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Shelf life of Stracciatella cheese under modified-atmosphere packaging

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ABSTRACT

The aim of this work is to evaluate the shelf life of Stracciatella cheese packaged in a protective atmosphere, using 4 different CO_2:N_2:O_2 gas mixtures [50:50:0 (M1), 95:5:0 (M2), 75:25:0 (M3), and 30:65:5 (M4) vol/vol] and stored at 8°C. Cheese in traditional tubs and under vacuum were used as the controls. Results showed that the modified-atmosphere packaging, in particular M1 and M2, delayed microbial growth of spoilage bacteria, without affecting the dairy microflora, and prolonged the sensorial acceptability limit.
Key words: Stracciatella cheese, modified-atmosphere packaging, shelf life

INTRODUCTION

Stracciatella cheese is produced from cow's milk in the Apulia region. It is a fresh cheese, white, and made up of fresh cream and frayed curd. It is stored and shipped like fresh Mozzarella and refrigerated in a tub. Considering that fresh cheeses have high moisture content and high fat content, these dairy products are very susceptible to microbial spoilage, especially under temperature abuse. Storage of fresh cheeses under aerobic conditions results in rapid spoilage.

The potential of modified-atmosphere packaging (**MAP**) for extending the shelf life of dairy products, including cheese, has been demonstrated (Floros et al., 2000; Papaioannou et al., 2007). These authors summarized that the success in cheese packaging is dependent on several important parameters such as the type of cheese, the use of starter cultures during production, its initial microbial contamination, and storage conditions. The gases normally used for MAP include CO_2, O_2, and N_2. The most important gas from a microbiological point of view is CO_2, used alone or in mixtures with N_2 or O_2, which inhibit the growth of many microorganisms, including spoilage bacteria (Daniels et al., 1985). Moir et al. (1993) demonstrated that a 40% CO_2 atmosphere inhibited the growth of *Pseudomonas* spp. inoculated into the creamed-style cottage cheese at 5 and 15°C. Inhibition by CO_2 was greater at 5°C and at the surface than in the interior of the cheese; the odor and the pH of the cheese were not affected by the gas. In a similar study, the effectiveness of flushing of headspace of commercial packages of cottage cheese with CO_2 was investigated (Mannheim and Soffer, 1996). Flushing the packages with pure CO_2 (25% vol/vol) increased the shelf life of cheese by increasing the lag phase of growth of coliforms, yeasts, molds, and gram-negative spoilage bacteria. The taste and texture of flushed cheese were not affected, and use of high-barrier packaging film to maintain the desired concentration of CO_2 was suggested. To date, few papers have been reported on Mozzarella cheese packaged in MAP, and no studies are reported on Stracciatella cheese. Eliot et al. (1998) reported that shredded Mozzarella cheese packaged in MAP containing concentrations of 75% CO_2 was well protected from undesirable organisms and gas formation. Alves et al. (1996) also found that the microbial growth in sliced Mozzarella cheese, packaged in MAP and stored at 7°C, was delayed with high concentrations of CO_2. The goal of this research is to determine the microbiological, pH, and sensory changes in Stracciatella cheese, stored under MAP conditions at 8°C.

MATERIALS AND METHODS

Cheese-Making of Stracciatella Cheese

The Stracciatella cheese used in this work was manufactured in a dairy plant "La Montanara" (Monte Sant'Angelo, Foggia, Italy), according to the following procedure: raw cow's milk was acidified with lactic acid and liquid rennet was added. Curd formation was achieved after about 15 to 20 min. When the curd pH reached a value of about 5.80, the whey was removed. The curd was cut, stretched, and after tempering in cold water, frayed and fresh cream was added. Samples were transported to the laboratory in polystyrene boxes containing ice and were used within 3 h after production.

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Sample Preparation

Portions (150 g) of cheese samples were packaged in commercially available bags with a thickness of 95 μm, provided by Valco (Bergamo, Italy). These were obtained by laminating a nylon layer and a polyolefin layer and have an O_2 transmission rate of 50 mL·m^{-2}·24 h^{-1} at 1 atm, measured at 23°C and 75% relative humidity. Four gas mixtures (vol/vol) were used: **M1** [50:50 (CO_2:N_2)], **M2** [95:5 (CO_2:N_2)], **M3** [75:25 (CO_2:N_2)], or **M4** [30:65:5 (CO_2:N_2:O_2)]. Cheese in tubs (**CT**) and under vacuum (**VP**) served as controls. All samples were stored at 8°C for 8 d. Determinations of microbial count, pH, headspace gas composition, and sensory evaluation were carried out before packaging and after 1, 2, 3, 4, 7, and 8 d of storage on different cheese samples.

Microbiological Analyses

Twenty grams of Stracciatella cheese was diluted in 180 mL of Ringer's solution in a Stomacher bag and blended with a Stomacher Lab Blender (International PBI, Milan, Italy). Serial dilutions of homogenates were plated on the appropriate media in Petri dishes. The media and conditions used were as follows: plate count agar (Oxoid, Hampshire, UK), incubated at 30°C for 48 h for total microbial count and at 4°C for 10 d for psychrotrophic microflora; de Man, Rogosa, and Sharpe agar (Oxoid), supplemented with cycloheximide (100 mg/L, Sigma-Aldrich, St. Louis, MO), incubated under anaerobiosis (Anaerogen Gas Pack, Oxoid) at 37°C for 48 h for lactic acid bacilli; M17 agar (Oxoid), incubated at 37°C for 48 h for lactococci; yeast peptone dextrose agar (Oxoid), supplemented with chloramphenicol (0.1 g/L, Oxoid) incubated at 30°C for 48 h for yeasts and molds; violet red bile lactose agar (Oxoid) incubated at 37°C for 24 h for total coliforms; violet red bile glucose agar (Oxoid) incubated at 37°C for 24 h for Enterobacteriaceae; and *Pseudomonas* agar base (Oxoid), added with SR103 E selective supplement (Oxoid) and incubated at 25°C for 48 h for *Pseudomonas* spp. Each microbial test was made twice on 2 different batches.

pH Determination

The pH values on each sample were determined by direct reading with a pH meter (Crison, Barcelona, Spain). Each value was the average of measures recorded on samples from 2 different batches.

Headspace Gas Composition

Before opening the cheese bags, headspace gas composition was determined by using a Checkmate 9900 gas analyzer (PBI Dansersor, Ringsted, Denmark). The volume taken from the package headspace for gas analysis was about 10 cm^3. To avoid modifications in the headspace gas composition due to gas sampling, each package was used only for a single determination of the headspace gas composition. Two samples were used for each test.

Sensorial Analysis

Sensory evaluation was carried out according to the method described by Pagliarini (2002), Bozzetti et al. (2004), and Chiavari et al. (2006). A panel composed of 7 members belonging to the food packaging laboratory was assembled. The panelists were selected based on their interest in the sensory evaluation of cheese and were trained by testing commercial Stracciatella cheese. Cheese samples (25 to 30 g) were submitted in a group to the 7 panelists. They were asked to evaluate the external appearance, consistency, color, odor, and overall acceptability of the cheese samples on a 7-point scale. A value of 4 indicated the attribute threshold for cheese acceptability. The cheese samples were randomly coded.

Statistical Analysis

The values of the microbial acceptability limit (**MAL**) and sensorial acceptability limit (**SAL**) and the shelf life of all systems were compared by 1-way ANOVA. Duncan's multiple range test, with the option of homogeneous groups ($P < 0.05$), to determine significance differences between the samples, was used. Statistica software, version 7.1 for Windows (StatSoft Inc., Tulsa, OK) was used for this purpose.

RESULTS AND DISCUSSION

Microbiological Quality

The initial microbial count of Stracciatella cheese was approximately 3.40, 3.93, 5.42, and 1.00 log (cfu/g) for Enterobacteriaceae, total coliforms, *Pseudomonas* spp., and yeasts-molds, respectively, consistent with microbial counts for pasta filata cheese reported by Salvadori del Prato (2001). This microbiological characteristic possibly reflected the quality of the milk, the survival of heat-sensitive microorganisms during cheese-making, and postprocessing microbial contamination (Spano et al., 2003). The coliform and *Pseudomonas* spp. counts of cheese samples packaged under MAP were lower than those of the CT and VP controls during storage at 8°C (Figures 1 and 2). Among the modified atmospheres, M2 and M3 were the most effective for the inhibition of coliforms and *Pseudomonas* spp., respectively, perhaps because of the inhibitory effect of the greater concen-

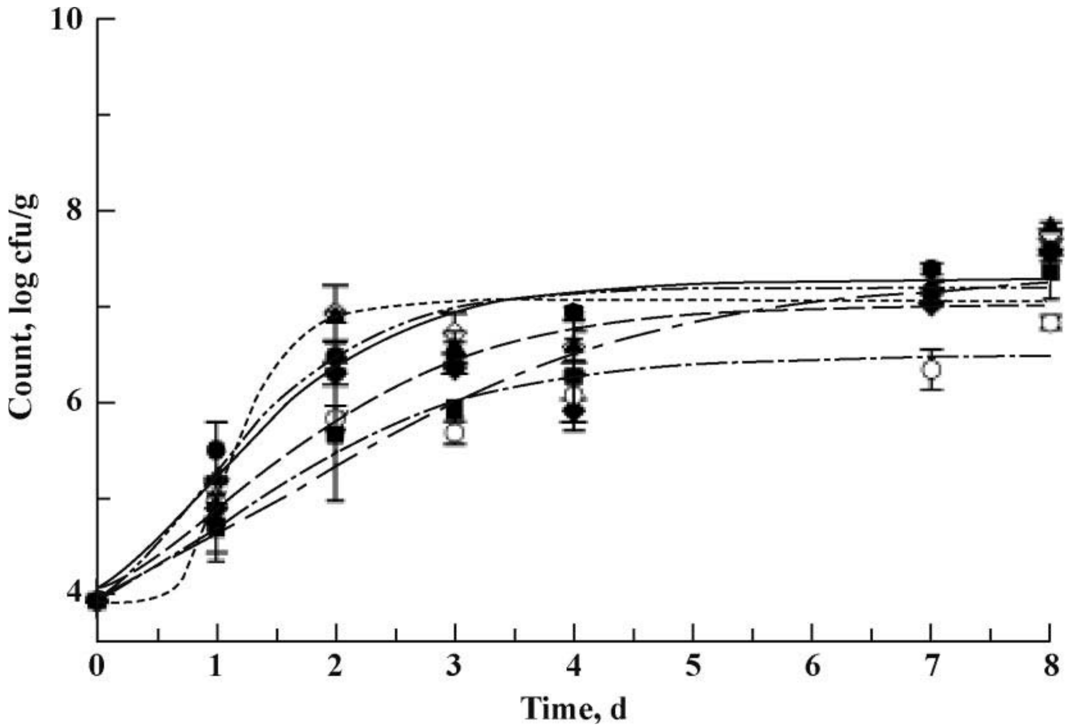

Figure 1. Evolution of total coliform count in Stracciatella cheese during storage at 8°C for 8 d. The curve is the best fit of equation [1] to the experimental data. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4. CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

tration of CO_2 on microbial growth. Because of its bacteriostatic effect, CO_2 inhibits the growth of aerobic gram-negative bacteria such as *Pseudomonas* spp. by extending the lag phase and decreasing the growth rate during the logarithmic phase (Farber, 1991). The 50:50 (CO_2:N_2) gas mixture (M1) was effective on the growth of coliforms and markedly effective on *Pseudomonas* spp. In contrast, the 30:65:5 (CO_2:N_2:O_2) gas mixture (M4) did not have an inhibitory effect on coliform growth, but a slight decrease on *Pseudomonas* spp. count was recorded. Similar MAP effects have been reported by other authors for various types of cheese, including Mozzarella (Alves et al., 1996; Eliot et al., 1998) and Cameros cheese (Gonzalez-Fandos et al., 2000).

To quantitatively determine the MAL of the MAP systems, the Gompertz equation as reparameterized by Corbo et al. (2006) was fitted to the experimental data:

$$\log\left[N(t)\right] = \log\left(N_{max}\right) - A \cdot \exp\left(-\exp\left\{\left[\left(\mu_{max} \cdot 2.71\right) \cdot \frac{\lambda - MAL}{A}\right] + 1\right\}\right) + A \cdot \exp\left(-\exp\left\{\left[\left(\mu_{max} \cdot 2.71\right) \cdot \frac{\lambda - t}{A}\right] + 1\right\}\right) \quad [1]$$

where N(t) is the viable cell concentration at time t, A is related to the difference between the decimal logarithm of maximum bacterial growth attained at the stationary phase and decimal logarithm of the initial value of cell concentration, μ_{max} is the maximal specific growth rate, λ is the lag time, N_{max} is the microbial threshold value, MAL is the microbiological acceptability limit [i.e., the time at which N(t) is equal to N_{max}], and t is the storage time. The value of N_{max} was set to 10^6 cfu/g for *Pseudomonas* spp. and 10^5 cfu/g for coliforms. The latter is imposed by the DPR 54/97 (European Union, 1997), whereas the former value is the contamination level at which the alterations of the product start to appear (Bishop and White, 1986). As can be inferred from Table 1, the worst results are those recorded for the Cnt and the VP samples. In contrast, the MAP had an inhibitor effect, especially the MAP with greater concentration of CO_2. This statement was also evident for *Pseudomonas* spp. To sum up, the MAL is more than 1 d, even though the MAP showed an antimicrobial effectiveness, if compared with the CT cheese. Moreover, high CO_2 concentrations were more effective than VP in decreasing the growth of spoilage bacteria in Stracciatella cheese, in agreement with results reported by Eliot et al. (1998) for Mozzarella and Gonzalez-Fandos

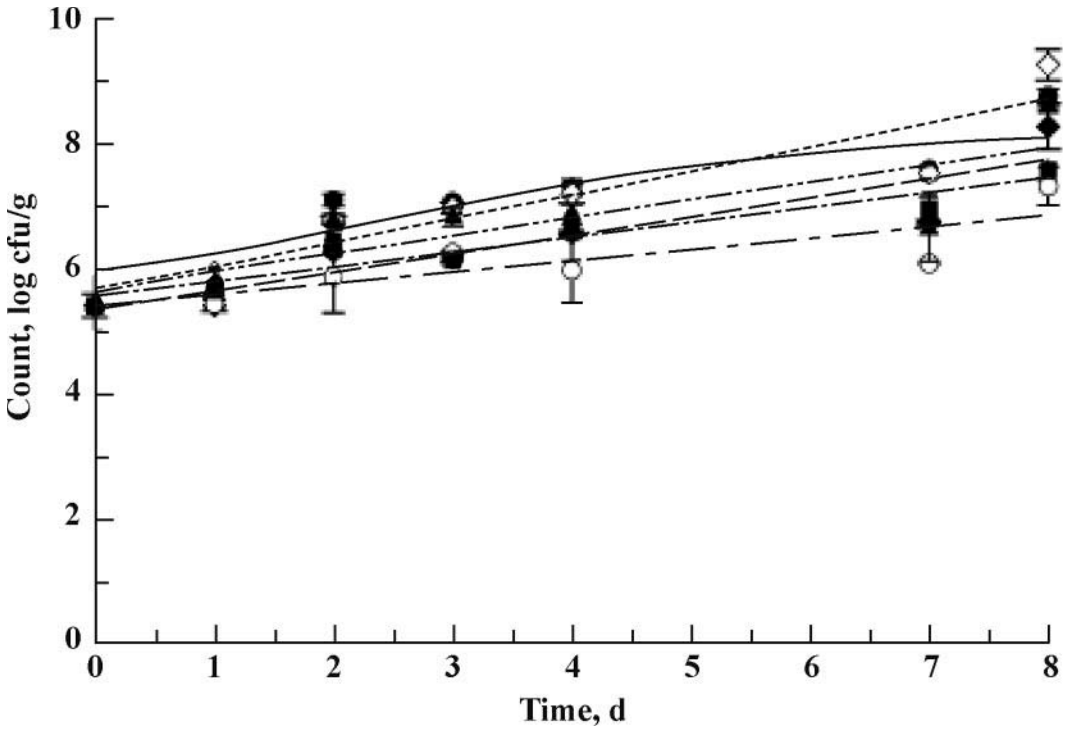

Figure 2. Evolution of *Pseudomonas* spp. count in Stracciatella cheese during storage at 8°C for 8 d. The curve is the best fit of equation [1] to the experimental data. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4). CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

et al. (2000) for Cameros cheese. Psychrotrophic microflora growth in Stracciatella cheese samples stored under VP, M1, M2, or M3 was partially retarded during the first days of storage (Figure 3), in agreement with results reported for Cameros cheese stored under high CO_2 concentrations (Gonzalez-Fandos et al., 2000). After a few days, the growth of psychrotrophic was not inhibited in VP samples; for all other samples, the concentration (about 8 log cfu/g) was reached at 8 d, therefore confirming earlier results for the growth of psychrotrophic in the presence of CO_2 (Alves et al., 1996; Pintado and Malcata, 2000).

The initial enterobacteria count (3.40 log cfu/g, Figure 4) suggests survival of heat-sensitive microorganisms and possible postprocessing contamination, as reported by Spano et al. (2003). Cheese samples packaged in vacuum showed greater counts of enterobacteria than the CT and those packaged under $CO_{2,}$ except for M4. Similar results on inhibition of enterobacteria by MAP have been demonstrated for Cameros cheese (Gonzalez-Fandos et al., 2000) and Greek whey cheese (Papaioannou et al., 2007).

Counts of cocci and rod lactic acid bacteria (data not shown) in all Stracciatella cheese samples remained

Table 1. Shelf life of Stracciatella samples evaluated on the basis of microbial acceptability limit (MAL) of coliforms (MAL_C), *Pseudomonas* ssp. (MAL_P), and sensorial acceptability limits (SAL)[1]

Samples[2]	MAL_C, d	MAL_P, d	SAL, d	Shelf life, d
CT	0.83 ± 0.15^{a}	0.03 ± 3.23^{a}	2.29 ± 0.12^{b}	0.03 ± 3.23^{a}
VP	1.00 ± 0.15^{ab}	0.80 ± 1.19^{a}	2.17 ± 0.03^{b}	0.80 ± 1.19^{a}
M1	1.13 ± 0.33^{abc}	2.14 ± 0.97^{a}	4.60 ± 0.51^{a}	1.13 ± 0.33^{a}
M2	1.37 ± 0.24^{bc}	3.21 ± 1.45^{a}	5.99 ± 0.36^{c}	1.37 ± 0.24^{a}
M3	1.53 ± 0.16^{c}	1.83 ± 0.90^{a}	4.45 ± 0.31^{a}	1.53 ± 0.16^{a}
M4	0.81 ± 0.21^{a}	1.03 ± 1.08^{a}	4.21 ± 0.15^{a}	0.81 ± 0.21^{a}

[a–c]Data in columns with different superscript letters are significantly different ($P < 0.05$).

[1]Data are presented ± standard error.

[2]CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

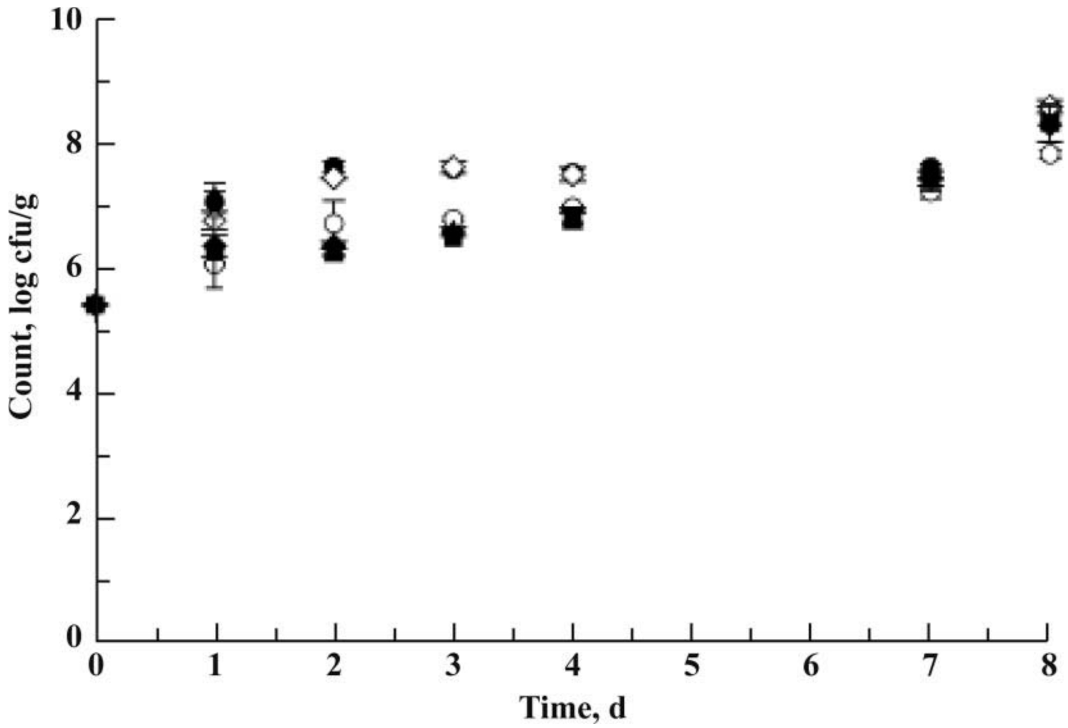

Figure 3. Evolution of psychrotrophic count in Stracciatella cheese during storage at 8°C for 8 d. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4). CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

unchanged. The MAP conditions do not influence the growth of typical dairy microorganisms (Maniar et al., 1994; Lioliou et al., 2001).

Finally, with regard to yeasts-molds (data not shown), the use of MAP gas mixtures was more efficient than VP in inhibiting yeast growth. Similar results have been shown for cottage cheese (Fedio et al., 1994), Mozzarella cheese (Alves et al., 1996; Eliot et al., 1998), and Greek whey cheese (Papaioannou et al., 2007).

pH and Headspace Gas Composition

In Figure 5, the pH trend of all samples is reported. As we can see, similar trends were recorded over an 8-d period. A gradual decline toward the end of the storage for all systems was noted, due to the considerable presence of lactic acid bacteria. The data agree with that reported in the literature for Mozzarella cheese (Salvadori del Prato, 2001). In addition, Moir et al. (1993) and Tsiotsias et al. (2002) found that the pH of cottage cheese and Anthotyros whey cheese was not affected by packaging in 40% CO_2 and VP, respectively.

The headspace atmosphere did not undergo significant changes in composition throughout the storage period (data not shown).

Sensorial Quality

Figure 6 shows the overall sensorial quality plotted as a function of storage time for the Stracciatella samples. To quantitatively determine the efficiency of the packaging system proposed in this work, in terms of sensorial quality preservation, the Gompertz equation as reparameterized by Corbo et al. (2006) was fitted to the sensorial data:

$$\mathrm{OSQ}(\mathrm{t}) = \mathrm{OSQ}_{\min} - \mathrm{A}^{\mathrm{Q}} \cdot \exp\left(-\exp\left\{\left[\left(\mu_{\max}^{\mathrm{Q}} \cdot 2.71\right) \cdot \frac{\lambda^{\mathrm{Q}} - \mathrm{SAL}}{\mathrm{A}^{\mathrm{Q}}}\right] + 1\right\}\right) + \mathrm{A}^{\mathrm{Q}} \cdot \exp\left(-\exp\left\{\left[\left(\mu_{\max}^{\mathrm{Q}} \cdot 2.71\right) \cdot \frac{\lambda^{\mathrm{Q}} - \mathrm{t}}{\mathrm{A}^{\mathrm{Q}}}\right] + 1\right\}\right) \quad [2]$$

where OSQ(t) is the Stracciatella overall sensorial quality at time t, A^Q is related to the difference between the Stracciatella overall sensorial quality attained at the stationary phase and the initial value of Stracciatella overall sensorial quality, μ_{max}^{Q} is the maximal rate at

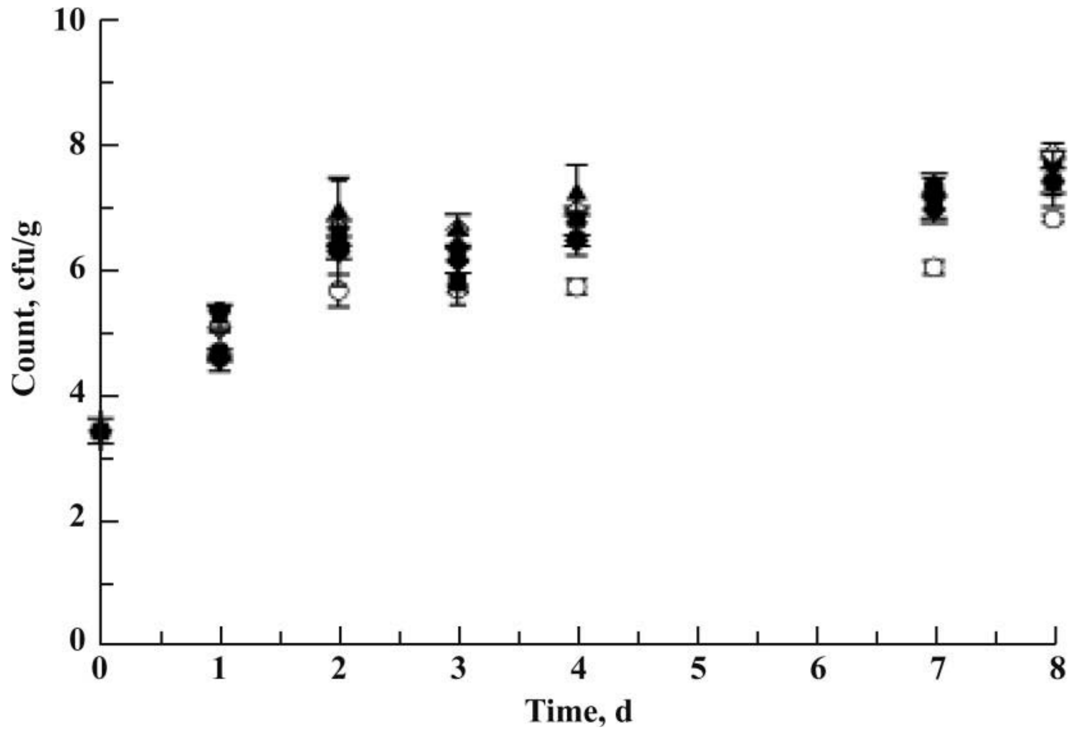

Figure 4. Evolution of Enterobacteriaceae count in Stracciatella cheese during storage at 8°C for 8 d. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4). CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

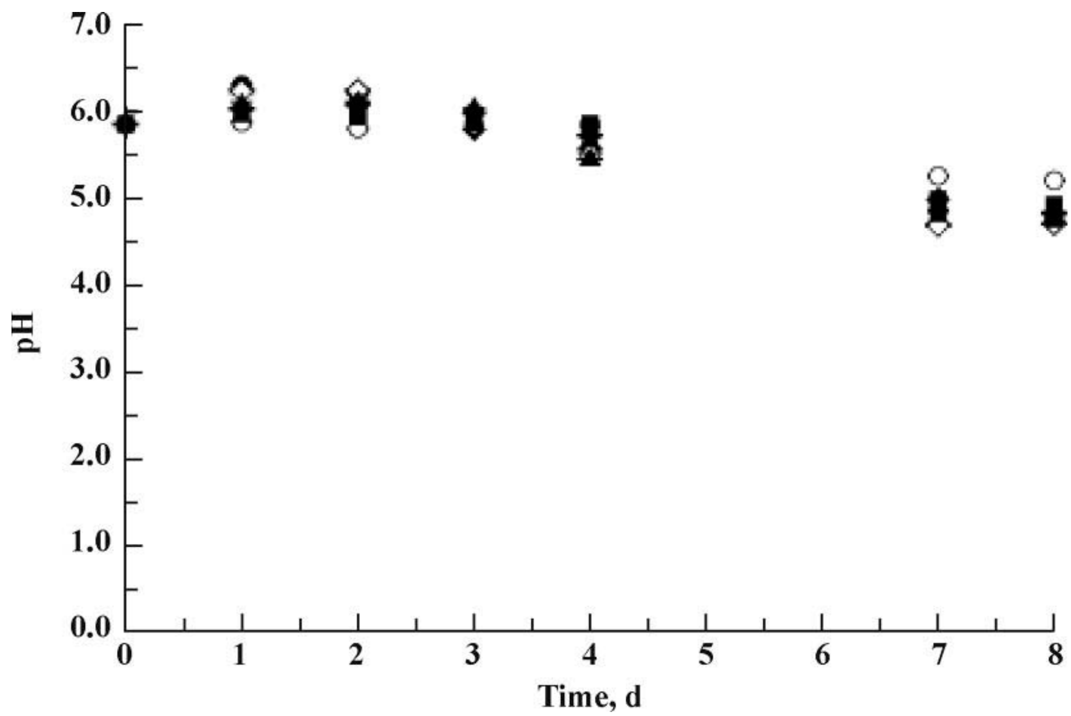

Figure 5. pH trend of Stracciatella samples packaged in different systems during the storage period. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4). CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

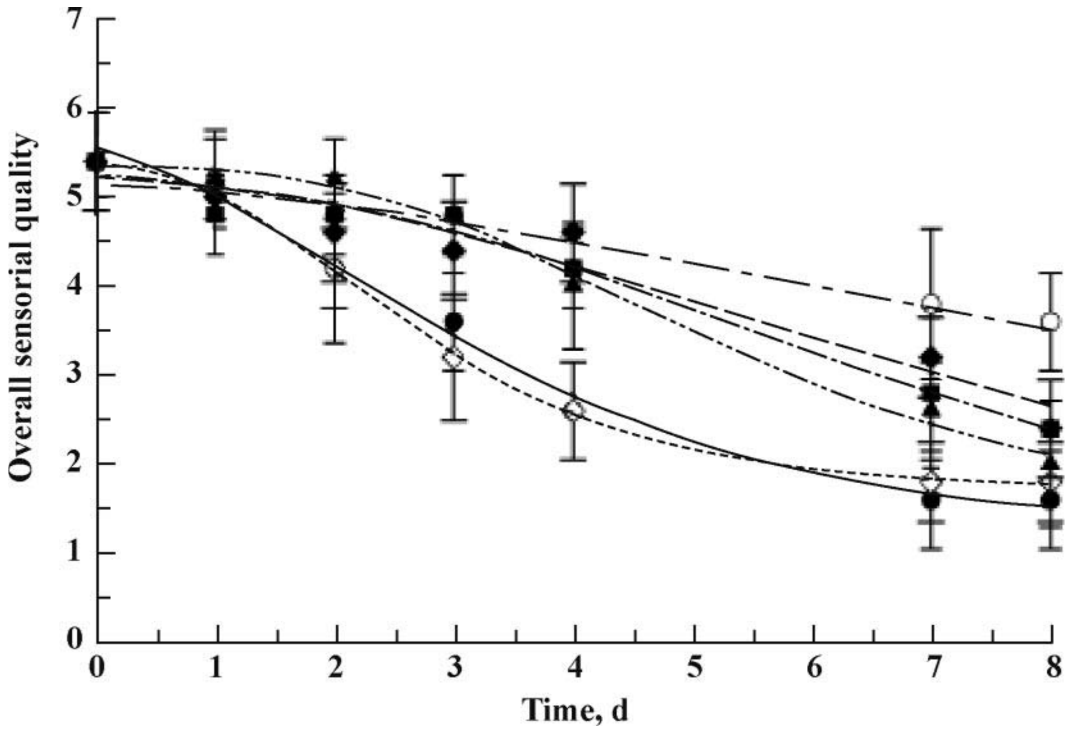

Figure 6. Stracciatella cheese sensorial quality during storage at 8°C for 8 d. The curves are the best fit of equation [2] to the experimental sensorial data. (● CT, ◊ VP, ◆ M1, ○ M2, ■ M3, ▲ M4). CT = cheese in tubs; VP = cheese under vacuum; M1 = 50:50 (CO_2:N_2); M2 = 95:5 (CO_2:N_2); M3 = 75:25 (CO_2:N_2); M4 = 30:65:5 (CO_2:N_2:O_2).

which OSQ(t) decreases, λ^Q is the lag time, OSQ_{min} is the Stracciatella overall sensorial quality threshold value, SAL is the sensorial acceptability limit [i.e., the time at which OSQ(t) is equal to OSQ_{min}], and t is the storage time. As reported in the Materials and Methods section, the value of OSQ_{min} is equal to 4. The curves shown in Figure 6 were obtained by fitting equation [2] to the experimental data; the values of obtained SAL are listed in the Table 1.

As can be seen, significantly greater SAL values were recorded for the samples packaged according to the proposed MAP techniques, compared with VP and CT. It is worth noting that in the CT and VP samples, the sensorial properties of the product exceed a little more than the 2-d storage period. In contrast, the MAP produced acceptable attributes in cheese for more than 4 d of storage at 8°C, maintaining good sensory characteristics.

Shelf Life Evaluation

Wherever the overall quality of a given product depends on several quality subindices, the shelf life of the packed product is, by definition, the time at which one of the product quality subindices reaches its threshold value. In the case under investigation, the shelf life of each tested sample was calculated as the lowest value between the MAL evaluated on the basis of coliforms, MAL evaluated on the basis of *Pseudomonas* spp., and the SAL values, and it was also reported in Table 1. As can be inferred from these data, the microbial quality is responsible for Stracciatella unacceptability in all samples. On the contrary, the sensorial quality does not limit the shelf life of the investigated food product in the packaging systems under study. In particular, M1 [50:50 (CO_2:N_2)] and M2 [95:5 (CO_2:N_2)] are the most effective in retaining good sensory characteristics.

CONCLUSIONS

Modified-atmosphere packaging conditions were used to prolong the shelf life of Stracciatella cheese. Microbial and sensorial properties, as well as pH and headspace gas composition, were monitored for about 8 d to determine the quality loss during storage at 8°C. Microbial stability limits the shelf life of all samples, whereas from a sensorial point of view, the samples under MAP have a better quality, if compared with the traditional packaging. The inhibitor effect of the selected gas on the spoilage bacteria growth could be improved if the quality of milk, the check during cheese-making, and the postprocessing are monitored carefully.

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