African Journal of Biotechnology Vol. 11(64), pp. 12773-12776, 9 August, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.949
ISSN 1684–5315 ©2012 Academic Journals

*Full Length Research Paper*

# The effect of smoking on changes in functional attributes of Mozzarella cheese

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Accepted 10 May, 2012

**Smoking of cheeses significantly modifies not only sensory attributes, but also determines the form of their further utilisation, packaging method and shelf life. The aim of thIS study was to evaluate functional characteristics of smoked and unsmoked Mozzarella cheeses subjected to 4-week storage. It was found that smoked cheese contained 7% less water than unsmoked cheese. Meltability of smoked cheese before storage was 2 times smaller than that of unsmoked cheese, but after 4 weeks, meltability was 21% greater. Smoked cheese not subjected to storage was 2.2 times harder than unsmoked cheese. During storage, hardness of smoked cheese decreased 4.6-fold, while that of unsmoked cheese only 1.1-fold. Storage time had an increase in stretchability of unsmoked and smoked cheeses by 4.2 and 14.9%, respectively.**

**Key words:** Mozzarella, meltability, texture.

## INTRODUCTION

In the development of cheese-making, a considerable role has always been played by the production of soft skinless rennet non-ripening cheeses. A typical representative of this group of cheeses is Mozzarella cheese, produced traditionally from buffalo or cow's milk (Kowalska et al., 2010). This cheese is available in retail in air-tight packaging in whey-water brine with an addition of salt. However, the form, in which the cheese is consumed and used, also depends on geographical conditions (Van Hekken et al., 2007). Frequently, in many countries, particularly in Eastern and Central Europe, Mozzarella cheese is additionally subjected to smoking. Such a method of thermal processing also influences the method of packaging. In such a case, cheese is not placed in brine, but rather vacuum packed or placed in ordinary plastic packaging. These cheeses are consumed as toppings for sandwiches or toasts, as snacks with wine, beer or in catering. They are eaten in the morning as breakfast and as packed lunch taken to school or work. Thus, an important technological aspect is connected with the sliceability of smoked cheese.

The mean shelf life of Mozzarella cheese is typically 4 weeks (Metzger et al., 2001). During storage, changes also occur in functional characteristics of cheese, such as its meltability, tenderness, hardness, elasticity and other parameters of texture (Gupta and Reuter, 1993; Adhikari et al., 2003; Awad et al., 2005).

The aim of this study was to evaluate parameters of texture and meltability in Mozzarella cheese subjected to the process of smoking and to further storage.

## MATERIALS AND METHODS

Material for analyses comprised of commercially available Mozzarella cheeses, both natural and smoked, purchased in retail outlets in Poland. Cheeses were from different producers and different production batches (n = 5 natural cheese, 7 smoked cheese). Cheese was offered in balls with unit weights ranging from 220 to 250 g. Cheeses were packed in vacuum. The mean shelf life of natural cheese, declared by producers was 28 days, while that of smoked cheese ranged from 35 to 40 days. The other analyses were also conducted after production and after 4 weeks of storage. Cheeses were stored at 4 ± 1°C. The performed analyses included six production batches and each assay or measurement was

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**Table 1.** Meltability of unsmoked and smoked Mozzarella cheese during storage.

| Meltability | Storage time (weeks) | Mozzarella cheese | |
|---|---|---|---|
| | | unsmoked | smoked |
| Tube test (mm) | 0 | $7.8^{aB}$ | $4.2^{aA}$ |
| | 4 | $7.1^{aA}$ | $8.3^{bB}$ |
| Schreiber test (scale 0 to 10) | 0 | $3.4^{aB}$ | $1.6^{aA}$ |
| | 4 | $3.1^{aA}$ | $3.9^{bB}$ |

$^{a-b}$Different lower case letters denote a significant effect of storage time, $^{A-B}$different capital letters denote the effect of smoking for the same parameter, $\alpha = 0.05$.

carried out in three replications.

**Compositional analysis**

Total nitrogen content using the Kjeldahl method was determined with the assistance of the Kjetec System 1026 apparatus of the Distilling Unit Tecator Company (Őrebro, Sweden). Water and fat contents in cheese were determined using standard methods (AOAC, 1995). The pH of the examined cheeses was determined using a pH-meter (CP-315, Elmetron Co., Zabrze, Poland), which was equipped with a combined ESAgP-301W type electrode (Eurosensor Co., Gliwice, Poland), consisting of a glass half-cell and a saturated chloro-silver half-cell.

**Cheese melt**

Meltability of cheese samples was determined by two methods: the Schreiber test and a method with test tube.

For the Schreiber test, a circular cookie cutter, of 39.5 mm in diameter, was used to cut 5-mm high discs of cheese. This disc was placed in a covered 15 x 100 mm thin-walled Pyrex Petri dish and heated in a forced draft oven preheated to 232°C. Heating was done in a heating chamber with a forced air circulation FED Binder (Tuttlingen, Germany). The samples were removed after 5 min and cooled for 30 min at room temperature. Specimen expansion was measured using a scale having six lines marked on a concentric set of circles. The Schreiber test meltability was given as the mean of six readings on the arbitrary scale of 0 to 10 units (Park et al., 1984).

For the other method, 10 g of grated cheese were placed in a tube (32 x 250 mm) and packed to form a plug at the bottom. The height of cheese was marked. The test tube was covered with aluminum foil and holes were made to let the hot gas escape during heating. The test tube was kept vertically in a refrigerator at 4°C for 30 min and then horizontally in an oven heated at 104°C for 60 min (Poduval and Mistry, 1999; Koca and Metin, 2004). Meltability was measured as flow distance in mm of melted cheese.

**Texture measurement**

Texture parameters were measured using a TA-TX.plus texture meter by Stable Micro Systems (Surrey, UK). The following attachments were used: A/CE, A/WEG and A/BC. Cheese samples were prepared in accordance with the recommendations of the apparatus manufacturer. Measurement conditions depended on the type of the used measuring attachment: the A/CE attachment with a PT 100 temperature sensor (test speed 20.0 mm* $s^{-1}$, post–test speed 20.0 mm*$s^{-1}$, distance 270 mm), the A/WEG attachment (test speed 2.0 mm*$s^{-1}$, post–test speed 10.0 mm*$s^{-1}$, distance 10 mm) and the A/BC attachment (test speed 0.5 mm*$s^{-1}$, post–test speed 10.0 mm*$s^{-1}$, distance 25.0 mm). Results were recorded in a Texture Expert TE32 version 6.0 computer programme.

**Statistical analysis**

Statistical calculations were performed using a STATISTICA (version 7.1) data analysis software system by StatSoft, Inc. (2005).

## RESULTS AND DISCUSSION

Based on the analyses, it was found that unsmoked and smoked Mozzarella cheeses contained statistically identical amounts of protein (24.2%) and fat (17.2%). Smoked Mozzarella cheese contained 66.44% water and it was 7% less than that in unsmoked cheese. Acidity of smoked cheese (pH 4.46) was significantly greater ($\Delta$pH = 0.06) than that of unsmoked cheese. After 4 weeks, the initial difference in active acidity of both cheeses was retained, but values were on average lower by 0.07 pH units.

Meltability of smoked Mozzarella cheese not subjected to storage was 2 times lower than that of unsmoked cheese, irrespective of the applied experimental method (Table 1). However, after 4 weeks, smoked cheese was characterised on average by 21% greater meltability than unsmoked cheese. Storage time significantly enhanced meltability of smoked cheese (1.9-fold in case of the tube test and 2.4-fold in case of the Schreiber test, respectively). At the same time, it was shown that storage time of unsmoked cheese did not have an effect on the results of either the tube test or the Schreiber test.

Analysis of texture parameters of cheeses made it possible to characterize functional characteristics connected with its stretchability, cohesion and sliceability (Table 2). The longest cheese strings were produced at stretching of smoked cheese stored for 4 weeks. They were significantly longer (4.7%) than those made from unsmoked cheese tested at the same time. Smoked Mozzarella cheese, but not subjected to a storage period, turned out to be the least stretchable. Storage time had an enhanced stretchability of unsmoked and smoked

**Table 2.** The effect of the smoking process on changes in texture parameters of unsmoked and smoked Mozzarella cheese during storage.

| Texture parameters | Storage time (weeks) | Mozzarella cheese | |
|---|---|---|---|
| | | unsmoked | smoked |
| **Stretch quality using extensibility rig (A/CE)** | | | |
| Extensibility force (g) | 0 | -37.5$^{aB}$ | -26.6$^{aA}$ |
| | 4 | -45.0$^{bB}$ | -41.1$^{bA}$ |
| Stretching (mm) | 0 | 134.7$^{aB}$ | 127.9$^{aA}$ |
| | 4 | 140.3$^{bA}$ | 146.9$^{bB}$ |
| **Using the fracture wedge set (A/WEG)** | | | |
| Hardness (g) | 0 | 230.9$^{bA}$ | 503.2$^{bB}$ |
| | 4 | 217.9$^{aB}$ | 109.9$^{aA}$ |
| Brittleness (mm) | 0 | -104.2$^{aA}$ | -101.1$^{aA}$ |
| | 4 | -103.4$^{aA}$ | -103.3$^{aA}$ |
| **Using the wire cutter (A/BC)** | | | |
| Cutting force (g) | 0 | 46.1$^{aA}$ | 48.0$^{aB}$ |
| | 4 | 48.6$^{bA}$ | 47.8$^{aA}$ |

$^{a-b}$Different small letters denote the effect of storage time for the same parameter, $^{A-B}$different capital letters denote a significant effect of smoking, $\alpha = 0.05$.

cheeses (4.2 and 14.9%, respectively). These results were reflected in the values of extensibility force required for sample stretching. Smoked cheese not subjected to storage was by 2.2 times harder than unsmoked cheese. During storage, hardness of smoked cheese decreased 4.6 times, while that of unsmoked cheese decreased by only 1.1 times, respectively. Brittleness of smoked cheese was lower than that of unsmoked cheese only before storage. After 4 weeks, the difference practically disappeared and both smoked and unsmoked cheeses were equally brittle. Similarly, no difference was found in the measurements of cutting force. Smoked cheese before and after storage was characterized by identical sliceability.

Water content in Mozzarella cheeses produced and tested by Zisu and Shah (2007) was 52.84 to 60.25% at a fat content of 5.7 to 6.5%. In turn, Wang and Sun (2002, 2004) in the analysed Mozzarella cheese reported 46.1% water and acidity of pH 5.37. A higher acidity was shown by Mathukumarappan et al. (1999) when testing commercially available unsmoked Mozzarella cheese (from pH 4.96 to 5.16). Irrespective of the applied technological procedures, active acidity in Mozzarella cheeses analyzed by Sheehan et al. (2005) increased with an extension of storage time. When investigating functional properties of Mozzarella cheeses, O'Reilly et al. (2002) determined 48.45% water content. The essence of the effect of water content on functional properties of Mozzarella cheese was shown in the study of Kindstedt and Guo (1998). Hong et al. (1998) linked changes in proteolysis parameters of Mozzarella cheese with its water content in the course of cold storage. The flowability of cheese during heating depends strictly on its water content, which was the subject of a study by Tunick et al. (1993).

When storing Mozzarella cheese for 6 weeks, Tunick et al. (1993) showed an increase in its meltability at the simultaneous reduction of hardness and springiness values. This trend was observed for cheeses irrespective of their fat contents. A many-fold increase in distance melt was described by Zisu and Shah (2007) when testing low-fat Mozzarella cheese in the course of storage at 4°C for 90 days. The authors recorded an increment in melt distance from 53 (day 7) to 72 mm (day 90). Firmness of Mozzarella cheeses, tested by Sheehan et al. (2005) throughout the entire 35-day storage, remained at the same level. Meltability of cheeses depending on temperature was investigated by Ko and Gunasekaram (2008). Merrill et al. (1996) also stated an increasing meltability from 6 to over 10 cm with an extension of cheese storage time (28 days). A model study on meltability conducted by Rudan and Barbano (1998) confirmed earlier observations concerning the effect of fat content on this attribute of cheeses.

## Conclusion

Based on the conducted analyses, it was stated that smoking of Mozzarella cheese caused loss of water

content and an increase in cheese active acidity. It influenced the scope of changes in cheese meltability during storage. Before storage, meltability of smoked cheese was lower than that of unsmoked cheese. However, after 4 weeks, the value of meltability in smoked cheese was much greater than that of unsmoked cheese. Changes in texture parameters of cheeses as a result of smoking depended on their storage time. Analysis of stretchability showed that the greatest length of cheese strings was obtained when stretching smoked cheese stored for 4 weeks. Smoked cheese not subjected to storage was harder than unsmoked cheese. Smoked cheese before and after storage was characterized by identical sliceability.

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