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Survival and Growth of *Listeria monocytogenes* and Enterohemorrhagic *Escherichia coli* O157:H7 in Minimally Processed Artichokes

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ABSTRACT

The ability of *Listeria monocytogenes* and *Escherichia coli* O157:H7 inoculated by immersion (at 4.6 and 5.5 log CFU/g, respectively) to survive on artichokes during various stages of preparation was determined. Peeling, cutting, and disinfecting operations (immersion in 50 ppm of a free chlorine solution at 4°C for 5 min) reduced populations of *L. monocytogenes* and *E. coli* O157:H7 by only 1.6 and 0.8 log units, respectively. An organic acid rinse (0.02% citric acid and 0.2% ascorbic acid) was more effective than a tap water rinse in removing these pathogens. Given the possibility of both pathogens being present on artichokes at the packaging stage, their behavior during the storage of minimally processed artichokes was investigated. For this purpose, batches of artichokes inoculated with *L. monocytogenes* or *E. coli* O157:H7 (at 5.5 and 5.2 log CFU/g, respectively) were packaged in P-Plus film bags and stored at 4°C for 16 days. During this period, the equilibrium atmosphere composition and natural background microflora (mesophiles, psychrotrophs, anaerobes, and fecal coliforms) were also analyzed. For the two studied pathogens, the inoculum did not have any effect on the final atmospheric composition (10% O_2, 13% CO_2) or on the survival of the natural background microflora of the artichokes. *L. monocytogenes* was able to survive during the entire storage period in the inoculated batches, while the *E. coli* O157:H7 level increased by 1.5 log units in the inoculated batch during the storage period. The modified atmosphere was unable to control the behavior of either pathogen.

Minimally processed fresh products include peeled, washed, and cut fresh vegetables and fruits that are ready to eat directly from the package or after a heat treatment. The artichoke (*Cynara scolymus* L.) is a highly valued vegetable in Spain, where its annual production level is 350,000 ton. To facilitate the artichoke's consumption, a procedure to market it as a minimally processed fresh product has been developed. This procedure includes peeling, sanitation, antibrowning treatment, and packaging under optimal conditions to preserve sensory quality under refrigeration.

The preparation of vegetables before packaging leads to cell and tissue damage. As a consequence of such damage, vegetable spoilage is accelerated and color and texture changes, as well as the generation of off-odors, occur. Color changes, mainly due to enzymatic browning reactions, are one of the main causes of artichoke quality losses *(50)*.

To extend the shelf life of minimally processed artichokes, it is necessary to use conditions that minimize enzymatic browning. Thus, it is necessary to implement careful handling and sanitation processes; expose the vegetable to ascorbic acid and citric acid; maintain the cold chain during the processing, storage, and distribution stages; and create an adequate modified atmosphere in the package.

There is a great concern about the microbiological safety of minimally processed vegetables. Under the minimal preparation, packaging, and storage conditions necessary to preserve the visual quality of the vegetable, pathogen growth may occur or even be stimulated before spoilage becomes evident *(42)*. Thus, handling and liquid losses during the preparation stage facilitate the dissemination and growth of microorganisms. The sanitation stage also raises a concern: the lack of effectiveness of the disinfection methods (e.g., immersion in chlorinated water) usually applied to vegetables has been demonstrated by different authors *(11, 24)*. After packaging, the modified atmosphere can allow the growth of microaerophilic microorganisms that may be psychrotrophic, and surviving pathogens may find adequate conditions for growth *(7, 33)*.

Listeria monocytogenes is of particular concern because of its ability to grow at low O_2 concentrations and at low temperatures *(9, 10)*. It can be present on fresh vegetables and is also psychrotrophic *(20)*. Indeed, several authors have reported that *L. monocytogenes* can survive and grow at refrigeration temperatures on packaged fresh products *(22, 29)*. Thus, this pathogen can grow on modified-atmosphere-packaged fresh-cut vegetables, although the extent of growth depends on the type of vegetable and the temperature involved *(16)*. Although no outbreaks involving *L. monocytogenes* in artichokes have been yet reported, the Spanish regulations applied to minimally processed vegetables set the maximum level for this pathogen at 2 log CFU/g in the final product *(12)*. For this reason, it is necessary to study the behavior of *L. monocytogenes* in these products.

In turn, foodborne *Escherichia coli* O157:H7 outbreaks have been associated with lettuce *(2)*, alfalfa sprouts *(18)*,

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and coleslaw *(49)*. Researchers have shown that *E. coli* O157:H7 can survive or grow on lettuce *(8)*, apples *(13)*, cantaloupe and watermelon *(19)*, and salad vegetables *(1)*. The similarities between the characteristics of these products and those of the artichoke make the study of the behavior of this pathogen interesting, although no artichoke-related *E. coli* O157:H7 outbreak has been reported so far.

Both *L. monocytogenes* and *E. coli* O157:H7 can contaminate vegetables during production. For example, manure and other animal wastes are widely used in agriculture. The use of manure as fertilizer causes concern because of the possible contamination of the produce with microbial pathogens, particularly *E. coli* O157 *(34)*. Runoff water from cattle feedlots and improperly treated sewage sludge used to irrigate the soil are other possible sources of contamination with *E. coli* O157:H7. The ubiquity of *L. monocytogenes* and its known presence in food-processing environments *(28)* explain the difficulty in producing minimally processed foods free of this pathogen. Recent outbreaks of listeriosis linked to vegetables like corn salad *(5)* have turned the focus to cross-contamination of processed foods from environmental sources *(45)*.

Contamination can also occur during the production stage through direct or indirect contact of the processed or semiprocessed produce with contaminated raw materials or through contact with contaminated handlers or equipment. Indeed, postprocessing contamination of food persists as a serious public health problem, particularly in the production of minimally processed and ready-to-eat foods *(24)*.

The objectives of the present study were to evaluate (i) the ability of *L. monocytogenes* and *E. coli* O157:H7 inoculated on artichokes to survive during the preparation stages and (ii) the behavior of these pathogens during the storage of packaged minimally processed artichokes. The survival and growth of the natural background microflora on artichokes during the storage period and the possible interactions with inoculated pathogens are also discussed.

MATERIALS AND METHODS

Preparation of *L. monocytogenes* and *E. coli* O157:H7 inocula. *L. monocytogenes* serovar 4b strain CECT 4032 (NCTC 11994), isolated from soft cheese and recommended by the Spanish Type Culture Collection (CECT; www.uv.es/cect) as a phenotypically typical strain, was grown in brain heart infusion broth (Unipath-Oxoid U.S., Columbia, Md.) for 18 h. The culture was then transferred to a sterile centrifuge bottle and centrifuged at 10,000 × *g* at 4°C for 10 min. The supernatant was decanted and the pellet was resuspended in a 0.1 M potassium phosphate buffer (pH 7.0) by vortexing. The washing step was repeated twice. The suspension of washed cells was diluted in a potassium phosphate buffer. Just before the artichokes were inoculated, the volume necessary to obtain the appropriate cell concentration was diluted in warm (20°C) water.

E. coli O157:H7 strain CECT 4782 (ATCC 43894), isolated from a human stool specimen obtained from an outbreak of hemorrhagic colitis, was prepared in the same way with tryptone soy broth (TSB; Unipath-Oxoid U.S.) for its growth.

Artichoke inoculation before processing. An appropriate suspension of *L. monocytogenes* or *E. coli* O157:H7 was prepared in water at 20°C (7.2 and 7.4 log CFU/ml, respectively). After being completely immersed in the inoculum for 15 min, fresh artichokes (of the Blanca de Tudela variety; obtained from growers in the area and stored for ca. 24 h at 4°C before processing) were drained for about 2 h at room temperature to remove the excess inoculum. After inoculation, the artichokes were aseptically peeled, washed, and rinsed as described below.

The leaves, stalks, and outermost bracts were manually removed. Then, the artichokes were washed with 50 mg liter^{-1} of chlorinated water at 4 ± 2°C (10 liters/kg) by immersion for 5 min *(44)*. Subsequently, the artichokes were rinsed by immersion for 5 min in two different ways: with the use of tap water and with the use of a 0.02% citric acid–0.2% ascorbic acid solution *(26)*. Then, the artichokes were taken out and the excess water was removed by centrifugation with a manual centrifuge. The survival of the inoculated pathogen after each prepackaging operation was determined. The experiment was replicated twice.

Artichoke contamination before packaging. Peeled, disinfected, and washed artichokes were inoculated before packaging by the same procedure used for fresh artichokes (with inoculum concentrations of 7.8 and 7.3 log CFU/ml for *L. monocytogenes* and *E. coli* O157:H7, respectively). Subsequently, groups of six artichokes were packaged in bags (20 by 25 cm) of an antimist-coated oriented polypropylene P-Plus film (35 μm thick) with an O_2 permeability of 15,000 cm^3 m^{-2} 24 h^{-1} at 25°C (according to the specifications of the manufacturer [Danisco, Bristol, UK]). The bags were thermally closed and stored under refrigeration (at 4°C) for 16 days.

Samples were taken on days 0, 1, 2, 4, 7, 10, 14, and 16. A number of microbiological analyses (to determine mesophile, psychrotroph, anaerobe, and fecal coliform counts and the survival of the inoculated pathogen) were performed, and the gas composition in the package was determined for each sample. A noncontaminated control batch was analyzed in the same way. The experiment was replicated twice.

Microbiological analysis. Artichokes were chopped under sterile conditions, and 25 g was aseptically weighed and homogenized for 2 min with 225 ml of sterile soy peptone water (0.1% soy peptone plus 0.5% sodium chloride) with a Stomacher (IUL, Barcelona, Spain). Further decimal dilutions were prepared with the same diluent. Mesophilic microorganisms were enumerated on plate count agar (Difco Laboratories, Detroit, Mich.) by the pour plate method and incubated at 31 ± 1°C for 72 h *(35)*. Psychrotrophs were evaluated on plate count agar (Merck, Darmstadt, Germany) after incubation at 7°C for 10 days by the pour plate method *(35)*. Fecal coliforms were evaluated by the most probable number method for a three-tube series with brilliant green bile lactose broth (Difco) incubated at 44°C for 48 h *(35)*. Anaerobic microorganisms were evaluated on plate count agar by the pour plate method and incubated under anaerobic conditions at 31 ± 1°C for 72 h *(35)*.

L. monocytogenes was enumerated by plating on Palcam agar (Merck) by the surface plate method with incubation at 37°C for 48 h *(41)*. Suspected colonies on Palcam agar were identified with API *Listeria* strips (BioMérieux, Marey Létoile, France). To determine the presence of *L. monocytogenes* in noninoculated samples, an enrichment step with *Listeria* enrichment broth (Merck), which contains cycloheximide, was included.

E. coli O157:H7 was enumerated by plating onto sorbitol MacConkey agar supplemented with cefixime-tellurite (Unipath-Oxoid U.S.) by the surface plate method with incubation at 37°C for 48 h. Suspected colonies were identified by the *E. coli* O157 Latex test (Unipath-Oxoid U.S.). To determine the presence of *E. coli* O157:H7 in noninoculated samples, an enrichment step using

TABLE 1. L. monocytogenes *and* E. coli *O157:H7 survival at different points of the prepackaging operations*

Prepackaging stage	Count (CFU/g) of pathogen[a]	
	L. monocytogenes	*E. coli* O157:H7
Inoculation	4.6 ± 0.3 B	5.5 ± 0.2
Peeling	4.6 ± 0.2 B	5.7 ± 0.2
Washing with 50-ppm Cl solution	3.7 ± 0.2 AB	5.1 ± 0.1
After rinse with tap water	3.6 ± 0.1 AB	5.0 ± 0.2
After rinse with ascorbic–citric acid solution	3.0 ± 0.1 A	4.7 ± 0.2

[a] Average ± standard deviation for two experiments each involving two samples. Means with different letters in the same column are significantly different ($P < 0.05$).

E.C. broth (with reduced bile salts; Unipath-Oxoid U.S.) was included. All analyses were performed in duplicate.

Other determinations. Carbon dioxide and oxygen were determined with an O_2 and CO_2 headspace gas analyzer (Checkmate model 9900, PBI-Dansensor, Denmark). For each measurement, the analyzer automatically extracts with a needle inserted into the container a small amount of gas, which is immediately analyzed. The determinations were carried out in duplicate. To measure the pH of the product, 25 g of artichoke was blended for 2 min with 25 ml of distilled and deionized water (pH 7). The pH of the macerate was determined with a Crison model 2002 pHmeter (Crison Instruments, Barcelona, Spain). Water activity (a_w) was measured at 20°C with a CX-1 dew-point hydrometer supplied by Decagon Devices (Pullman, Wash.).

Statistical analysis. The experiments were replicated twice for each condition tested, and all of the analyses were performed in duplicate. Variance analysis was performed with the SPSS software for Windows (Statistics version 10.0). Significance was defined as $P < 0.05$. Tukey's test was run for the comparison of means with the same program. Means with different letters in the same column differed significantly. The plate count data were transformed to log values before statistical analysis.

RESULTS AND DISCUSSION

Survival of *L. monocytogenes* and *E. coli* O157:H7 in the artichoke after prepackaging operations. Artichokes (pH 6.6 ± 0.2; a_w, 0.98 ± 0.01) were inoculated separately with *L. monocytogenes* and *E. coli* O157:H7. Table 1 summarizes the counts for both pathogens during the prepackaging operations. After immersion of artichokes in the inoculation suspension of *L. monocytogenes* (7.2 log CFU/ml) for 15 min, the artichokes contained *L. monocytogenes* levels of 4.6 log CFU/g. The peeling stage did not have any impact on the presence of *Listeria*. Disinfection with chlorinated water caused a reduction of about 1 log unit. This result is in agreement with that of Lee et al. *(38),* who reported that treatment of *L. monocytogenes*–inoculated mung bean sprouts with 200 ppm of sodium hypochlorite reduced pathogen counts by 1 log unit. This reduction did not result in further increases during the rinse stage, when tap water was used. However, the use of an ascorbic–citric acid rinse solution caused an additional reduction of about 0.5 log unit.

On the other hand, as can be seen in Table 1, after immersion for 15 min in a suspension of *E. coli* O157:H7 (at 7.4 log CFU/ml), the artichokes contained initial *E. coli* levels of 5.5 log CFU/g. The peeling step led to a slight increase in levels of *E. coli,* probably due to recontamination during handling. Disinfection with chlorinated water resulted in a reduction of only 0.6 log units. This reduction did not result in further increases in *E. coli* levels during the rinse stage, when tap water was used. However, the use of an ascorbic–citric acid rinse solution caused an additional reduction of about 0.4 log units.

It is important to note that the sanitation method used (immersion in 50-ppm chlorine water for 5 min) was initially selected because of its effectiveness in reducing the microbial load (providing a ~2-log reduction in mesophilic counts) without damaging the appearance of the artichoke *(44).* However, this procedure was not very effective against the pathogens studied in this work. Indeed, these prepackaging operations managed to reduce *Listeria* and *Escherichia* populations by only 1.6 and 0.8 log units, respectively. Moreover, the survival rates for both pathogens might be higher considering that the plating method used may not recover injured bacteria *(27, 30).*

Under the same inoculation conditions, the level of contamination with *E. coli* O157:H7 was significantly higher than the level of contamination with *L. monocytogenes.* On the other hand, the sanitation method used was more effective in reducing numbers of *L. monocytogenes.* Most *E. coli* O157:H7 isolates are not particularly resistant to chlorine *(51).* The ability of *E. coli* to attach to vegetable structures (particularly injured tissues) that play a role in protection against chlorine inactivation has already been reported by several authors *(4, 8, 14, 30).* This ability could account for the different behaviors of the two pathogens in this study.

However, Park et al. *(43)* found that acidified chlorinated water treatments were slightly more effective in killing *E. coli* O157:H7 than in killing *L. monocytogenes* on lettuce. The low pH (2.5) of the sanitizing solution used by these authors could be the reason for the differences between their results and ours.

As for the rinse stage, ascorbic acid is often used on minimally processed fruits and vegetables to improve their appearance, since it prevents browning and other oxidative reactions *(6, 37).* This effect is enhanced by the addition of citric acid *(21),* and the two acids are often used together *(48).* In a prior test, the effects of the immersion of artichokes in solutions of ascorbic acid, citric acid, and combinations of both after disinfection with chlorine were studied *(26).* Artichokes immersed in 0.2% ascorbic acid and 0.02% citric acid solutions for 5 min were found to have a better appearance than those that were only rinsed with tap water. The use of these acid solutions at higher concentrations caused off-flavors to appear in artichokes.

Some authors have reported antimicrobial activity of ascorbic acid *(3, 15, 25)* and citric acid *(39).* In our study of artichokes inoculated with *E. coli* O157:H7 and, partic-

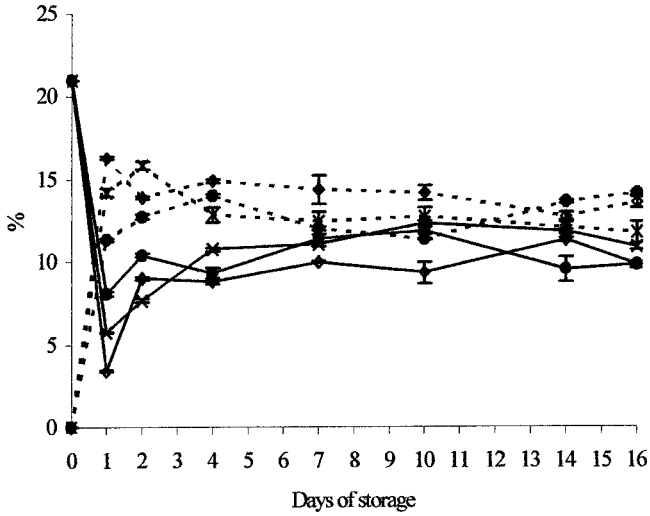

FIGURE 1. *Oxygen (——) and carbon dioxide (– – –) concentrations within packages of minimally processed artichokes.* ●, *noninoculated batch;* ◇, *batch inoculated with* Listeria monocytogenes*;* ×, *batch inoculated with* Escherichia coli *O157:H7.*

ularly, with *L. monocytogenes,* the rinse with an ascorbic-citric acid solution caused larger reductions in the counts of these microorganisms than did tap water (Table 1). Indeed, Burnham et al. *(15)* proved the effectiveness of ascorbic acid in inactivating pathogen microorganisms such as *E. coli* O157:H7 in apples.

Evolution of packaged artichokes. The ability of *L. monocytogenes* and *E. coli* O157:H7 to survive the prepackaging operations led us to study the behavior of both pathogens during the storage stage. For this purpose, peeled, disinfected, and washed artichokes were inoculated with *L. monocytogenes* (5.5 log CFU/g) or *E. coli* O157:H7 (5.2 log CFU/g) and packaged. The survival rates for these artichokes were compared with those for noninoculated artichokes (control batch) packaged and stored under the same conditions.

The kinetics of the O_2 and CO_2 changes within the packages depended mainly on the permeability of the film and the respiration rate of artichokes at 4°C (Fig. 1). Inoculation with *L. monocytogenes* or *E. coli* O157:H7 did not substantially modify the composition of the equilibrium atmosphere generated during the storage stage. Thus, for both the inoculated and the noninoculated batches, the equilibrium atmosphere was composed of about 10% O_2 and 13% CO_2. However, significant differences between the atmospheres of the packages were observed in the first 48 h. During this period, the batches inoculated with *L. monocytogenes* and *E. coli* consumed O_2 faster and exhibited increased CO_2 production. This finding could be due to the inoculation procedure (immersion in a bacterial solution at 20°C for 15 min). The higher temperature of the inoculated artichokes during the packaging stage might accelerate the respiration rate and delay the generation of the equilibrium atmosphere. The microbial load of the product may also affect the O_2 uptake and CO_2 evolution, as reported by Hotchkiss and Banco *(33).* In the present case, although pathogen inoculation caused differences in mesophilic

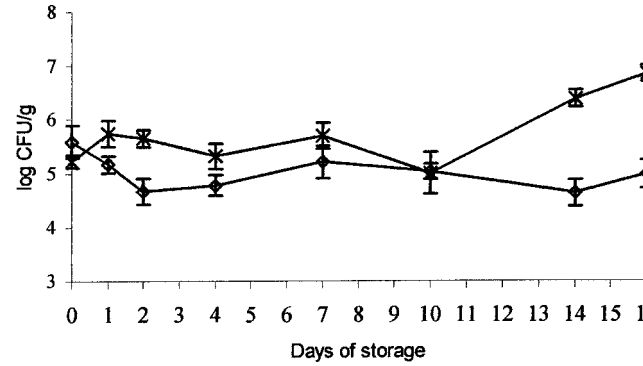

FIGURE 2. *Survival of* Listeria monocytogenes *(◇) and* Escherichia coli *O157:H7 (×) in inoculated minimally processed artichokes stored at 4°C.*

counts (Table 2), the oxygen and carbon dioxide evolution patterns for the three batches were similar.

The evolution of the natural background microflora (mesophiles, psychrotrophs, and anaerobes) is shown in Table 2. In principle, the inoculated batches showed higher counts than the noninoculated batch for all of these groups, and this difference was particularly relevant with respect to anaerobes because of the facultative anaerobic condition of the studied pathogens. These differences could be observed for the duration of the storage period studied. Indeed, the evolution patterns for the three batches were similar, and no differences between the batches inoculated with *L. monocytogenes* and the batches inoculated with *E. coli* O157:H7 were found.

It is important to note that the mesophilic counts for all of the batches at the end of storage period were only 0.5 log units higher than those observed at packaging time. This finding proves the effectiveness of the preservation method used in controlling this group of microorganisms. However, unlike the case for mesophiles, the evolution of psychrotrophs and anaerobes did not have a lag phase because of the storage conditions. Thus, the final counts of psychrotrophs for each batch were very similar to the mesophilic counts obtained on day 16. These data are in agreement with those of Garg et al. *(24),* who reported that psychrotrophic and mesophilic counts were comparable in many vegetables and that the shelf life of refrigerated vegetables was affected mainly by the psychrotrophic population.

Fecal coliform counts were <0.47 log CFU/g for all of the batches analyzed. This finding might be related to the hygienic handling conditions implemented.

Figure 2 shows the survival of *L. monocytogenes* and *E. coli* O157:H7 in inoculated minimally processed artichokes stored at 4°C. A significant decrease (of ca. 1 log unit) in the numbers of *L. monocytogenes* was observed during the first 2 days and was followed by a period during which levels of the microorganism did not increase or decrease, with counts remaining at about 4.5 log CFU/g until the end of the storage period. These results are in agreement with those reported by Francis and O'Beirne *(23)* with regard to the survival of *L. monocytogenes* on minimally processed lettuce. Likewise, Ukuku and Fett *(46)* reported that

TABLE 2. *Effects of inoculation on mesophile, psychrotroph, and anaerobe counts for minimally processed artichokes*

Microorganisms	Artichoke batch	Count (log CFU/g) of microorganisms after storage time (days)[a]						
		0	1	2	4	7	10	14	16
Mesophiles	Control batch	3.9 ± 0.3 A	3.2 ± 0.3 A	3.3 ± 0.2 A	4.0 ± 0.2 A	4.2 ± 0.3 A	4.7 ± 0.1 A	4.6 ± 0.2 A	4.5 ± 0.2 A
	Listeria batch	7.6 ± 0.3 B	6.5 ± 0.1 B	6.5 ± 0.1 B	7.4 ± 0.2 B	7.8 ± 0.1 B	8.0 ± 0.1 B	7.7 ± 0.2 B	7.8 ± 0.3 B
	E. coli O157:H7 batch	7.5 ± 0.2 B	6.5 ± 0.2 B	6.5 ± 0.1 B	7.2 ± 0.3 B	7.6 ± 0.1 B	7.7 ± 0.1 B	8.2 ± 0.2 B	7.9 ± 0.2 B
Psychrotrophs	Control batch	3.2 ± 0.2 A	3.3 ± 0.3 A	3.5 ± 0.2 A	3.7 ± 0.1 A	4.0 ± 0.2 A	3.7 ± 0.3 A	4.0 ± 0.3 A	4.0 ± 0.2 A
	Listeria batch	6.5 ± 0.3 B	6.8 ± 0.2 B	6.8 ± 0.2 B	7.3 ± 0.2 B	7.6 ± 0.1 B	7.7 ± 0.1 B	7.8 ± 0.2 B	7.9 ± 0.2 B
	E. coli O157:H7 batch	6.5 ± 0.2 B	6.6 ± 0.3 B	6.7 ± 0.2 B	7.0 ± 0.4 B	7.5 ± 0.3 B	7.4 ± 0.2 B	7.6 ± 0.2 B	7.7 ± 0.1 B
Anaerobes	Control batch	1.6 ± 0.4 A	1.6 ± 0.2 A	1.8 ± 0.3 A	2.0 ± 0.2 A	2.4 ± 0.2 A	1.9 ± 0.1 A	1.7 ± 0.2 A	2.9 ± 0.1 A
	Listeria batch	5.9 ± 0.2 B	6.0 ± 0.3 B	5.7 ± 0.2 B	5.9 ± 0.1 B	5.8 ± 0.2 B	6.2 ± 0.3 B	6.5 ± 0.2 B	6.3 ± 0.1 B
	E. coli O157:H7 batch	6.0 ± 0.3 B	5.7 ± 0.2 B	5.5 ± 0.2 B	5.6 ± 0.3 B	5.5 ± 0.2 B	5.7 ± 0.2 B	6.8 ± 0.2 B	6.8 ± 0.3 B

[a] Average ± standard deviation for two experiments each involving two samples. Means with different letters in the same column for the same group of microorganisms are significantly different ($P < 0.05$).

L. monocytogenes survived, but did not grow, on inoculated fresh-cut pieces of melon over 15 days of storage at 4°C.

E. coli O157:H7 counts on inoculated artichokes showed a general tendency to increase, particularly at the end of the storage period. *E. coli* O157:H7 levels increased throughout the storage period (except on day 10), and the final population was 1.5 log units larger than the initial one. This increase contradicts the generally accepted idea that *E. coli* O157:H7 will not multiply in refrigerated food because the lowest temperature that is conducive to the multiplication of this pathogen is 7 to 8°C *(36)*. The particular characteristics of the strain of *E. coli* O157:H7 chosen for the present study could be a reason for the results obtained. The poor effectiveness of modified atmosphere packaging in controlling the growth and survival of *E. coli* O157:H7 has already been reported by several authors *(31, 47)*. Some authors have suggested that MAP might alter the composition of the background microflora and that the survival or even the growth of pathogens may be the result of changes in the competitive balance between the pathogens and the background microflora *(17, 23, 32)*. Neither *E. coli* O157:H7 nor *L. monocytogenes* was detected in noninoculated artichokes.

The results of this study show that in spite of the efficiency of the preservation system selected to control the growth of natural background microflora in fresh artichokes, both *L. monocytogenes* and *E. coli* O157:H7 are capable of surviving on these artichokes and *E. coli* is even capable of growing on them. This finding, together with the poor effectiveness of prepackaging operations in eliminating these pathogens, is a significant source of concern.

Given that the particular characteristics of the artichoke did not allow for harder processing conditions without damage to its organoleptic qualities, it is necessary to apply extremely high standards of hygienic and sanitary quality to the raw materials and processing stages. The prevention of the contamination of artichokes with bovine feces that may contain *E. coli* O157:H7 or *L. monocytogenes* is essential for the minimization of health risks. Therefore, methods to reduce or even eliminate pathogenic microorganisms on fruits and vegetables are needed. Presently, no processing method capable of inactivating all of the pathogens present on fresh products without compromising their sensory quality exists. It is necessary to develop sanitizers that are more efficient than chlorine to eliminate pathogens without damaging the sensory and qualitative characteristics of vegetables in general and of artichokes in particular *(37, 40, 43)*.

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