APPLIED AND ENVIRONMENTAL MICROBIOLOGY, June 1990, p. 1734–1742
0099-2240/90/061734-09$02.00/0

Vol. 56, No. 6

Inhibitory Effects of Raw Carrots on *Listeria monocytogenes*

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Received 9 February 1990/Accepted 2 April 1990

The survival and growth of two strains of *Listeria monocytogenes* on raw and cooked carrots stored at 5 and 15°C and in carrot juice media at 30°C were investigated. The influence of shredding, chlorine treatment, and packaging under an atmosphere containing 3% O_2 and 97% N_2 on the behavior of *L. monocytogenes* and naturally occurring microflora was determined. Populations of viable *L. monocytogenes* decreased upon contact with whole and shredded raw carrots but not cooked carrots. Viable populations also decreased in cell suspensions in which raw carrots were dipped. Small populations of *L. monocytogenes* detected on whole carrots immediately after dipping were essentially nondetectable after 7 days of storage at 5 or 15°C. After a lag of 7 days at 5°C, significant ($P \leq 0.05$) increases in populations were detected on shredded carrots after 24 days of storage. Carrots stored at 5 or 15°C spoiled before *L. monocytogenes* grew. Populations of mesophilic aerobes, psychrophiles, and yeasts and molds increased throughout storage at 5 and 15°C. Cutting treatment (whole or shredded carrots), chlorine treatment, and modified-atmosphere packaging had no effect on the survival or growth of *L. monocytogenes* or naturally occurring microflora. The presence of raw carrot juice in tryptic phosphate broth at a concentration as low as 1% substantially reduced the maximum population of *L. monocytogenes* reached after 24 h at 30°C. The anti-*Listeria* effect of carrots was essentially eliminated when the carrots were cooked. Additional research is needed to characterize, on a molecular level, the component(s) in raw carrots which is toxic to *L. monocytogenes*.

Consumption of commercially prepared, ready-to-eat, fresh salad vegetables has increased dramatically in recent years. Although these vegetables, whether offered for sale in retail groceries, vending machines, restaurant salad bars, or in fast-food operations, are kept under refrigeration to maintain sensory qualities, the potential for growth of pathogens such as *Listeria monocytogenes* exists.

The presence of *L. monocytogenes* on decaying vegetation (17), agronomic crops (16), and silage (14) is well documented. The organism has also been isolated from radishes, cucumbers, cabbage, and potatoes (8). A large outbreak (7 adult and 34 perinatal cases) of infection due to *L. monocytogenes* occurred in the Maritime Provinces of Canada in 1979 to 1981 (12). The source of infection was attributed to ingestion of coleslaw. Ho et al. (9) suggested that consumption of raw celery, tomatoes, and lettuce may be linked to listeriosis in hospitalized, immunosuppressed patients.

L. monocytogenes has been observed to grow in lettuce juice (15) and on lettuce (L. R. Beuchat and R. E. Brackett, J. Food Sci., in press) and cabbage (3) stored at 5°C. Of 60 prepacked, ready-to-eat salads purchased in supermarkets, four salads representing two salad types contained *L. monocytogenes* (13). One salad consisted of cabbage, celery, raisins, onions, and carrots while the other consisted of lettuce, cucumber, radish, fennel, watercress, and leeks. The population of *L. monocytogenes* increased about twofold when salads were held at 4°C for 4 days.

Reported here are results from experiments designed to determine the growth and survival of *L. monocytogenes* inoculated on carrots. The effects of chlorine wash treatment, shredding, modified-atmosphere packaging, and storage at 5 and 15°C were determined. The survival and growth of microflora naturally occurring on carrots were also monitored.

MATERIALS AND METHODS

Source and preparation of carrots. Carrot (*Daucus carota*) roots (25-lb [ca. 11-kg] bags) were purchased from the Georgia State Farmers' Market, Forest Park, Ga. Raw, whole carrots (4 to 6 cm long) and carrots shredded with a Kitchen Center (Oster, Milwaukee, Wis.) equipped with a salad maker-shredder disk were subjected to treatments outlined in Fig. 1. The carrots were adjusted to the desired storage temperature (5 or 15°C) before treatments were initiated.

The growth and survival of *L. monocytogenes* on cooked carrots were also investigated. Carrots were sliced into disks about 0.5 cm thick, cooked in boiling water until tender, and cooled to 5 or 15°C before being inoculated with *L. monocytogenes*.

Preparation of *L. monocytogenes* inocula. *L. monocytogenes* Scott A and LCDC 81-861 were cultured in tryptic phosphate broth (TPB; pH 7.3) at 30°C. Preliminary studies were designed to determine the population of *L. monocytogenes* in suspensions necessary to result in about 10^4 CFU/g of raw carrots after submersion for 1 min. Cultures which had been loop transferred at 24-h intervals for a minimum of 3 successive days were diluted in 0.1 M potassium phosphate buffer (pH 7.0) to yield two suspension populations of each strain for dipping carrots. Populations of the Scott A strain in dip suspensions were 1.0×10^6 and 7.0×10^6 CFU/ml; the LCDC 81-861 strain buffered suspensions contained 7.7×10^5 and 6.1×10^6 CFU/ml. In subsequent experiments (Fig. 1), populations of *L. monocytogenes* in suspensions used for raw carrots ranged from 1.1×10^5 to 2.2×10^5 CFU/ml; suspensions used for cooked carrots contained 1.0×10^5 to 1.6×10^5 CFU/ml.

Preparation of chlorine dip. Water containing 200 to 260 μg

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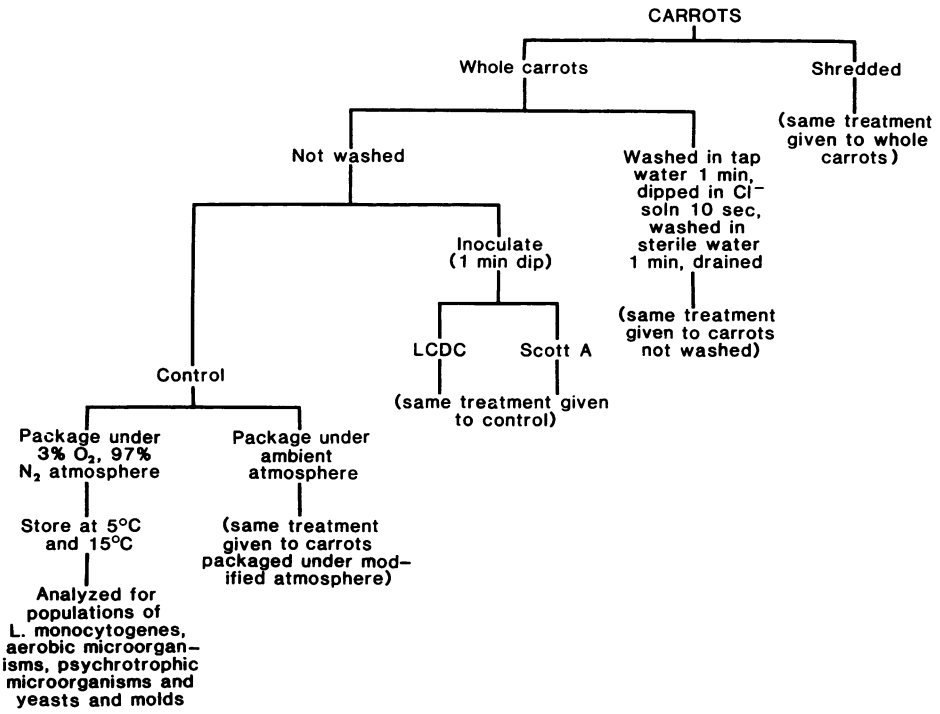

FIG. 1. Scheme for determining the effect of shredding, chlorine washing, and modified-atmosphere packaging on survival and growth of *L. monocytogenes*, mesophilic aerobes, psychrotrophic microorganisms, and yeasts and molds on raw carrots stored at 5 and 15°C.

of free chlorine per ml was prepared and analyzed according to the procedure described by Brackett (4).

Procedure for inoculating carrots. In each experiment involving raw carrots, 4 kg of whole or shredded carrots was subjected to the washing and chlorine treatments and inoculation procedures outlined in Fig. 1. The volume of dipping solutions and suspensions was 12 to 14 liters. In all instances, carrots were thoroughly drained after being dipped.

In experiments designed to determine the behavior of *L. monocytogenes* on cooked carrots, both the Scott A and LCDC 81-861 strains were tested. However, the carrots were not subjected to chlorine treatment and modified-atmosphere packaging. Cooked carrots (1.5 kg) were dipped in 5 liters of buffered suspensions of *L. monocytogenes*, drained, and sealed under an air atmosphere.

Controls consisted of cooked carrots dipped in sterile buffer.

Packaging procedure. Uninoculated (control) and inoculated raw carrots (130 to 140 g) were placed in L-Bags (Cryovac Inc., Duncan, S.C.). The oxygen transmission rate of L-Bags at 23°C is 3,000 ml/m^2 per 24 h; the water vapor transmission rate at 38°C is 0.65 ml/100 in^2 (ca. 645 cm^2) per 24 h. Half of the samples were flushed three times with a modified gas mixture containing 3% O_2 and 97% N_2 before being sealed. The other half of the samples, sealed under ambient air, served as controls. The samples were incubated at 5°C for 0, 3, 7, 18, and 24 days or at 15°C for 0, 3, and 7 days before being subjected to microbiological analyses.

Uninoculated and inoculated cooked carrots (130 to 140 g) were sealed under an air atmosphere in L-Bags and analyzed for populations of *L. monocytogenes* after 0, 3, 6, 9, and 14 days of storage at 5 and 15°C.

Procedures for enumerating microorganisms. Duplicate plates of duplicate samples from two replicate trials were examined on each date of analysis.

To determine *L. monocytogenes* populations, carrots (50 g) were combined with 200 ml of sterile 0.1 M potassium phosphate buffer (pH 7.0) and pummeled with a stomacher for 2 min. The stomacher bag was rinsed with 250 ml of buffer which was then combined with the carrot-buffer mixture. Appropriately diluted wash buffer was surface spread (0.1 ml) on modified Vogel Johnson agar (MVJA) plates (5) and incubated for 44 to 48 h at 30°C before presumptive *L. monocytogenes* colonies were counted. *L. monocytogenes* was confirmed as described by Golden et al. (7).

Populations of *L. monocytogenes* in suspensions immediately before and after raw and cooked carrots were dipped were also determined. Samples were analyzed by surface plating 0.1 ml of decimally diluted suspensions on MVJA.

Pummeled samples, appropriately diluted in buffer, were

TABLE 1. Populations of *L. monocytogenes* Scott A and LCDC 81-861 and aerobic microorganisms on carrots dipped in buffered cell suspensions

Carrot treatment	*L. monocytogenes* strain	*L. monocytogenes* population in dip[a]	Log_{10} CFU/g of vegetable	
			L. monocytogenes	Aerobic microorganisms
Whole	Scott A	Small	4.08	7.60
	Scott A	Large	5.62	7.40
	LCDC 81-861	Small	3.97	7.11
	LCDC 81-861	Large	3.54	7.23
Shredded	Scott A	Small	<2.00[b]	7.32
	Scott A	Large	<2.00	6.30
	LCDC 81-861	Small	<2.00	7.23
	LCDC 81-861	Large	2.30	6.78

[a] For Scott A: small, 1.0 × 10^6 CFU/ml; large, 7.0 × 10^6 CFU/ml. For LCDC 81-861: small, 7.7 × 10^5 CFU/ml; large, 6.1 × 10^6 CFU/ml.

[b] Lower limit for detection.

TABLE 2. Populations of *L. monocytogenes* on carrots stored at 5 and 15°C

Carrot treatment	Inoculum	Packaging atmosphere	Log_{10} CFU of *L. monocytogenes*/g[a] after storage at:							
			5°C					15°C		
			0 days	3 days	7 days	18 days	24 days	0 days	3 days	7 days
Not washed										
Whole	Control	Control	0[b]		0	0		0	0	0
		Modified	0		0	0		0	0	0
	LCDC 81-861	Control	2.48 (a)		0 (b)	0 (b)		1.80 (a)	1.10 (ab)	0 (b)
		Modified	2.48 (a)		0 (b)	0 (b)		1.80 (a)	1.40 (a)	0 (a)
	Scott A	Control	2.96 (a)		0 (b)	0 (b)		0	0	0
		Modified	2.96 (a)		0 (b)	0 (b)		0	0	0
Shredded	Control	Control	0 (a)	2.21 (a)	0 (a)		0 (a)	0	0	0
		Modified	0	0	0		0	0	0	0
	LCDC 81-861	Control	2.05 (b)	1.57 (b)	2.54 (b)		4.43 (a)	0 (b)	2.30 (a)	0 (b)
		Modified	2.05 (b)	2.24 (b)	3.87 (b)		4.54 (a)	0 (b)	3.77 (a)	0 (b)
	Scott A	Control	1.10 (b)	2.10 (b)	2.17 (b)		3.75 (a)	0	0	0
		Modified	1.10 (b)	1.80 (b)	3.10 (b)		4.40 (a)	0 (a)	3.00 (a)	0 (a)
Chlorine washed										
Whole	Control	Control	0		0	0		0	0	0
		Modified	0		0	0		0	0	0
	LCDC 81-861	Control	2.88 (a)		0 (b)	0 (b)		1.80 (a)	1.80 (a)	0 (a)
		Modified	2.88 (a)		0 (b)	0 (b)		1.80 (a)	1.40 (a)	0 (a)
	Scott A	Control	2.64 (a)		0 (b)	0 (b)		2.35 (a)	1.40 (b)	0 (b)
		Modified	2.64 (a)		1.40 (b)	0 (b)		2.35 (a)	0 (b)	0 (b)
Shredded	Control	Control	0	0	0		0	0	0	0
		Modified	0	0	0		0	0	0	0
	LCDC 81-861	Control	2.44 (b)	1.88 (b)	3.73 (b)		4.36 (a)	0 (b)	5.57 (a)	4.12 (b)
		Modified	2.35 (b)	2.84 (b)	4.09 (b)		4.62 (a)	0 (b)	5.65 (a)	3.42 (b)
	Scott A	Control	2.62 (b)	1.80 (b)	3.04 (b)		4.62 (a)	0 (b)	5.43 (ab)	5.85 (a)
		Modified	2.62 (b)	2.46 (b)	4.03 (ab)		4.38 (a)	0 (b)	4.89 (ab)	5.71 (a)

[a] Each value represents the mean of eight determinations. Values in the same row within each storage temperature which are not followed by the same letter are significantly different ($P \leq 0.05$).
[b] Less than 1.00 log_{10} CFU/g.

analyzed for total mesophilic aerobic microorganism populations by surface spreading duplicate 0.1-ml samples on plate count agar. Colonies were counted after 48-h incubation at 30°C.

Carrots were analyzed for psychrotrophic microorganism populations by surface spreading duplicate 0.1-ml samples of wash buffer on plate count agar; the plates were incubated at 7°C for 10 days before colonies were counted.

Total yeast and mold populations were determined by surface spreading duplicate 0.1-ml samples on plate count agar supplemented with 100 μg of chlortetracycline per ml. The plates were incubated at 25°C for 4 days before colonies were counted.

Investigation of anti-*Listeria* properties of carrot juice. Experiments using whole and shredded raw carrots revealed that this vegetable exhibited anti-*Listeria* activity. Experiments were therefore conducted to determine the behavior of *L. monocytogenes* when suspended in carrot juice.

Carrot juice was prepared by using a household vegetable-fruit juicer and combined with phosphate buffer to yield juice concentrations of 0, 0.1, 1.0, 10, and 100%. Scott A and LCDC 81-861 strains (24 h, TPB, 30°C) were diluted 10^{-2} in buffer, and 1.0 ml was added to 9.0 ml of diluted carrot juice. The suspensions were analyzed for viable *L. monocytogenes* after 0, 30, and 120 min of incubation at 30°C.

The effect of supplementing TPB with carrot juice on growth of *L. monocytogenes* was investigated. Double-strength TPB (5 ml per 16- by 120-mm tube), carrot juice, and sterile water were combined to result in 10-ml quantities of medium containing 0, 1.0, 10, and 50% carrot juice upon the addition of 1.0 ml of a 24-h culture of *L. monocytogenes* which had been grown in TPB at 30°C and diluted 10^{-5} in buffer. Viable *L. monocytogenes* cells were enumerated after 0, 2, 7, 12, and 24 h of incubation at 30°C.

Zones of inhibition of *L. monocytogenes* on MVJA as influenced by contact with paper disks saturated with various concentrations of carrot juice were determined. Suspensions (0.1 ml) of 10^{-4} dilutions of *L. monocytogenes* were surface spread on MVJA. Sterile 6-mm paper disks were dipped in 0, 0.1, 1.0, 10, and 100% concentrations of carrot juice diluted with buffer, blotted, and placed on the surface of MVJA plates. The plates were examined for zones of inhibition after 48 h at 30°C.

Statistical analysis. Data were subjected to the Statistical

TABLE 3. Populations of *L. monocytogenes* in buffered dipping suspensions before and after carrots were dipped

Carrot treatment	Strain	Population (log_{10} CFU/ml) of *L. monocytogenes* in dipping suspension[a]	
		Before dipping	After dipping
Raw			
Whole	Scott A	5.13 (a)	4.58 (b)
	LCDC 81-861	5.26 (a)	4.58 (b)
Shredded	Scott A	5.54 (a)	5.08 (b)
	LCDC 81-861	5.32 (a)	4.85 (b)
Cooked			
Sliced	Scott A	5.79 (a)	5.80 (a)
	LCDC 81-861	5.18 (a)	5.28 (a)

[a] Each value represents the mean of four determinations. Values in the same row which are not followed by the same letter are significantly different ($P \leq 0.05$).

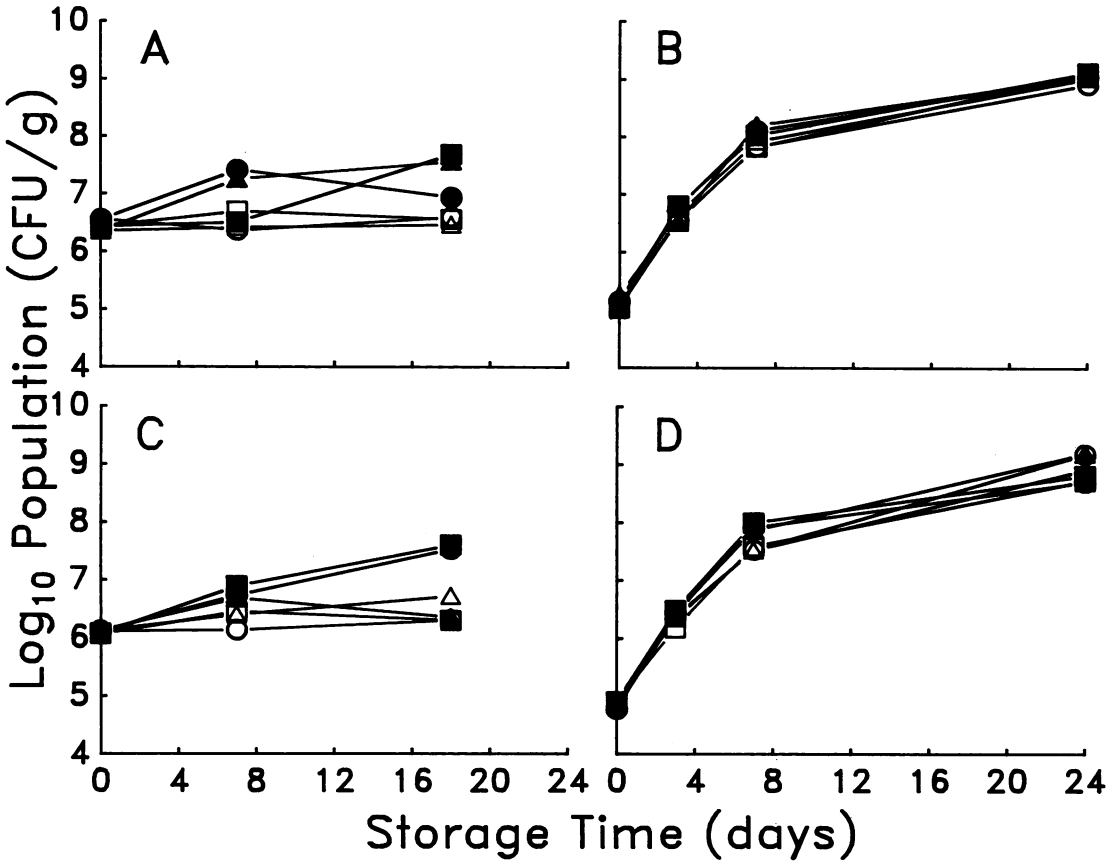

FIG. 2. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 5°C for up to 24 days on changes in mesophilic aerobic microorganism populations. Whole carrots (A and B) and shredded carrots (C and D) were not treated with chlorine (A and C) or were chlorine treated (B and D). Symbols: triangles, uninoculated; circles, inoculated with *L. monocytogenes* LCDC 81-861; squares, inoculated with *L. monocytogenes* Scott A; open symbols, packaged under ambient air atmosphere; closed symbols, packaged under 3% oxygen and 97% nitrogen.

Analysis System (SAS Institute, Cary, N.C.) for analysis of variance and Duncan's multiple range test.

RESULTS AND DISCUSSION

Results from preliminary experiments designed to determine populations of *L. monocytogenes* on carrots after dipping as affected by populations of the organism in dip suspensions are shown in Table 1. Very small populations or no viable *L. monocytogenes* were detected on shredded carrots compared with whole carrots. One might predict just the opposite; i.e., larger populations would be detected on shredded carrots, since the surface area/weight ratio is higher than for whole carrots. Smaller viable populations of *L. monocytogenes* on shredded carrots suggests that naturally occurring constituents or phytoalexins in cellular and vascular fluids which may be released as a result of rupturing carrot cells have a toxic effect. It is interesting that Heisick et al. (8) isolated four *Listeria* species from fresh vegetables, including potatoes, radishes, cabbage, cucumbers, mushrooms, and lettuce, but detected none on carrots.

Shown in Table 2 are the results of experiments designed to determine the survival and growth patterns of *L. monocytogenes* on carrots as affected by chlorine wash treatment, shredding, initial atmospheric gas composition within packages, temperature, and storage time. It should also be noted that, for the purpose of comparison, the same values for populations determined to be present on day 0 samples are reported for both control and modified-atmosphere packaging conditions. It is assumed that initial populations on these samples were the same on carrots to be subsequently stored under control or modified atmospheres.

With one exception (storage for 3 days at 5°C), *L. monocytogenes* was not detected on uninoculated control samples. The presence of *L. monocytogenes* on one sample of uninoculated carrots is attributed to contamination in the laboratory. Small populations detected on whole carrots immediately after dipping were essentially nondetectable after 7 days of storage at 5 or 15°C. After a lag of 7 days at 5°C, significant increases in populations were detected on shredded carrots after 24 days of storage. *L. monocytogenes* survived, and there is some indication that it may have started to grow on chlorine-washed, shredded carrots stored at 15°C for 7 days. In similar experiments on lettuce (Beuchat and Brackett, in press), much larger populations (10^4 to 10^5 CFU/g) of *L. monocytogenes* were detected immediately after dipping in suspensions containing populations of cells similar to those used for dipping carrots. This tends to confirm observations on the killing effect of carrots on *L. monocytogenes* made in preliminary experiments.

The appearance of shredded carrots after 7 days and whole carrots after 24 days at 5°C had deteriorated substan-

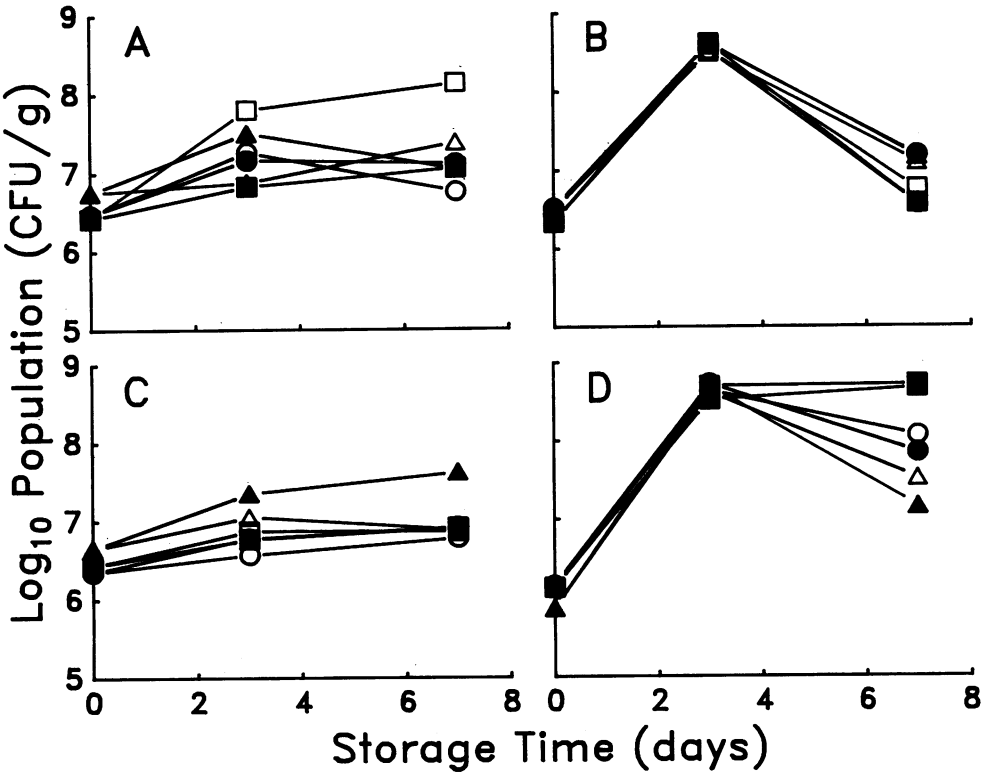

FIG. 3. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 15°C for up to 7 days on changes in mesophilic aerobic microorganism populations. Panels and symbols are as described in the legend to Fig. 2.

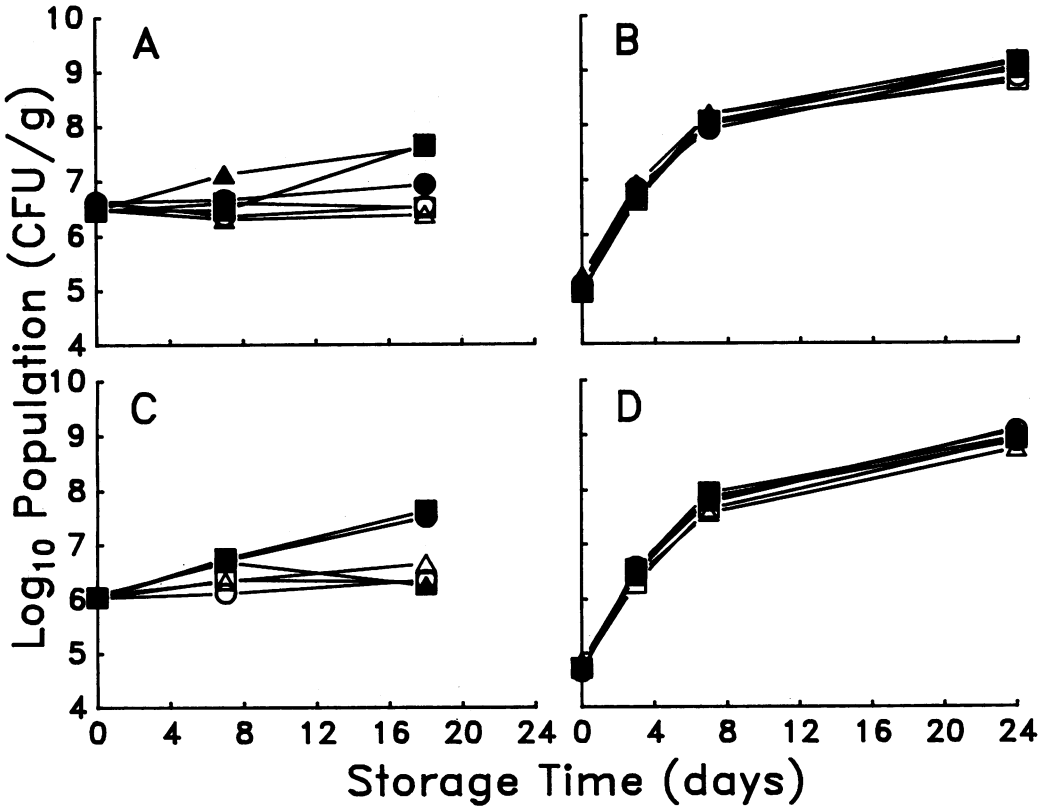

FIG. 4. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 5°C for up to 24 days on changes in populations of psychrotrophic microorganisms. Panels and symbols are as described in the legend to Fig. 2.

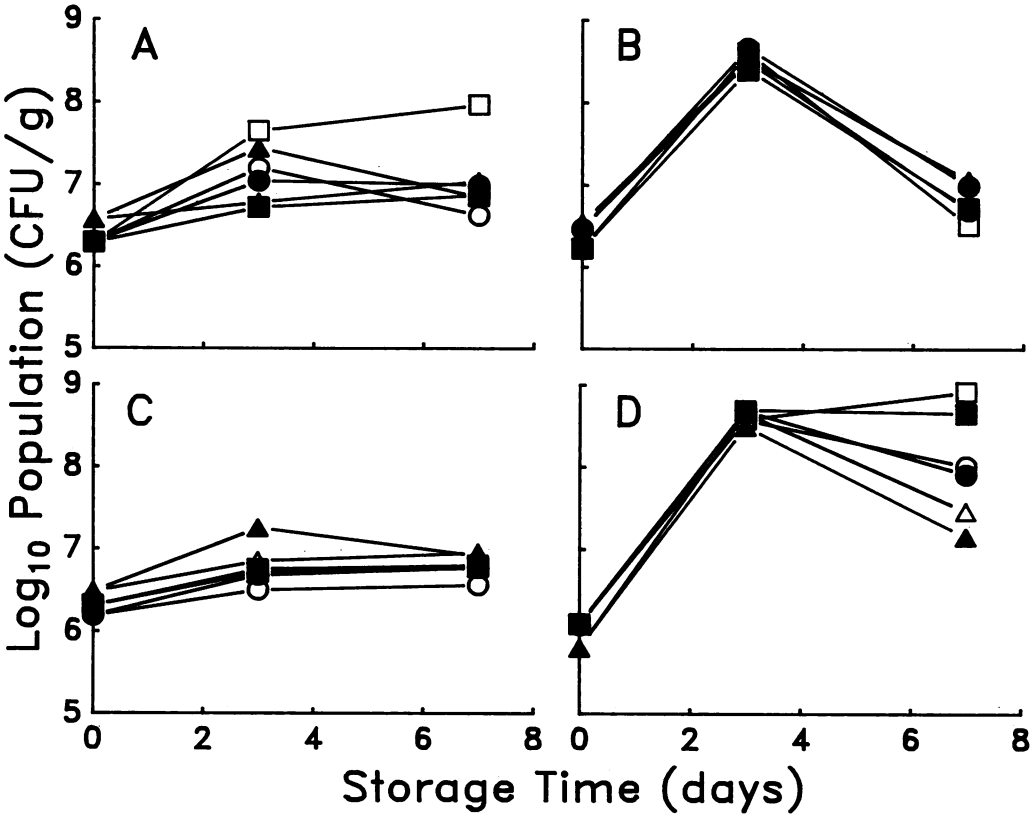

FIG. 5. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 15°C for up to 7 days on changes in populations of psychrotrophic microorganisms. Panels and symbols are as described in the legend to Fig. 2.

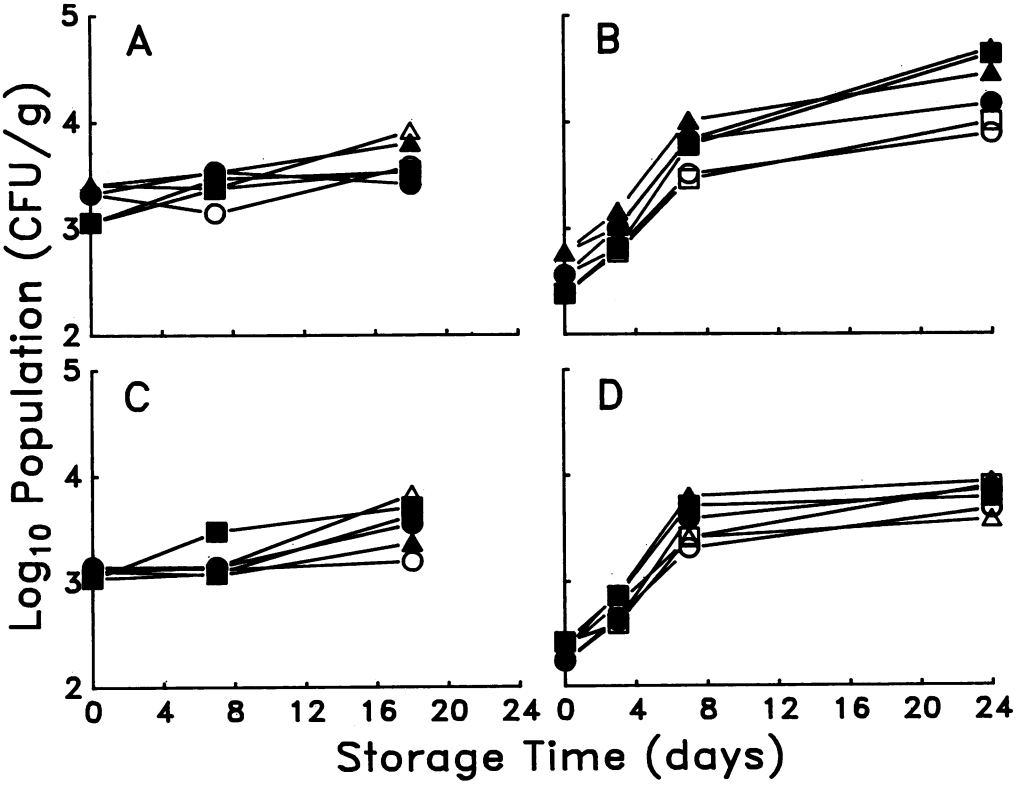

FIG. 6. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 5°C for up to 24 days on changes in populations of yeasts and molds. Panels and symbols are as described in the legend to Fig. 2.

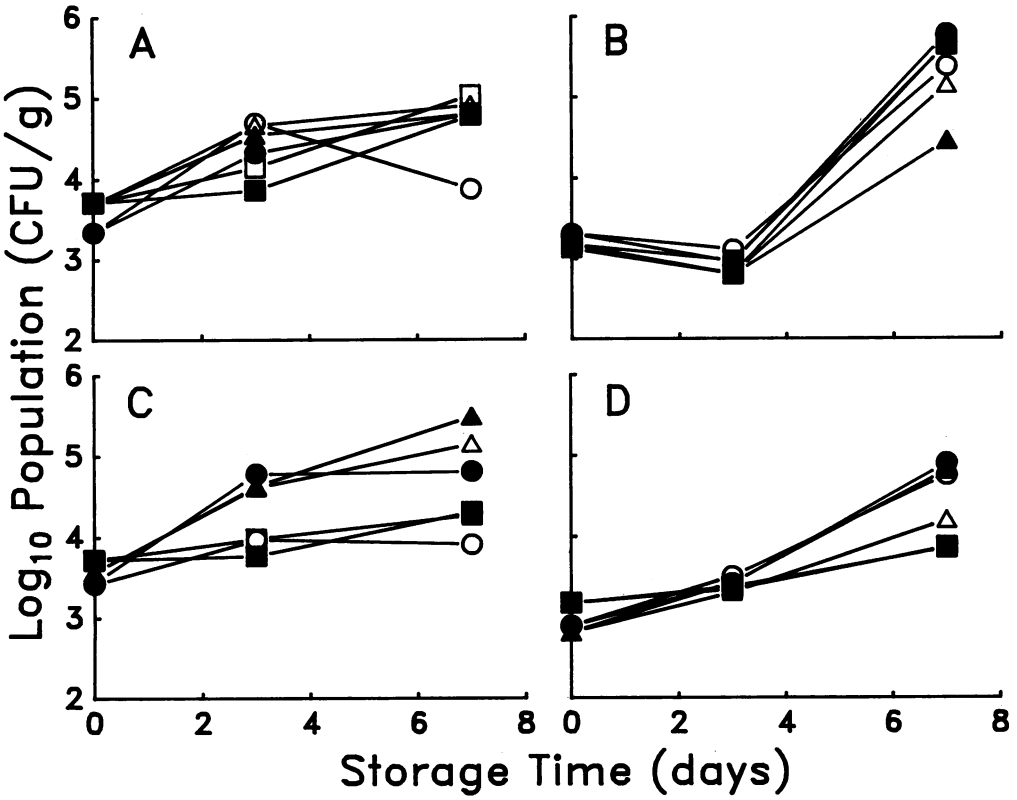

FIG. 7. Effects of shredding, chlorine treatment, and modified-atmosphere storage of carrots at 15°C for up to 7 days on changes in populations of yeasts and molds. Panels and symbols are as described in the legend to Fig. 2.

tially due to slime development, mold growth, and off odors. Deterioration occurred more rapidly when carrots were stored at 15°C. Populations of *L. monocytogenes* were essentially unaffected by cutting treatment (whole or shredded carrots), chlorine treatment, or the initial composition of gaseous atmospheres within packages. Storage at 15°C appeared to cause *L. monocytogenes* to die more rapidly than at 5°C, although a clear case for this trend cannot be made. Populations of *L. monocytogenes* recovered from carrot samples stored at 5 and 15°C were quite variable. Therefore, emphasis should not be placed on occasional significant differences between various values. A more important observation is that *L. monocytogenes* did not grow on carrots stored at 5 or 15°C before their shelf life would be considered by subjective evaluation of appearance to have expired.

TABLE 4. Viable populations of *L. monocytogenes* Scott A and LCDC 81-861 in various concentrations of carrot juice incubated at 30°C

Strain	Juice concn (%) in medium	Log_{10} CFU/ml after (min):		
		0[a]	30	120
Scott A	0	8.15	6.19	6.70
	0.1	8.15	6.08	6.02
	1.0	8.15	5.98	5.65
	10	8.15	6.10	5.70
	100	8.15	5.58	5.33
LCDC 81-861	0	8.03	6.06	5.90
	0.1	8.03	5.84	5.69
	1.0	8.03	5.84	5.75
	10	8.03	5.70	5.71
	100	8.03	5.65	5.55

[a] Initial populations of each strain were the same in all concentrations of carrot juice medium.

An analysis of *L. monocytogenes* populations in suspensions immediately before and after whole and shredded raw carrots were dipped revealed significant reductions in viable cell populations as a result of dipping (Table 3). Apparently, the toxic component(s) is dispersed in buffer, where it remains active at considerably reduced concentrations. Dipping cooked carrots in buffered *L. monocytogenes* suspensions had no effect on cell viability, indicating that the concentration of the toxic component in carrots is reduced or rendered insoluble or inactive upon exposure to heat.

Populations of mesophilic aerobic microorganisms on whole carrots (Fig. 2A and C) remained the same or increased by less than 100-fold during 18 days of storage at 5°C. Much greater increases were noted for shredded carrots (Fig. 2B and D); populations increased by about 100-fold within 3 days. The increased surface area of cut tissue in shredded carrots provided increased nutrients, which enhanced the growth of naturally occurring microflora. Chlorine treatment reduced the initial population by at least 90%, but neither chlorine treatment nor modified-atmosphere conditions substantially influenced growth patterns of mesophilic aerobes on carrots stored at 5°C. Similar reductions in populations of microflora on whole lettuce leaves treated with hypochlorite solutions containing available free chlorine at 100 ppm (100 μg/ml) were reported by Adams et al. (1).

Similar observations were made for mesophilic aerobic populations on carrots stored at 15°C; however, increases in

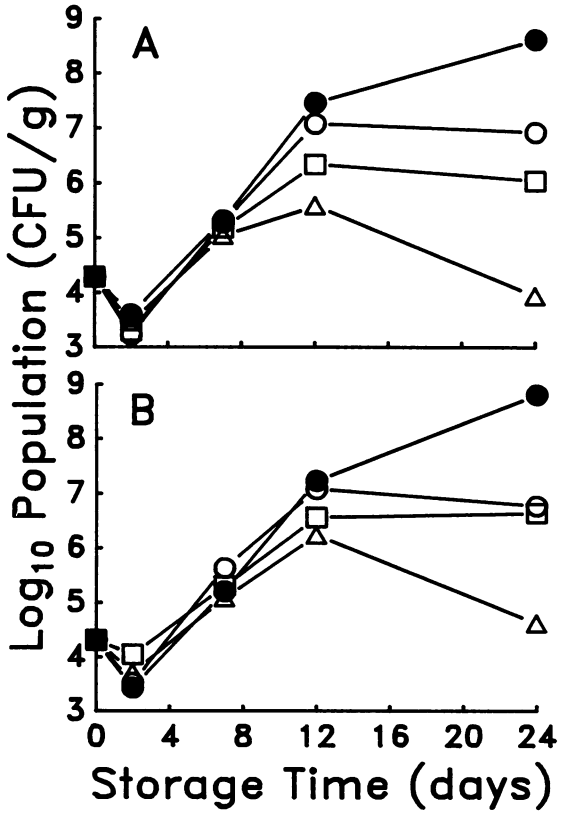

FIG. 8. Growth of *L. monocytogenes* Scott A (A) and LCDC 81-861 (B) in TPB containing 0% (●), 1% (○), 10% (□), and 50% (△) (vol/vol) carrot juice in place of water.

populations occurred earlier in the storage period (Fig. 3). Populations decreased after 3 days on shredded carrots which had not been chlorine washed (Fig. 3B). Decreases were also noted on chlorine-washed, uninoculated and LCDC 81-861-inoculated shredded carrots after 3 days (Fig. 3D).

Populations of psychrotrophic microorganisms on carrots stored at 5°C (Fig. 4) and 15°C (Fig. 5) followed the same trends noted for mesophilic aerobes. Thus, the natural microflora on carrots consisted largely of organisms capable of growing in a temperature range of 5 to 30°C. These observations are in contrast to those reported by Buick and Damoglou (6). These researchers observed that microbial development on vacuum-packaged carrots stored at 4, 10, and 15°C was slower than that on aerobic packs.

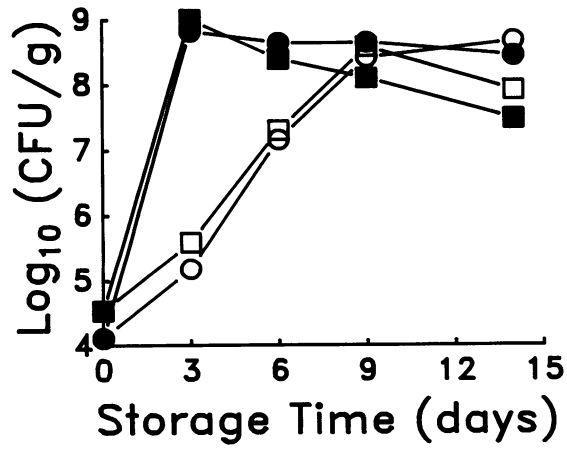

FIG. 9. Growth of *L. monocytogenes* Scott A (squares) and LCDC 81-861 (circles) on cooked carrots stored at 5°C (open symbols) and 15°C (closed symbols).

Chlorine treatment reduced the initial population of yeasts and molds on carrots. Populations increased significantly on most carrot samples analyzed within 18 days (whole carrots) and 24 days (shredded carrots) of storage at 5°C (Fig. 6). Significant increases were noted after 7 days of storage at 15°C (Fig. 7). Other experimental parameters had little or no effect on the populations of yeasts and molds on any given day of analysis.

Observations on the apparent inhibitory effect of shredded carrots led us to design some simple experiments to further examine this phenomenon. The effects of inoculating *L. monocytogenes* into various concentrations of carrot juice are shown in Table 4. While there was a decrease in population during the first 30 min, populations were essentially unchanged between 30 and 120 min after inoculation. A decrease in viable population was directly correlated with an increased percentage of carrot juice in the suspending solution.

Growth patterns of *L. monocytogenes* in TPB supplemented with carrot juice are shown in Fig. 8. The viable cell population of both test strains decreased during the first 2 h of incubation. This decrease was followed by growth in all test media. Both test strains continued to grow in the control broth (TPB not supplemented with carrot juice) during the 24-h period of analysis. Growth in TPB containing carrot juice, in contrast, ceased at 12 h. The rate of growth during the first 12 h of incubation was inversely proportional to the concentration of carrot juice in TPB. The presence of carrot juice at a concentration as low as 1% substantially reduced the maximum population of *L. monocytogenes* reached after 24 h of incubation. In TPB containing 50% carrot juice, viable populations of the organism decreased between 12 and 24 h. Growth patterns were not influenced by nutrient availability, since the same concentrations of nutrients supplied by TPB were present in all test media.

Surprisingly, no zones of inhibition of *L. monocytogenes* were observed when disks saturated with various concentrations of carrot juice were placed on the surface of heavily inoculated MVJA. Perhaps the anti-*Listeria* component in carrot juice reacts with some component in MVJA to render it inactive.

The behavior of *L. monocytogenes* on cooked carrots stored at 5 and 15°C is illustrated in Fig. 9. Either the anti-*Listeria* component(s) is heat labile or it is leached into the cooking water. Even the viable population of *L. monocytogenes* detected on cooked carrots immediately after being dipped in cell suspension (day 0) was larger than that on raw carrots immediately after being dipped (Table 2), although the populations of *L. monocytogenes* in suspensions used to dip cooked and raw carrots were essentially the same. Storage of cooked inoculated carrots at 5°C resulted in significant increases in both test strains within 9 days; after 14 days, there was an additional significant increase in population of the LCDC 81-861 strain, while the Scott A strain decreased significantly. Significant increases in populations of both strains were observed within 3 days of storage at 15°C. Significant decreases in population, particularly with the Scott A strain, were noted as storage at 15°C progressed to 6, 9, and 14 days.

While significantly larger populations of the LCDC 81-861 strain were detected on cooked carrots stored at 15°C for 3, 6, and 9 days compared with those on carrots stored at 5°C for the same respective periods, the reverse was true after 14 days. A similar observation was made for the Scott A strain, although the reversal in significant differences in population was detected on day 9. Thus, both strains grew more rapidly at 15 than at 5°C, and some death occurred after maximum populations were reached, regardless of storage temperature.

Further investigation is warranted to define the characteristics of the carrot component(s) responsible for toxic or otherwise inhibitory effects on *L. monocytogenes* as well as perhaps other foodborne pathogens. Several naturally occurring and inducible phenolic compounds have been identified in carrot roots (11). These include isocoumarin, eugenin, and related compounds. Amin et al. (2) studied the biochemical mechanism for the antiyeast effect of the carrot phytoalexin 6-methoxymellein. Results suggest that the compound exerts its toxic effects by interacting with cell membranes and disturbing membrane-associated functions. 6-Methoxymellein inhibits the growth of both fungi and bacteria (10). Whether these compounds are toxic to *L. monocytogenes* is not known.

ACKNOWLEDGMENTS

This research was supported in part by the International Life Sciences Institute—Nutrition Foundation, Washington, D.C.

We are grateful to Cryovac Inc. for supplying L-Bags for the study and to Brenda Nail, Lynn Cheney, and Kim Knowles for technical assistance.

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