An Integrated Approach To Extend the Shelf Life of a Composite Pastry Product (Cannoli)

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ABSTRACT

In this study, a combined approach is proposed to extend the shelf life of a composite pastry product (cannoli). In particular, to delay moisture migration, one, two, or three layers of a zein-based coating were studied. A three-layer coating represented the most effective solution to prevent rapid pastry softening. A subsequent experimental trial was aimed to prolong the shelf life of the ricotta-based stuffing. To this aim, two different antimicrobial compounds (lysozyme and lemon extract) at three concentrations (2,000, 3,000, and 4,000 ppm) were investigated separately from a microbiological and a sensorial point of view. Lemon extract was the active compound that received a better score, thus suggesting using 2,000 ppm of citrus extract in the last step. In the final experimental trial, cannoli were coated with three layers of zein, stuffed with ricotta containing the selected active agent, and packaged in two microperforated films. The use of zein-based coating and the lemon extract in the ricotta stuffing, combined with the barrier properties of the selected packaging materials, allowed a significant prolongation of cannoli shelf life, regardless of the type of film: a shelf life of more than 3 days was recorded, compared with the control samples, which were acceptable for less than 2 days. It is reasonable to assume that the proposed integrated approach could boost the distribution of the investigated typical pastry beyond local borders.

Cannoli are typical Sicilian pastries—a crisp crust filled with ricotta and candied fruit, very diffuse worldwide in terms of presentation. Various ingredients can be added to the ricotta-based stuffing, producing cannoli with slightly different characteristics. The shelf life of this pastry is limited because of water migration from ricotta to the crust, thus causing an unacceptable softening of the product. This aspect ties cannoli to many other assorted confectionery products containing adjoining moist and dried ingredient layers. For this reason, cannoli is not easily exported beyond local borders, and thus cannot reach high-income markets, which are more compatible with large-distribution criteria.

The control of moisture migration in heterogeneous foods, such as pastry stuffed with cream, can be achieved either by reducing the difference in water content between food components, by using chocolate, or by using an edible hydrophobic coating between the humid and dry layers of a food matrix (18, 23, 28). Chocolate coatings—used abundantly in confectionery with soft centers and in cookies and wafers to maintain crispness—could make the product highly fattening and unacceptable to diet-conscious consumers. Hence, the application of edible films or coatings to separate different layers of a food pastry could represent a more agreeable solution. Moreover, a thin coating could provide the necessary barrier properties, without compromising the aesthetic appearance and the typical taste of the final product.

To date, edible coatings based on renewable polymeric materials such as proteins, polysaccharides, and lipids have been widely used to protect fruit and vegetables from dehydration, because they provide a barrier to water transfer from product surface (8, 13, 19). Among several available biopolymers, zein, which consists mostly of the prolamin fraction of corn, has been extensively used to develop films and coatings intended for food applications, being insoluble in water and able to form a tough, glossy, hydrophobic, and greaseproof polymeric matrix resistant to microbial attack (12, 24, 27, 36). Zein is classified as generally recognized as safe and as non-allergenic material by the U.S. Food and Drug Administration.

Another factor limiting cannoli shelf life is the presence of ricotta. Due to its high moisture level, initial pH above 6.0, and low salt content, ricotta is very susceptible to spoilage bacteria, mainly molds and yeasts, and has a shelf life of a few days (15). To prevent ricotta deterioration, natural antimicrobial agents could be added to the stuffing. Dairy researchers have found that selected plant essential oils can act as inhibitors of spoilage microorganisms in food products (6, 16, 35). Most studies on antimicrobial effectiveness of plant extracts have been conducted by in vitro testing (4, 5, 9), and little information exists on their antimicrobial activity in real confectionery products (22), thus suggesting that further investigation on active agents applied to ricotta could make a new contribution to this field.

Regarding appropriate packaging for cannoli pastries, it should be considered that high-water-vapor permeable films

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are greatly desirable in order to avoid accumulation of humidity in the package headspace and, consequently, crust softening during storage. A polymeric matrix with this requested characteristic is represented by perforated film. Because of increasing attention to the impact of packaging on the environment, the use of ecofriendly polymers could be of great interest for the industry. At this time, the application of low-environmental-impact microperforated films is limited to few food categories (21), and the extension of this packaging to pastry products, such as cannoli, could receive substantial interest among industrial producers.

Based on the above issues, the aim of the current work was to prolong the shelf life of a heterogeneous stuffed pastry, cannoli, by using an integrated approach. Three different experimental trials were run in order to optimize the number of coating layers on the inner side of cannoli, to select the type and amount of antimicrobial compound to be added to the ricotta stuffing, and to integrate the above-mentioned best solutions with two different microperforated packaging films.

MATERIALS AND METHODS

First step: coating optimization. Samples of cannoli and ricotta from sheep milk were purchased from a local market in Lucera (Foggia, Italy). Zein (molecular mass of 38 kDa; Sigma-Aldrich, Milan, Italy) was selected as the polymeric matrix to prepare coating. Zein solutions were obtained by dissolving 5 g of zein into 16 ml of ethanol (96%) and adding 1 g of glycerol to the coating solution (Sigma-Alrich). These solutions were stirred continuously for 10 min at 50°C (IKA Labortechnik, Staufen, Germany), and then cooled to room temperature. After cooling, the dissolved zein solution was spread onto the inner surface of cannoli to obtain a uniform inner layer of edible coating. A total of 5 ml of solution was painted homogeneously. This operation was repeated one, two, and three times to obtain cannoli mono-, bi-, and trilayer coating. The amount of applied solution was 0.22, 0.44, and 0.65 ml/g (volume per unit mass of cannoli) for mono-, bi-, and trilayer-coated cannoli, respectively. After spreading each zein layer, the samples were dried at room temperature for 24 h. Therefore, a total of 48 h were necessary to prepare the cannoli with a double layer, and 72 h for cannoli with the thickest coating. Cannoli samples without coating were used as the control.

The thickness of the coating was measured by image analysis using the software Image Pro-Plus (version 6, Media Cybernetics, Silver Spring, MD). To this aim, each sample of cannoli (uncoated samples and samples with one, two, and three zein layers, respectively) was cut in half, and a section was scanned (Perfection V750 PRO, Epson, Amsterdam, The Netherlands). All images were obtained at the same conditions (true color, 24 bits; resolution of 300 bits per pixel) by positioning each sample onto the scanner, held in a black box to exclude the surrounding light. Due to the difficulty in separating the coating from the crust, thickness measurements of the coating were obtained by taking into account the thickness of the entire product at four different areas of each picture. For this measure, a previously calibrated software tool was used. The difference in thickness between the uncoated and the three differently coated samples allowed us to calculate approximately the coating thickness for each pastry.

The ricotta cream was prepared by mixing for 5 min all ingredients with a food processor (Multichef, Ariete, Firenze, Italy) in the following amounts: 1,000 g of ricotta, 400 g of sugar, and 0.5 g of vanillin. Ricotta humidity was 68.92% ± 0.16%. It was calculated by thermogravimetric analysis at 130°C for 15 to 18 min by means of a thermobalance (Sartorius, Ravenna, Italy).

In order to study crust hydration kinetics, coated and uncoated cannoli were first weighed and then internally covered with sterile gauze to facilitate the removal of the ricotta cream; afterward, each cylindrical pastry was stuffed with 40 g of the previously prepared ricotta dough. All stuffed cannoli were stocked at room temperature (relative humidity 50%) for 5 days. Each pastry crust was weighed, at selected times, after removing the ricotta stuffing by means of the sterile gauze. The crust hydration kinetic was followed for 100 h and comprised very short intervals at the beginning of the assay and larger intervals after 50 h. The increase in crust moisture content was determined according to the expression

\[
\%U(t) = \frac{W_f - W_i}{W} \cdot 100
\]

where \(\%U(t)\) is the percentage crust water content at time \(t\), \(W_f\) is the crust weight at time \(t\), and \(W_i\) is the initial crust weight. The crust weight was assessed by means of a digital precision balance (+0.1 g; Gibertini, Europe, Italy). At each sampling period, the crust weight was measured twice on two different cannoli.

Second step: optimization of ricotta stuffing. The second step was focused on ricotta stuffing. Raw materials with the same characteristics reported in the previous step were purchased from a local market and used to prepare the ricotta-based stuffing, according to the same procedure reported above. Two different, natural active compounds were added to the prepared stuffing: lemon extract (Citrus Medica Limonum Oil, 100%; Akott, Milan, Italy) and lysozyme (about 50,000 units/mg protein from chicken egg white; Sigma Aldrich, Milan, Italy) with Na₂-EDTA (50 mM; J. T. Baker, Milan, Italy). Both lemon extract and lysozyme were added at concentrations of 2,000, 3,000, and 4,000 ppm, respectively. The lemon extract was dissolved directly in the ricotta cream, whereas the lysozyme was first dissolved in 1 ml of distilled water and then added to the ricotta mixture after adding Na₂-EDTA. As control, stuffing without any natural compound was also used. The various ricotta stuffings were distributed in polypropylene tubes with polycarbonate covers (Ferro-Past, Vimodrone, Italy) and having a volume of 120 ml. All samples were stored at a refrigerated temperature (4°C). Microbiological analyses, sensory analyses, and determination of pH were made during 7 days.

For microbiological analyses, each type of stuffing (10 g) was diluted with 90 ml of sterile saline solution (0.9% NaCl) in a stomach bag and homogenized for 1 min in a stomacher (InterScience, Saint Nom La Bretèche, France). Serial dilutions of stuffing homogenates were plated onto the surface of the appropriate media in petri dishes. The media and the conditions used were as follows: plate count agar incubated at 7°C for a week, or 30°C for 48 h, for total psychrotrophic and mesophilic bacteria counts, respectively; Pseudomonas agar base with cephaloridine-fucidin-cetrimide selective supplement incubated at 25°C for 48 h for Pseudomonas spp.; deMan Rogosa Sharpe agar supplemented with cycloheximide (100 mg/liter; Sigma-Aldrich) incubated under anaerobiosis (AnaeroGen gas pack, Oxoid, Milan, Italy) at 37°C for 48 h for lactic acid bacilli; Sabouraud dextrose agar supplemented with chloramphenicol (0.1 g/liter) incubated at 25°C for 48 h for yeasts and 5 days for molds; and violet red bile agar incubated at 37°C for 24 h for total coliforms. All media were from Oxoid (Milan, Italy). The microbiological analyses were carried out twice on two different batches.

The measurement of pH was conducted twice on each homogenized stuffing sample, at each sampling time, by means of a pH meter (Crisson, Barcelona, Spain).
A panel of five judges, consisting of researchers of the Department of Food Science (Agricultural Faculty) of the University of Foggia, used a hedonic scale ranging from 1 to 5 (where 1 = dislike very much and 5 = like very much) to quantitatively determine the overall quality of the investigated samples, according to a similar procedure reported in the literature (7, 13, 16). Moreover, panelists were also asked to determine color, odor, and appearance of each ricotta mixture. In fact, panelists were asked to base their decision on overall quality only by taking into account color, odor, and appearance. Therefore, sample overall quality was considered as an average of the above-mentioned sensorial attributes. A score of 3 was used as the threshold for product acceptability. During the test sessions, the samples presentation order was randomized.

Third step: integrated approach between process and packaging. Three layers of zein coating and 2,000 ppm of lemon extract were selected as adequate to prepare stuffed cannoli for the last trial. Cannoli, ricotta, and various ingredients were purchased from a local market, as described previously. Afterward, coated and uncoated cannoli samples were stuffed with the ricotta mixture (with and without lemon extract). For packaging, each stuffed pastry was placed in a polystyrene tray (Sirap-Gema, Brescia, Italy) containing blotting paper and packaged in two types of microperforated bags made up of multilayer polypropylene films (35 by 50 cm, thickness of 19 mm; OPTI 320, Sealed Air, Passirana di Rho, Italy), deemed pack 1 and pack 2. The difference between the two selected films was in the diameter of holes (0.9 and 0.5 mm for packs 1 and 2, respectively), and in the number of holes per unit of area (66 and 200 holes per in² [per ca. 6.45 cm²]) for packs 1 and 2, respectively, in such a way as to obtain two films with similar water vapor transport properties (38°C and 100% relative humidity were 580 and 600 g/m² 24 h for packs 1 and 2, respectively). All cannoli samples were stored at 4°C.

The samples of cannoli were used for a sensory evaluation, performed according to the procedure reported above.

Two samples of each batch were also used daily for microbiological analyses and pH measurement, according to the same procedures described above. Briefly, total mesophilic and psychrotrophic bacteria, *Pseudomonas* spp., lactic acid bacteria, total coliforms, yeasts, and molds were enumerated on each specific medium.

**MAL determination.** In order to determine the microbial acceptability limit (MAL) (i.e., the storage time at which the viable cell concentration reached its threshold value), the Gompertz equation as reparameterized by Corbo et al. (10), was fitted to the microbiological experimental data related to *Pseudomonas* spp. and total coliforms of both second and third steps:

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

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, \(\mu_{\text{max}}\) is the maximal specific growth rate, \(\lambda\) is the lag time, \(N_{\text{max}}\) is the microbial threshold value, \(MAL\) is the microbiological acceptability limit [i.e., the time at which \(N(t)\) is equal to \(N_{\text{max}}\)], and \(t\) is the storage time. The value of \(N_{\text{max}}\) was set to \(10^6\) CFU/g for *Pseudomonas* spp. and \(10^8\) CFU/g for coliforms. The latter microbial level is generally imposed by law (DPR 54/97, European Union, 1997), whereas the former is the contamination level at which the alterations of the product start to appear (1).

**SAL determination.** To determine the sensory acceptability limit (SAL) of the studied pastry, a first-order kinetic-type equation was fitted to the sensory data of both second and third steps:

\[
SA(t) = \frac{SA_{\text{min}} - SA_0 \times \exp(-k \times SAL)}{1 - \exp(-k \times SAL)} + \frac{SA_0 - SA_{\text{min}}}{1 - \exp(-k \times SAL)} \times \exp(-k \times t)
\]

where \(SA(t)\) is the cannoli sensory attribute at time \(t\), \(k\) is the kinetic constant, \(SA_0\) is the initial value of the cannoli sensory attribute, \(SA_{\text{min}}\) is the sensory attribute threshold value for the investigated pastry, SAL is the sensory acceptability limit (i.e., the time at which \(SA(t)\) is equal to \(SA_{\text{min}}\)), and \(t\) is the storage time.

**Statistical analyses.** To determine whether significant (\(P < 0.05\)) differences existed among the mean values of the fitting parameters (MAL and SAL, respectively), one-way analysis of variance and Duncan’s multiple range test with the option of homogeneous groups were used by means of STATISTICA 7.1 for Windows (StatSoft, Inc., Tulsa, OK).

**RESULTS AND DISCUSSION**

An integrated approach was proposed to extend the shelf life of cannoli. In particular, low-environmental-impact technologies, such as zein-based edible coating, natural antimicrobial compounds in the stuffing, and polypropylene for packaging, were combined to prolong the shelf life of the pastry. The work was articulated in three subsequent steps: first, the effectiveness of zein edible coating in reducing the water uptake of the pastry cylindrical shell was examined; second, the antimicrobial activity of two different natural compounds against the main spoilage ricotta microorganisms was evaluated; and third, microperforated films performance in prolonging the shelf life of stuffed pastry was assessed. The above-mentioned steps are presented and discussed separately.

**First step: pastry water uptake.** Figure 1 shows the pastry shell water uptake plotted as a function of time. The curves shown in the figure were drawn only with the aim of highlighting the trend of data. As can be observed, all the water uptake kinetic curves showed an overshoot. In fact, the pastry experienced two main mass fluxes: the first was driven by the difference between the relative humidity of the inner stuffing and that of the pastry crust, and it was always directed toward the pastry crust; i.e., the stuffing-crust mass flux (SCMF), whereas the second came from the difference between relative humidity of the pastry crust and environmental humidity, and it can be directed either out from the pastry shell or toward the pastry shell, i.e., the crust-environment mass flux (CEMF). At the very beginning, both the SCMF and CEMF were directed toward the crust, as the latter had a relative humidity lower than that of both stuffing and environment; consequently, an increase in the
pastry shell water content can be observed. With increased contact time between stuffing and crust, the pastry shell humidity increased, so the CEMF decreased until it reversed its direction, whereas the SCMF steadily decreased. When the sorption kinetic curve reached a peak, the CEMF was directed out of the crust, overwhelming the SCMF and bringing about a decrease in the pastry shell water content. After this, an equilibrium value in the water uptake was reached, where the two mass fluxes equaled each other. The data shown in Figure 1 suggested that zein-based coatings reduced the amount of water absorbed by the pastry crust. Literature data also confirmed that an edible coating could act as a barrier to moisture migration (26, 29–31). In particular, the zein coating acted as a barrier to water migration from the stuffing to the shell, therefore reducing the SCMF. A reduction in the SCMF brings about a reduction in the maximum amount of water absorbed by the pastry. Data shown in Figure 1 also highlighted that one- and two-layer coatings showed a similar behavior, whereas a three-layer coating strongly reduced the maximum pastry shell water content. It is worth noting that data collection for the control sample was limited to about 30 h, since with high pastry water content, it was not possible to handle cannoli for the measurements.

These results could be also related to the thickness of the coating layer. Commonly used tools do not allow precise measurement of the coating thickness because cannoli has an uneven surface. Therefore, in this work, image analysis was used to measure the thickness of the edible layers. Figure 2 shows the section images of each coated and uncoated pastry. As can be seen, each zein coating was completely joined with the crust; thus, no substantial difference between the samples is evident. The adopted technique was useful to calculate the difference in thickness between the investigated samples. Average values equal to 0.084 ± 0.056, 0.102 ± 0.0619, and 0.149 ± 0.34 mm were obtained for one-, two-, and three-layer-coated cannoli, respectively. As can be inferred from the obtained results, increasing the number of coating layers does not assure a proportional increase in coating thickness, most probably because the merging process occurs when a new layer is spread over the older one. Increasing the number of layers could moderate this phenomenon. In fact, with a three-layer coating, a slight increase in thickness was recorded, thus justifying the differences recorded in the water uptake kinetics.

**Second step: microbial growth in ricotta stuffing.**

Figure 3a and 3b shows the evolution of *Pseudomonas* spp. and total coliforms viable cell concentration plotted as a function of storage time for all the tested samples. The MAL$_{Pseudomonas}$ and MAL$_{coliforms}$ were determined according to the fitting procedure (equation 1) reported above. As can be inferred, for both microbial groups, the viable cell concentration of the control samples went above the respectively selected threshold values ($10^6$ CFU/g for *Pseudomonas* spp. and $10^5$ CFU/g for coliforms). The obtained MAL values for these samples were $3.28 ± 0.391$ and $5.29 ± 0.505$ days for *Pseudomonas* spp. and total coliforms, respectively. For all the other ricotta samples, the viable cell concentration of these two spoilage microbial groups was below the threshold value during the entire observation period, suggesting that both types of antimicrobial agents were effective in preventing microbial proliferation, with a comparable effect at all tested concentrations. Scientific literature is abundant in works dealing with antimicrobial effect of natural active agents.

![FIGURE 1. Section images of coated pastry samples and of an uncoated pastry sample.](image1)

![FIGURE 2. Pastry shell water uptake kinetic plotted as a function of storage time. The kinetics were followed at room temperature for 5 days. (o) Uncoated cannoli, (▲) cannoli with a monolayer coating, (△) cannoli with a bilayer coating, (■) cannoli with a three-layer coating.](image2)
extracted from plants or from animal sources (4, 25); however, no data are available on ricotta or ricotta-based stuffing for confectionery products. For example, dairy researches have demonstrated that lemon extract may exert an inhibitory effect on the same spoilage microorganisms, being dissolved in mozzarella cheese brine or in a gel put in contact with mozzarella cheese (8, 16). In addition, Sinigaglia et al. (34) and later Conte et al. (7) demonstrated the effectiveness of lysozyme and EDTA with regard to dairy spoilage flora growth, when these compounds were dissolved in the brine of mozzarella or incorporated in an alginate-based coating applied to the fresh cheese.

With respect to other microbial groups studied in this work (data not shown), the trends for mesophilic and psychrotrophic bacteria were found similar to those of *Pseudomonas* spp. and total coliforms, confirming the antimicrobial properties of the selected active compounds even on total bacterial counts (16). No molds were recorded in ricotta, whereas the yeast population proliferated from $10^2$ to $10^6$ CFU/g during the first 4 days, regardless of the active compound incorporated in the stuffing, in accordance with what reported in the literature for other dairy products (16). Similar to yeasts, the count of lactic acid bacilli seemed to be a little affected by the presence of the selected natural preservatives. Over the broad spectrum, their concentration increased from $10^4$ to $10^7$ CFU/g throughout the storage period, suggesting that the selected antimicrobial agents did not control the growth of lactic acid bacteria. In fact, among the generally sensitive gram-positive bacteria, lactic acid bacteria are the most resistant to essential oils (2, 8, 16, 33).

With respect to pH measurements (data not shown), the values ranged between 5.5 and 6.5, without any substantial difference between the tested samples; therefore, it is reasonable to suggest that the antimicrobial effectiveness of the investigated active compounds cannot be reflected by changes in the pH values.

Figure 4 shows the stuffing overall quality plotted as a function of storage time for all the investigated samples. The curves shown in the figure were obtained by fitting equation 2 to the sensory data. The SAL values of each sensory attribute, obtained according to the fitting procedure described above, are listed in Table 1. It is worth noting that the SAL values were determined only for sensory data whose attribute at the end of the observation period received a score lower than the threshold value (i.e., a score of 3). As can be inferred from the table, the sensory quality was acceptable at least up to 8 days, thus not representing a limiting factor for the stuffing shelf life, if the microbial quality was considered. A slightly better result was observed for lemon extract–loaded samples, even at the lowest concentration, thus allowing the selection of this compound for the subsequent last step.

**Third step: packaging system.** As reported above, a three-layer coating was used to slow the pastry-crust water uptake, as it was the most effective moisture barrier coating.
among those tested in this work. The stuffing pastry was loaded with lemon extract at 2,000 ppm, as there were no differences among the three tested lemon concentrations from a microbiological point of view and, in addition, the lemon extract–loaded stuffing received a slightly better sensory score when compared with ricotta with lysozyme and EDTA (Table 1). In fact, citrus extract imparted a pleasant odor to the dairy product, highly valued by all panelists. The two selected microperforated films, even though characterized by similar water vapor barrier properties, were selected for their different potential commercial applications because of a different printable area.

Figure 5a and 5b shows the Pseudomonas spp. and total coliforms viable cell concentration plotted as a function of storage time for all stuffed cannoli, prepared according to the procedure described in the third step. MAL values were calculated as above; results are listed in Table 2. The data shown in Table 2 highlighted that the microbial growth observed in cannoli was faster than that measured for the stuffing as standalone (MALPseudomonas and MALcolioms). Most probably, this is due to the different processing conditions necessary to prepare and package the stuffing alone and the stuffed cannoli (14). As expected, cannoli pastries with active stuffing show MALPseudomonas and MALcolioms higher than those of the control, regardless of the microperforated film adopted in this experiment. Concerning the influence of packaging material, as expected, there was only a slight difference between the two types of packaging on microbial growth. In fact, even though the selected films had different available printing areas that allowed using them for different commercial applications, they exerted very comparable microbial shelf life extension because of their similar barrier properties. For other counted microorganisms (data not shown), the growth kinetics were similar to those recorded in the previous step, relative to the control and the active ricotta mixtures.

The pH also did not change greatly throughout storage, without difference among the various samples (data not shown); a slight decrease was observed in all tested cannoli, approximately 6.0. As reported in the literature for other soft cheeses, the correlation between

<table>
<thead>
<tr>
<th>Sample</th>
<th>Color</th>
<th>Odor</th>
<th>Appearance</th>
<th>Overall quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>&gt;8</td>
<td>7.70 ± 0.974</td>
<td>&gt;8</td>
<td>7.64 ± 0.289</td>
</tr>
<tr>
<td>Lemon (2,000 ppm)</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
</tr>
<tr>
<td>Lemon (3,000 ppm)</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
</tr>
<tr>
<td>Lemon (4,000 ppm)</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>&gt;8</td>
</tr>
<tr>
<td>Lysozyme (2,000 ppm)</td>
<td>&gt;8</td>
<td>&gt;8</td>
<td>7.48 ± 0.553</td>
<td>8.22 ± 0.659</td>
</tr>
<tr>
<td>Lysozyme (3,000 ppm)</td>
<td>&gt;8</td>
<td>8.43 ± 1.54</td>
<td>7.25 ± 0.504</td>
<td>8.06 ± 0.871</td>
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<tr>
<td>Lysozyme (4,000 ppm)</td>
<td>&gt;8</td>
<td>8.12 ± 1.03</td>
<td>8.93 ± 0.767</td>
<td>8.22 ± 0.417</td>
</tr>
</tbody>
</table>

Values are means ± standard deviations.
TABLE 2. SAL, MAL, and shelf life values of stuffed cannoli samples stored in each packaging system at 4°C

<table>
<thead>
<tr>
<th>Sample</th>
<th>Shelf life (days)</th>
<th>Microbiological quality (MAL) (days)</th>
<th>Sensory quality (SAL) (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control pack 1</td>
<td>7.20 ± 1.16 A</td>
<td>1.66 ± 0.35 A</td>
<td>4.68 ± 0.1670 A</td>
</tr>
<tr>
<td>Active pack 1</td>
<td>7.20 ± 1.16 A</td>
<td>1.66 ± 0.35 A</td>
<td>4.68 ± 0.1670 A</td>
</tr>
<tr>
<td>Control pack 2</td>
<td>7.20 ± 1.16 A</td>
<td>1.66 ± 0.35 A</td>
<td>4.68 ± 0.1670 A</td>
</tr>
<tr>
<td>Active pack 2</td>
<td>7.20 ± 1.16 A</td>
<td>1.66 ± 0.35 A</td>
<td>4.68 ± 0.1670 A</td>
</tr>
</tbody>
</table>

Values are means ± standard deviations.

Figure 6 shows the stuffed cannoli overall quality plotted as a function of the storage time. The calculated SAL values are listed in Table 2. As expected, the active sample packaged in both microperforated films showed SAL values higher than those of the controls. In fact, zein coating, slowing down the pastry shell water uptake kinetic, increased the value of SAL and pH evolution can be evenly suggested (32, 37).

As can be inferred from the data listed in Table 2, microbial growth remained the restrictive quality parameter for both the active and the control samples. However, an increment in the shelf life higher than 100% was observed for the active samples packaged in both microperforated films, due to the combined technological strategies adopted. Therefore, the results confirmed that the combination of different preservation strategies could significantly prolong the shelf life of cannoli, being effective both in preventing softening of the crust and slowing down microbial spoilage of ricotta. The selected microperforated films seemed to contribute in the same way to cannoli preservation, having similar barrier properties but with different available area for proliferation of lactic acid bacteria and pH evolution.

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printing. The experimental data clearly indicated that the studied integrated approach could receive industrial attention by producers of such pastry products. From a scientific viewpoint, additional work could be oriented toward testing new antimicrobial compounds able to further extend the shelf life of pastries.

REFERENCES