Influence of Modified Atmosphere Packaging (MAP) on textural properties of Mozzarella cheese during refrigeration storage

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ABSTRACT

The study was conducted to assess the textural quality of mozzarella cheese using MAP. 300 g of mozzarella cheese was placed in high barrier bags under five different atmospheres viz., air (atm 1), vacuum (atm 2), 100 % CO₂ (atm 3), 100 % N₂ (atm 4) and a mixture of 50% N₂ and 50% CO₂ (atm 5). Periodically, the product was evaluated for its textural quality with respect to its hardness, cohesiveness, gumminess, chewiness and springiness. Among the different modified atmospheres studied, atm 3 showed minimum changes on the textural quality in MAP Mozzarella cheese during storage, thus proving to be the best, followed by the samples packed in atm 5, atm 4, atm 2 and atm 1 respectively, in descending order. The five types of atmospheres and the intervals of storage period, each individually, influenced the textural quality of Mozzarella cheese.

Key words: MAP, Mozzarella cheese, Refrigeration storage, Shelf-life, Textural properties.

INTRODUCTION

Modified Atmosphere Packaging (MAP) is an enclosure of food products in high barrier materials, in which gaseous environment has been modified as a result of dynamic interaction between the atmosphere and the product (Church and Parson 1995; Khoshgozaran et al. 2012). In recent years, consumers’ demands for fresh, naturally preserved food products have grown dramatically. MAP has proved to be the most innovative and novel growth area in food packaging (Alam and Goyal 2008). The study was conducted for enhancement of shelf life of Mozzarella cheese by using MAP. Mozzarella cheese is an active ingredient in pasta, stretched curd, cheeses, pizzas etc. The technology of packaging products in modified atmosphere is the most advanced food preservation technique having many advantages. MAP is a process by which the quality and shelf life of food products is significantly increased (Kindstedt 2004; Alam and Goyal 2006a; Shrivastava and Goyal 2009). It is used to extend the product’s shelf life and to maintain the product’s initial quality for much longer period. An effective tool used to reduce postharvest quality losses in highly perishable commodities and retain the nutritional compounds in food is MAP (Li et al. 2014). It helps in increasing the wide range of distribution, retains the aesthetic appeal of the product and retards the growth of moulds and bacteria (Alam and Goyal 2011). At present, the shelf life of mozzarella cheese, being an essential ingredient of pizza, is approximately 14-15 days (Alam and Goyal 2006a; 2007) during refrigeration storage, since the atmospheric air affects the quality and textural properties of Mozzarella cheese (Alam and Goyal 2006; 2007a) Cheese spoilage due to fungal contaminant causes serious financial losses to the food industry and to consumers. Since most contamination occur due to surface contamination, it is very important to enhance the safety and quality of mozzarella cheese. A recent study also suggested that stuffed and sliced mozzarella cheese samples stored with MAP at 4 °C had better sensory score as compared to any other packaging technique (Akarcı et al., 2015). No information is available on the influence of MAP on its textural properties during refrigeration. Therefore, the studies were undertaken to investigate and evaluate the influence of MAP on textural characteristics of mozzarella cheese under refrigerated conditions. The attributes assessed for this textural analysis of mozzarella cheese are hardness, cohesiveness, springiness, gumminess and chewiness.

MATERIALS AND METHODS

The study was carried out at National Dairy Research Institute, Karnal, India. Both, qualitative as well as quantitative methodology had been adopted for the evaluation. A similar study on ready to eat pizza had been conducted by Singh et al. (2011) using cheddar cheese to assess its textural properties and to prolong its shelf life.

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Preparation of mozzarella cheese: For preparing mozzarella cheese (Fig.1), an admixture of buffalo and cow milk was procured at the receiving platform of the Experimental Dairy, National Dairy Research Institute, Karnal. The cow milk was obtained from the herd of crossbred Indian cows, while buffalo milk was from Murrah herd. In the present study, the method standardised by Kanawjia (1996) with slight modifications, for the preparation of mozzarella cheese samples was followed. For production of mozzarella cheese from mixed milk, the milks were first filtered/clarified, standardized (buffalo: cow: 60:40) and the fat content was adjusted to 3 %. Then, this standardized milk was pasteurized by LTLT (low temperature and long time: 62 °C for 30 min) method and cooled to 5-6 °C. The chilled milk was then acidified to 5.5-5.6 pH with 25 % HCl @ 3.25 ml conc. HCl/1 milk. The HCl used in the trials was obtained from M/s SD Fine Chem Ltd. Mumbai-400 025. Further, the temperature of the acidified milk was raised to 27 °C. Next, diluted microbial rennet, i.e. Meito (1: 40 in distilled water) was added @ 0.75-0.80 g /100 l milk. The renneted milk was left undisturbed for 15 min for setting of curd. Microbial rennet produced by Mucor pusillus var. lindt was obtained in the form of powder from M/s Meito Sangyo Co. Ltd., Tokyo, Japan. The properly set curd was cut with sterilized cheese knives, and then allowed to stand in whey for 5 minutes. The temperature of curd was raised @ 1 °C /5 min till the temperature reached 38 °C and was maintained for 30 min with continuous stirring in order to achieve uniform cooking and to avoid lump formation. Then, the whey was drained to allow aggregation of curd particles. For proper stretching and elasticity, mozzarella cheese was stretched in hot water (82-85 °C) for 10 min. Finally, it was moulded into a ball shape, each ball weighing approximately 300 g. These mozzarella cheese balls were then immersed in pasteurised chilled (8-10 °C) brine solution (20% w/v) for 4 hours. The commercial grade fine grain salt (Tata salt) was procured from local market. After brining, the surface drying of mozzarella cheese was done in a cold storage maintained at 5-6 °C for 6 hours.

Packaging materials used: For packaging and storage of mozzarella cheese, high barrier bags namely Cryovac (70 m) and LLD/BA*/Nylon-6/BA*/LDPE (110 m) (*poly binding agent) were used. The water vapour transmission

Fig 1: Flow diagram for the manufacture of mozzarella cheese using direct acidification method.
rate (WVTR) and oxygen transmission rate (OTR) of the Cryovac were 0.5-0.6 g/sq in/24h and 3-6 ml/sqm/24 h, respectively. The WVTR and OTR of the LLD/BA*/Nylon-6/BA*/LDPE were 3.96 g/sqm/24 hrs and 36 ml/sqm/24 h, respectively. The dimensions of the packages used in the study were 19.0 X 22.5 cm (L X B) for conventional (atmosphere) packaging, 16.5 X 18.0 (L X B) cm for vacuum packaging, and 22.5 X 32.5 cm (L X B) for MAP. The packages were acquired from reputed industries of the country. Packaging under modified atmospheres was accomplished using method given by Day (1992) and followed by Shrivastava et al. (2013) by using a vacuum chamber Quick 2000 machine (a ALFA– LAVAL, KRAMER GREBE, GmbH & Co. KG Maschinenfabrik, 3560 Biedenkopf-Wallau, Germany), with gas injection after establishing a vacuum of 25 inches Hg (ca.85 Pa). The injection conditions of the gases were optimised in order to obtain gas headspace. Packaging under atmosphere (air) was done by using vertical heat-sealing machine model QS-300 FE, procured from M/s Sevana Traders Pvt Limited, Kizhakkambalam, Kerala. The empty packages were sterilized under UV-light for 30 min immediately before packaging of the cheese samples. The freshly prepared mozzarella cheese balls (300 g each) were individually packaged in sterilized packages under different atmospheres (atm), i.e. air (atm 1), vacuum (atm 2), 100% CO₂ (atm 3), 100% N₂ (atm 4) and 50% CO₂ / 50% N₂ (atm 5) by using packaging machines (Quick 2000). Initially the gas headspace to cheese weight ratio was approximately 2 litres of gas/kg of the product (Alam and Goyal 2011). The packaged samples were then stored at 7±1 °C. Industrial grade gases were acquired from a reputed supplier. Before analyses, mozzarella cheese samples were removed from storage and thawed. Fig. 2 shows the flow sheet for MAP of mozzarella cheese.

Textural profile analysis (TPA): The stored test samples were reheated in an oven for about 2 min at 100% power level. Single samples were placed in the central position on the turntable, in order to minimize variability during reheating. This reheating time (2 min) was based on the amount of time necessary for the product to gain an adequately reheated appearance. The samples were removed from the oven and allowed to stand at room temperature for 25 min. The textural analysis tests were then performed using TAXT2i (Stable micro system, Godalming, Surrey, UK) textural analyser fitted with a 25 kg load cell. The cubes of mozzarella cheese samples 2 x 2 x 2 cm³ were subjected to mono-axial compression of 80% success on the textural analyser. Using Texture Expert Exceed Software that was supplied along with the instrument, the graphs obtained were analysed for hardness, springiness, cohesiveness, gumminess and chewiness (Table 1).

Statistical analysis: Experiments were replicated twice on different occasions with different mozzarella cheese samples. Different packages were sampled on predetermined time intervals. Each replicate was again run in triplicates (n= 2 X 3). Experimental data were subjected to analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Textural analysis: Instrumental textural evaluation of mozzarella cheese samples show that the hardness (N) averaged 138.89, cohesiveness averaged 0.38, springiness (mm) averaged 0.50, gumminess (N) averaged 50.34 and chewiness (N X mm) averaged 25.17.

Changes in textural properties

Hardness: The changes in hardness of mozzarella cheese samples packaged in two different materials under modified atmospheres, and stored at 7±1 °C are depicted in Fig. 3. The analysis of variance (ANOVA) of the data is given in Table 1.

The hardness of mozzarella cheese exhibited a decreasing trend throughout the entire period of storage in both the packaging materials, and at all the atmospheres for 7±1°C (Fig 3). The initial hardness value of 138.89 (N) decreased (atm 1) to 100.63 and 94.11 respectively, in P₁ and P₂ after 6 weeks of storage. Fig. 3 also indicates that at the end of storage period of 12 weeks, the hardness was minimum for the samples packed under atm 3 (100% CO₂) (P₁: 98.15; P₂: 91.08) followed by atm 5 (50% CO₂ / 50% N₂) (P₁: 94.88; P₂: 87.71), atm 4 (100% N₂) (P₁: 93.00; P₂: 89.17) and atm 2 (100% CO₂) (P₁: 91.78; P₂: 87.31).

Table 1: Analysis of variance for textural properties of MAP mozzarella cheese stored in different packages at 7±1 °C.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>Hardness (N)</th>
<th>Cohesiveness (A2/A1)</th>
<th>Springiness (mm)</th>
<th>Gumminess (N)</th>
<th>Chewiness (N X mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among intervals of storage</td>
<td>6</td>
<td>20658.288b</td>
<td>0.226b</td>
<td>0.365b</td>
<td>4402.364b</td>
<td>1947.609b</td>
</tr>
<tr>
<td>Among atmospheres</td>
<td>4</td>
<td>3916.217b</td>
<td>0.022b</td>
<td>0.034b</td>
<td>429.745b</td>
<td>94.717b</td>
</tr>
<tr>
<td>Between packages</td>
<td>1</td>
<td>285.162</td>
<td>0.003c</td>
<td>0.006c</td>
<td>39.868</td>
<td>41.274</td>
</tr>
<tr>
<td>InteractionIntervals x atmospheres</td>
<td>24</td>
<td>488.184</td>
<td>0.002</td>
<td>0.003</td>
<td>24.931</td>
<td>3.533</td>
</tr>
<tr>
<td>InteractionIntervals x packages</td>
<td>6</td>
<td>11.351</td>
<td>0.002</td>
<td>0.001</td>
<td>2.489</td>
<td>1.585</td>
</tr>
<tr>
<td>InteractionAtmospheres x packages</td>
<td>4</td>
<td>6096.301b</td>
<td>0.033b</td>
<td>0.053b</td>
<td>677.262b</td>
<td>142.268b</td>
</tr>
<tr>
<td>InteractionIntervals x atmospheres x Packages</td>
<td>24</td>
<td>778.111b</td>
<td>0.003</td>
<td>0.005</td>
<td>38.877</td>
<td>5.763</td>
</tr>
<tr>
<td>Error</td>
<td>140</td>
<td>565.345</td>
<td>0.003</td>
<td>0.005</td>
<td>48.582</td>
<td>13.201</td>
</tr>
</tbody>
</table>

a Degree of freedom
b Significant at 1 % level of probability
c Significant at 5 % level of probability

The analysis of variance (ANOVA) of the data is given in Table 1.
Filling of balls in Cryovac & LLD / BA / Nylon-6 / BA / LDPE
Evacuation
Flushing with N₂ / CO₂ / mixture using Quick 2000
Sealing
Storage
Refrigeration (7±1°C)

Fig 2: Flow diagram for Modified Atmosphere Packaging (MAP) of mozzarella cheese.

P₁; 84.95) and atm 2 (vacuum) (P₁; 78.00; P₂; 71.24) respectively.

These results pertaining to proteolysis of samples during refrigeration storage (7±1 °C) also showed that the soluble N₂ content was lowest in case of product that was packed under atm 3 followed by atm 5, atm 4, atm 2 and atm 1, respectively. The results coincide with the observation of Federick and Dulley (1984) and Fathollahi et al. (2010) that lesser degree of proteolysis significantly contributes to the higher degree of hardness in cheese samples. The results in general, are in accordance with the findings of Olson and Johnson (1990), Ghosh (1996) and Lawrence et al. (1987), who inferred that values for hardness decreased significantly with time. However, the results are contradictory with the observations of Tunick et al. (1991) who compared mozzarella cheese of various ages and found that reduced moisture levels in mozzarella cheese resulted in higher values for hardness.

ANOVA of the data on hardness (Table 1) reveals that intervals of storage, types of atmospheres and interaction between atmospheres x packages contributed significantly (P<0.01) towards the changes in hardness during storage, whereas interaction intervals x atmospheres x packages was significant (P<0.01) for 7±1 °C storage only. However, effect of types of package, and interaction intervals x packages were not significant for the storage condition.

Cohesiveness: Cohesiveness may be defined as molecular attraction by which the particles of a body are bonded throughout the mass. The changes in cohesiveness (A₂/A₁) of mozzarella cheese samples packaged in two different materials under modified atmospheres, and stored at 7±1 °C are presented in Fig. 4.

The cohesiveness of mozzarella cheese showed a decreasing trend throughout the entire period of storage in both the packaging materials, and for all the atmospheres at 7±1°C (Fig. 4). The initial cohesiveness value of 0.38 (atm 1) decreased to 0.19 and 0.15 respectively, in P₁ and P₂ after 6 weeks of storage. The minimum decrease in cohesiveness was observed for the samples packed under atm 3 (100% CO₂) (P₁; 0.21; P₂; 0.19) followed by atm 5 (50% CO₂ / 50% N₂) (P₁; 0.20; P₂; 0.18), atm 4 (100% N₂) (P₁; 0.18; P₂ 0.17) and atm 2 (vacuum) (P₁; 0.18; P₂; 0.14) respectively after 12 weeks of storage. Our results pertaining to proteolysis of samples during storage also showed that the soluble N₂ content was lowest in case of product packed under atm 3 > atm 4 > atm 2 > atm 1, resulting in increased cohesiveness in respective order (Bhaskaracharya and Shah 2000).

Fig 3: Effect of MAP on hardness of mozzarella cheese stored in different packages at 7±1 °C. Each point is the mean±SE (0.1 - 0.6) of two replicate experiments.
Fig 4. Effect of MAP on cohesiveness of mozzarella cheese stored in different packages at 7±1 °C. Each point is the mean±SE (0.1 – 0.6) of two replicate experiments.

ANOVA of the data on cohesiveness (Table 1) revealed that the intervals of storage, and interaction atmospheres x packages contributed significantly (P<0.01) towards the changes in cohesiveness for refrigeration storage conditions. The effect of types of package was less significant (P<0.01) for refrigeration storage condition, while influence of atmospheres was highly significant (P<0.01) in case of 7±1 °C storage. Other studied interactions were found to be not significant.

Gumminess: Fig. 5 represents the changes in gumminess of mozzarella cheese during storage. The mean initial value of gumminess was found to be 50.34 N and it continued to decrease in all the cheese samples during storage. At the end of 6 weeks storage (7±1 °C), the values for gumminess (atm 1) decreased to 23.83 N in case of P₁ and 15.52 N for P₂. Further storage of samples under other four modified atmospheres for 12 weeks at 7±1 °C showed (see Fig. 5) that the rate of decrease was minimum for the samples of atm 3 (P₁: 25.41, P₂: 22.10), and maximum for atm 2 (19.55 P₁, 17.32 P₂), while the decrease had been moderate with the samples packed under atm 4 (P₁: 22.31, P₂: 18.96) and atm 5 (P₁: 23.29, P₂: 20.89). From these results, it can be inferred that the gumminess decreased consistently in all packages during storage. The results are in agreement with the findings of Ghosh et al. (1996) who also reported a decrease in gumminess of cheese samples during storage. They also reported that values for gumminess of stored mozzarella cheese decreased significantly with time.

Analysis of variance of the data concerning gumminess of the product stored at 7±1 °C revealed that the influence of different intervals of storage and effect of different atmospheres was highly significant (P<0.01) for storage conditions, while interaction atmospheres x packages was significant (P<0.01) for 7±1 °C storage only. However, interactions intervals x atmospheres, intervals x packages, and also between packages were not significant for both the storage conditions.
Chewiness: Data on the chewiness of mozzarella cheese samples packed in 5 modified atmospheres and stored in different packages at 7±1 °C are illustrated in Fig. 6. The statistical analysis of the data on chewiness is presented as a part of Table 1. Perusal of the Fig. 6, indicate decreasing trend in the values for chewiness of mozzarella cheese during storage. The pattern was almost similar to gumminess and springiness. This was expected as the chewiness is a secondary parameter derived from springiness and gumminess. The initial chewiness value of 25.15 (Nmm) of mozzarella cheese decreased to 5.20 and 4.98 respectively, in P \(_1\) & P \(_2\) (atm1) after 6 weeks of storage at 7 ±1 °C. More decrease in chewiness was noted in P \(_2\) compared to P \(_1\). In case of mozzarella cheese packed under vacuum (atm 2), the initial chewiness (25.15) decreased to 7.25 and 4.00 (Nmm) in P \(_1\) & P \(_2\) respectively.

The chewiness of mozzarella cheese samples in the packages with 100% CO\(_2\) (atm 3), 50 % CO\(_2\)/50 % N\(_2\) (atm 5) and 100% N\(_2\) (atm 4) respectively, decreased to 10.67 (P \(_1\)), 7.64 (P \(_2\)); 9.78 (P \(_3\)) and 7.45 (P \(_4\)) and 7.23 (P \(_5\)), 5.02 (P \(_6\)); indicating that the minimum increase in the value had been with the samples packed in P \(_1\) (atm 3), and maximum for P \(_2\) (atm 2) establishing a very significant influence of MAP on the chewiness characteristic of mozzarella cheese during storage.

ANOVA of the data on chewiness of the stored mozzarella cheese samples revealed (Table 1) that the intervals of storage and interaction atmospheres x packages were highly significant (P< 0.01) with regard to changes in chewiness characteristic. The influence of different atmospheres was found significant (P<0.01) for 7±1 °C storage. Other studied interactions were not significant.

Springiness: The changes in springiness of mozzarella cheese samples packaged in two different materials under modified atmospheres and stored at 7±1 °C are depicted in Fig. 7. The analysis of variance of the data is given in Table 1.

The initial mean springiness value for fresh mozzarella cheese sample was 0.50 mm, which decreased to 0.27 and 0.20 in P \(_1\) and P \(_2\) respectively at the end of 6 weeks of storage at 7±1 °C in atm 1. After 12 weeks the values were found to be atm 2 (P \(_1\); 0.24; P \(_2\); 0.19), atm 3 (P \(_1\); 0.28; P \(_2\); 0.25), atm 4 (P \(_1\); 0.26; P \(_2\); 0.22) and atm 5 (P \(_1\); 0.27, P \(_2\); 0.24). Fig. 7 indicates that least change in springiness occurred in samples packaged under atm 3 followed by atm 5, atm 4 and atm 2 respectively, in ascending order. Perhaps higher degree of proteolysis (Lawrence et al. 1987) might be the reason for medium decrease in springiness in case of samples packaged under atm 3.

Statistically, the influence of intervals of storage on the springiness of mozzarella cheese samples was highly significant (P<0.01) for both the conditions of storage, while interaction atmospheres x packages was significant (P<0.01) for 7±1 °C storage only. The variation among atmospheres and between packages, both individually, was observed to be significant (P<0.05) for both the storage conditions. Other studied interactions were, however, found to be not significant under any of the studied storage condition.

CONCLUSIONS

Of the five packaging atmospheres studied, it was observed that the type of atmosphere plays a very significant role in textural properties and proteolysis of mozzarella cheese. Among the five systems evaluated, 100% CO\(_2\) (atm 3) was most effective in preserving the textural properties during storage, thus proving to be the best, followed by the
Fig 7: Effect of MAP on springiness of mozzarella cheese stored in different packages at 7±1 °C. Each point is the mean±SE (0.1 – 0.6) of two replicate experiments.

samples packed in mixture of 50% N₂ and 50% CO₂ (atm 5) 100% N₂ (atm 4), vacuum (atm 2) and air (atm 1) in descending order. The five types of atmospheres and the intervals of storage period, each individually, influenced the textural quality of MAP stored mozzarella cheese during refrigeration condition. The result confirmed that MAP is effective in retaining the textural properties and to check the proteolysis of Mozzarella cheese.

REFERENCES


