0.01 <sup>a</sup>	0.23±0.02 <sup>b</sup>	0.28±0.03 <sup>b</sup>
Springiness (mm)	6.04±0.04 <sup>a</sup>	6.90±0.10 <sup>a</sup>	6.41±0.09 <sup>a</sup>	6.10±0.07 <sup>a</sup>
Stringiness (mm)	24.06±1.52 <sup>a</sup>	25.21±2.11 <sup>a</sup>	27.12±1.24 <sup>a</sup>	30.33±2.96 <sup>a</sup>
Cohesiveness (ratio)	0.78±0.02 <sup>a</sup>	0.79±0.01 <sup>a</sup>	0.77±0.03 <sup>a</sup>	0.73±0.03 <sup>a</sup>
Chewiness (J)	232.55±36.15 <sup>a</sup>	248.06±19.51 <sup>a</sup>	185.43±14.17 <sup>a</sup>	210.55±16.46 <sup>a</sup>
Gumminess (N)	8.41±1.31 <sup>b</sup>	13.30±0.83 <sup>c</sup>	7.95±0.52 <sup>b</sup>	6.85±0.59 <sup>a</sup>
Resilience (ratio)	7.9±0.02 <sup>a</sup>	7.5±0.01 <sup>a</sup>	7.8±0.02 <sup>a</sup>	7.5±0.02 <sup>a</sup>
Colour profile				
Lightness $L^*$	79.05±1.84 <sup>b</sup>	75.81±1.22 <sup>a</sup>	82.34±1.61 <sup>b</sup>	78.77±1.43 <sup>b</sup>
Redness $a(-)^*$	1.74±0.12 <sup>a</sup>	3.50±0.20 <sup>c</sup>	2.83±0.16 <sup>b</sup>	2.99±0.19 <sup>b</sup>
Yellowness $b^*$	19.74±0.49 <sup>c</sup>	16.60±0.31 <sup>b</sup>	11.33±0.14 <sup>a</sup>	14.16±0.83 <sup>b</sup>

n=9, Full-fat mozzarella cheese, FFMC: milk with 6.0% MF (milk fat) and 8.5% SNF (non-fat solids), Low-fat mozzarella cheese, LFMC: <0.5% MF and 8.5% SNF (skim milk), LFMC-CMC: skim milk+0.4% CMC, LFMC-SA: skim milk+0.3% SA. Mean ± SD, with different superscripts in the row differ significantly (P<0.05)

Instrumental colour profile (Table 2) revealed lower  $L^*$  value for LFMC, whereas comparable for FFMC, LFMC-CMC, and LFMC-SA. Redness ( $a^*$ ) value was higher (P<0.05) in FFMC than treated samples. However, yellowness ( $b^*$ ) decreased with the decrease in fat content and was highest in FFMC and lowest in LFMC-CMC. Similar findings were observed by KAHYAOGU and co-workers (2005) in Gaziantep cheese.

### 2.3. Sensory evaluation

Figure 1 revealed that all sensory attributes (appearance and colour, flavour, texture, juiciness, and overall acceptability) remained significantly higher (P<0.05) in FFMC than in all LFMC variants, irrespective of with or without, type, and quantity of fat replacer. These results are confirmed by the findings of instrumental colour profile. SAMEEN and co-workers (2008) also documented poor, rough, and lusterless appearance of low-fat cheese. Similar observations were reported by RUDAN and co-workers (1999) for mozzarella and KOCA and METIN (2004) for fresh Kashar cheeses. Overall, it was observed that reduction in fat content adversely affected all sensory attributes, especially flavour, and fat reduction lead to flavour dilution attributed to excessive moisture retention (SIPAHIOGLU et al., 1999). However, sensory attributes were better maintained in cheese with fat replacers, and were significantly higher (P<0.05) in LFMC-SA than LFMC-CMC. Texture and juiciness were also non-significantly

higher for LFMC-SA than LFMC-CMC. Hence, sodium alginate treated cheese (LFMC-SA) was graded as best among all low-fat cheeses and recommended for industrial use.

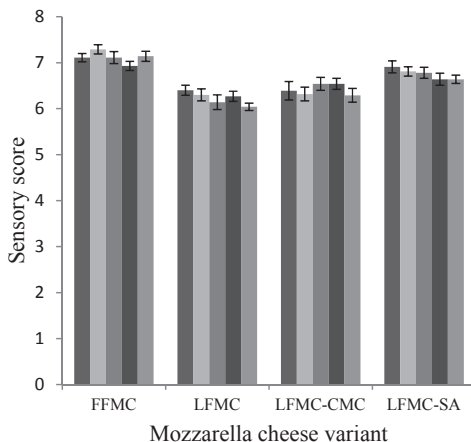


Fig. 1. Effect of fat replacers on the sensory attributes of mozzarella cheese n=21, Full-fat mozzarella cheese, FFMC: Milk with 6.0% MF (milk fat) and 8.5% SNF (non-fat solids), low-fat mozzarella cheese, LFMC: <0.5% MF and 8.5% SNF (skim milk), LFMC-CMC: skim milk+0.4% CMC, LFMC-SA: skim milk+0.3% SA  
 ■: Appearance + colour; ■: flavour; ■: texture; ■: juiciness; ■: overall acceptability

### 3. Conclusions

Results concluded that low-fat fresh buffalo mozzarella cheese from buffalo milk can be successfully developed with the incorporation of 0.3% sodium alginate as fat replacer with comparable and acceptable physico-chemical, textural, colour, and sensory attributes, and almost 44% lower calories than full fat mozzarella cheese.

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