Journal of Food Protection, Vol. 69, No. 4, 2006, Pages 801–814

Death of *Salmonella, Escherichia coli* O157:H7, and *Listeria monocytogenes* in Shelf-Stable, Dairy-Based, Pourable Salad Dressings

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MS 05-511: Received 17 October 2005/Accepted 11 December 2005

ABSTRACT

The objectives of this study were to determine the death rates of *Salmonella*, *Escherichia coli* O157:H7, and *Listeria monocytogenes* in three commercially manufactured full-fat ranch salad dressings, three reduced-fat ranch salad dressings, two full-fat blue cheese salad dressings, and two reduced-fat blue cheese salad dressings and to affirm the expectation that these dressings do not support the growth of these pathogens. The respective initial pH values of the four types of shelf-stable, dairy-based, pourable dressings were 2.87 to 3.72, 2.82 to 3.19, 3.08 to 3.87, and 2.83 to 3.49, respectively. Dressings were inoculated with low (2.4 to 2.5 log CFU/g) and high (5.3 to 5.9 log CFU/g) populations of separate five-strain mixtures of each pathogen and stored at 25°C for up to 15 days. Regardless of the initial inoculum population, all test pathogens rapidly died in all salad dressings. *Salmonella* was undetectable by enrichment (<1 CFU/25-ml sample in three replicate trials) in all salad dressings within 1 day, and *E. coli* O157:H7 and *L. monocytogenes* were reduced to undetectable levels by enrichment between 1 and 8 days and 2 and 8 days, respectively. *E. coli* O157:H7 was not detected in 4 of the 10 salad dressings stored for 2 or more days and 9 of the 10 dressings stored for 6 or more days after inoculation. *L. monocytogenes* was detected in 9 of the 10 salad dressings stored for 3 days but in only one dressing, by enrichment, at 6 days, indicating that it had the highest tolerance among the three pathogens to the acidic environment imposed by the dressings. Overall, the type of dressing (i.e., ranch versus blue cheese) and level of fat in the dressings did not have a marked effect on the rate of inactivation of pathogens. Total counts and populations of lactic acid bacteria and yeasts and molds remained low or undetectable (<1.0 log CFU/ml) throughout the 15-day storage period. Based on these observations, shelf-stable, dairy-based, pourable ranch and blue cheese salad dressings manufactured by three companies and stored at 25°C do not support the growth of *Salmonella, E. coli* O157:H7, and *L. monocytogenes* and should not be considered as potentially hazardous foods (time-temperature control for safety foods) as defined by the U.S. Food and Drug Administration Food Code.

Commercial sterilization of salad dressings by treatment at high temperatures is not an option for eliminating microorganisms because it would destroy the physical integrity and result in products with substantially different sensory qualities. Commercial processing and preservation of salad dressings instead depends on a combination of intrinsic factors, and possibly mild heat treatments, to reduce, control, or eliminate microorganisms *(6, 11).* Commercial salad dressings are also manufactured under strict quality controls as manufacturers adhere to good manufacturing practices.

Aciduric bacteria, yeasts, and molds that survive processing may eventually grow and cause spoilage of these products. Lactic acid bacteria and acid-tolerant yeasts and molds are the most common causes of microbial spoilage of salad dressings. The presence of acetic acid, and to a lesser extent, lactic and citric acids, in the aqueous phase, coupled with a low pH, salt, natural antimicrobials, and preservatives such as sorbic acid and/or benzoic acid create a harsh environment for foodborne bacterial pathogens such as *Salmonella, Escherichia coli* O157:H7, *Listeria monocytogenes,* and *Staphylococcus.* Rapid death of these and other pathogens in mayonnaise and salad dressings has been well documented *(1–5, 8, 9, 14).* Statistical analysis of data reported by several researchers has revealed that *Salmonella* and *Yersinia enterocolitica* die off more rapidly than *E. coli* O157:H7 and *L. monocytogenes (11).* The most significant factor in salad dressings and mayonnaise that contributes to lethality of pathogenic bacteria is pH as adjusted with acetic acid, followed by the concentration of acetic acid in the aqueous phase. For these and other reasons, foodborne illness associated with the consumption of commercially prepared acidic salad dressings has not been documented.

Storage temperature can affect the physical stability and sensory quality of salad dressings as well as the rate of growth of spoilage microorganisms. The lethality of the harsh environment imposed by intrinsic factors characteristic of salad dressings to foodborne pathogens that may become contaminants during postprocess handling would be anticipated to act synergistically or additively with nonrefrigerated temperatures to cause death of these pathogens at a more rapid rate. Inactivation of *Salmonella* Enteritidis

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in mayonnaise is known to be more rapid at 20 to 24°C than at 4°C *(5, 8)*. Hathcox et al. *(4)* observed that increases in storage temperature from 5 to 20°C and from 20 to 30°C resulted in dramatic increases in the rate of inactivation of *E. coli* O157:H7 in real (full-fat) and reduced-calorie (reduced-fat) mayonnaise. The death rate of *E. coli* O157:H7 in a formulation of refrigerated ranch salad dressing was slower at 4°C than in mayonnaise stored at 22°C *(9)*. Zhao and Doyle *(14)* reported that *E. coli* O157:H7, initially at 3.8 log CFU/g of mayonnaise (pH 3.6 to 3.9) survived for 34 to 55 days at 5°C and for 8 to 21 days at 20°C. Rates of inactivation of *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes* in commercially manufactured dairy-based, pourable salad dressings formulated to be microbiologically stable at ambient temperatures have not been reported.

The amounts and types of pourable salad dressings available for purchase in large containers for use in food service and home settings have increased in recent years. This presents an increased possibility of postprocess contamination, e.g., at salad bars where portions are removed from the same container by several different people over an extended period of time. Criteria used to define potentially hazardous foods (time-temperature control for safety foods) are listed and described in the U.S. Food and Drug Administration (FDA) Food Code *(12)*. Although shelf-stable, dairy-based, pourable salad dressings do not meet these criteria, the behavior of *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes* that may contaminate salad dressings at some point after opening containers in foodservice or home settings has not been critically evaluated.

The objectives of this study were to determine the death rate of *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes* in shelf-stable, dairy-based, pourable salad dressings inoculated to contain an initial population of 5 to 6 log CFU/g and to affirm the expectation that these dressings do not support the growth of these pathogens inoculated to contain an initial population of 2 to 3 log CFU/g.

MATERIALS AND METHODS

Salad dressings evaluated. Ten shelf-stable, dairy-based, pourable salad dressings produced by three commercial manufacturers and representing 70 to 75% of the retail sales of this group of dressings in the United States were evaluated. Three types of full-fat ranch, three reduced-fat ranch, two full-fat blue cheese, and two reduced-fat blue cheese dressings were examined. Dressings were arbitrarily assigned code numbers (1, 2, 3) to indicate the manufacturer. Three different lots of each salad dressing were used in three replicate experiments over a 4-month period. Evaluation of each dressing manufactured at three different times, i.e., three different lots representing three replicate experiments created a more robust experimental design than, for example, subdividing each dressing from a single lot into three groups and designating each group as a replicate experiment. Dressings were supplied by manufacturers and stored at 25°C until inoculated with test pathogens, which was within the first quarter of shelf life.

Pathogens. *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes* were studied for their ability to survive in salad dressings stored for up to 15 days at 25°C. Most of the strains selected for evaluation were isolated from acidic foods or from patients with illness associated with eating these foods. Five serotypes of *Salmonella enterica* were used: Enteritidis E190-88 (a human isolate), Michigan (an isolate from a patient in an outbreak associated with cantaloupe), Montevideo G4639 (from a patient in an outbreak associated with tomatoes), Muenchen 372 (an isolate from orange juice), and Typhimurium DT104 (resistant to multiple antibiotics). Five strains of *E. coli* O157:H7 were used: SEA 13B88 (an isolate from a patient in an outbreak associated with unpasteurized apple juice), 30-2C4 (from salami), LJH 557 (from unpasteurized apple cider), CDC-658 (from a cantaloupe-associated outbreak), and E0139 (from beef jerky). Five strains of *L. monocytogenes* were used: 302 (serotype 1, an isolate from Cheddar cheese), 310 (serotype 4b, from goat cheese), G1091 (serotype 4b, from a patient in a coleslaw-associated outbreak), F8369 (serotype 1/2a, from corn), and H0222 (serotype 1/2a, from potatoes).

Growth of pathogens for preparation of inocula. Pathogens were grown in broths supplemented with glucose to achieve greater reduction in the pH of cultures from which cells were collected for preparing inocula, thereby habituating cells to mildly acidic environments and potentially promoting higher tolerance to the acidic pH of salad dressings. *Salmonella* and *E. coli* O157:H7 were grown in 10 ml of tryptic soy broth (BBL/Difco, Becton Dickinson, Sparks, Md.) supplemented with 1% glucose (TSBG) and *L. monocytogenes* was grown in 10 ml of brain heart infusion broth (BBL/Difco, Becton Dickinson) supplemented with 1% glucose at 37°C for 24 to 26 h. One loopful (ca. 10 μl) of each strain was transferred into 10 ml of broth three times at 24-h intervals immediately before harvesting cells to be used as inocula. Cultures were centrifuged (2,000 × *g*, 15 min, 21°C), and cells were washed in sterile potassium phosphate-buffered (0.05 M, pH 6.5) saline solution (0.85% NaCl) (PBS). Cells were collected by centrifugation and resuspended in PBS. Five-serotype and five-strain mixtures of each pathogen were prepared by combining suspensions to give approximately equal populations of each serotype or strain, respectively, and a population of 8.3 to 8.9 log CFU/ml of the mixture. These suspensions (high CFU per milliliter) were used as inocula to determine death rate responses of pathogens (high CFU per milliliter) in salad dressings. Suspensions were serially diluted in PBS to give 5.4 to 5.5 log CFU/ml. These suspensions (low CFU per milliliter) were used as inocula for challenge studies.

Procedure for inoculating salad dressings. With the exception of one salad dressing (ranch reduced-fat 1), which was in 36-oz (1,021-g) bottles, commercially processed products were provided by manufacturers in 16-oz (454-g) bottles. All dressings were adjusted to 25°C. Caps were removed from bottles, 100 ml of dressing was aseptically withdrawn, and inoculum (0.5 ml for 454-g bottles or 1.1 ml for 1,021-g bottles) was deposited in each bottle. Bottles were capped and vigorously shaken by hand for 15 s, followed by removing caps, returning the same 100 ml of salad dressing previously withdrawn, capping, and vigorously shaking by hand for 5 s. Controls (uninoculated dressings) consisted of salad dressings to which sterile PBS was added instead of inoculum. With the exception of dressings subjected to microbiological analyses on day 0 (within 30 min after inoculation), control and inoculated dressings were immediately placed in an incubator at 25°C.

Microbiological analyses. Populations of pathogens in 24-h single-serotype and single-strain cultures and in the mixed-serotype and mixed-strain inocula were determined by serially diluting each culture in sterile 0.1% peptone and surface plating (0.1 ml in duplicate) on tryptic soy agar (BBL/Difco, Becton Dickinson) supplemented with 0.1% pyruvate (TSAP) and on selective media.

Suspensions of *Salmonella* were also surface plated on Hektoen enteric (HE) agar (BBL/Difco, Becton Dickinson) supplemented with 0.1% pyruvate (HEP). Suspensions of *E. coli* O157:H7 were surface plated on sorbitol MacConkey agar (BBL/Difco, Becton Dickinson) supplemented with 0.1% pyruvate (SMACP) and suspensions of *L. monocytogenes* were surface plated on modified Oxford medium (Oxoid, Basingstoke, UK) supplemented with 0.1% pyruvate (MOXP). Plates were incubated at 37°C for 24 h before *Salmonella* and *E. coli* O157:H7 colonies were counted and for 44 to 48 h before *L. monocytogenes* colonies were counted.

On days 0 (within 30 min after inoculation), 1, 2, 3, 6, 8, 10, 13, and/or 15 of storage at 25°C, depending on the initial inoculum and whether a given pathogen was detected by direct plating or enrichment on previous days of analysis, the pH of inoculated and uninoculated salad dressings was measured and dressings were subjected to microbiological analyses. If a pathogen in a particular salad dressing was not detected by enrichment on at least three consecutive sampling days, that dressing was not analyzed again until day 15, on which all dressings were analyzed. The entire content of each 454-g bottle was poured into a Stomacher 400 bag (Seward Medical, Inc., London, UK) and pummeled in a Stomacher 400 (Seward Medical, Inc.) for 1 min at medium speed. Ranch reduced-fat 1 salad dressing (1,021 g per bottle) was poured into a 1-gal (3.6-liter) Ziploc freezer bag (S. C. Johnson, Racine, Wis.) and vigorously mixed by hand for 1 min.

The basis for analyzing salad dressings was by volume (milliliters) rather than weight (grams), with the recognition that inoculation was on a CFU-per-gram basis and that density of the dressings was slightly less than 1.0. Populations of microorganisms recovered from dressings are reported as log CFU per milliliter. In the first replicate experiment, samples (0.25 ml in quadruplicate and 0.1 ml in duplicate) of undiluted salad dressings and samples (0.1 ml in duplicate) of dressing serially diluted in 0.1% peptone were surface plated on media to enumerate pathogens, total aerobic microorganisms, lactic acid bacteria, and yeasts and molds. To determine the presence of low numbers of pathogens in dressings, 25 ml of undiluted sample was combined and thoroughly mixed with 225 ml of preenrichment broth (lactose broth) (BBL/Difco, Becton Dickinson) to detect *Salmonella* or enrichment broth, double modified tryptic soy broth (dmTSB) *(7)* to detect *E. coli* O157:H7, and *Listeria* enrichment broth (BBL/Difco, Becton Dickinson) to detect *L. monocytogenes.* Samples (45 g) of each dressing were also deposited in 50-ml vials, sealed, and stored at −20°C for potential additional analysis at a later date. In the second and third replicate experiments, because of difficulty in accurately depositing desired volumes of undiluted salad dressings onto the surface of enumeration media, dressings were not direct plated on media. Instead, samples of a 1:10 dilution of salad dressings in preenrichment or enrichment broth were surface plated (0.25 ml in quadruplicate and 0.1 ml in duplicate) on appropriate enumeration media. This procedure resulted in a minimum detection limit of 1.0 log CFU/ml of salad dressing.

The population of *Salmonella* in salad dressings was determined by surface plating undiluted and/or diluted samples (depending on the replicate experiment) on HEP agar. Plates were incubated at 37°C for 24 h before presumptive-positive *Salmonella* colonies were counted. If *Salmonella* was not detected on HEP agar, the preenrichment mixture of lactose broth and salad dressing was streaked on HE agar; samples (1 ml) were also inoculated into 10 ml of Rappaport-Vassiliadis broth (BBL/Difco, Becton Dickinson). Plates were incubated at 37°C for 24 h before examining for presumptive *Salmonella* colonies. If none was detected, inoculated Rappaport-Vassiliadis broth incubated at 42°C for 24 h was streaked on HE agar. Plates were incubated at 37°C for 24 h before examining for presumptive *Salmonella* colonies. Up to five colonies per sample were subjected to confirmation assays using the *Salmonella* latex agglutination test (Oxoid) and API 20E biochemical tests (bioMérieux, Hazelwood, Mo.).

To enumerate *E. coli* O157:H7, undiluted and/or diluted samples of salad dressings were surface plated on SMACP agar. Plates were incubated at 37°C for 24 h before examining for presumptive-positive colonies of *E. coli* O157:H7. If none was detected, the mixture of dressing and dmTSB incubated at 37°C for 24 h was streaked on SMACP agar. Plates were incubated at 37°C for 24 h before examining for presumptive-positive *E. coli* O157:H7 colonies. Up to five colonies per sample were subjected to the *E. coli* O157 latex agglutination test (Oxoid) and the API 20E biochemical assay for confirmation.

The number of *L. monocytogenes* surviving in salad dressings was determined by surface plating undiluted and/or diluted samples on MOXP agar. Plates were incubated at 37°C for 44 to 48 h before presumptive-positive *L. monocytogenes* colonies were counted. If none was detected, samples from the mixture of salad dressing and *Listeria* enrichment broth incubated at 37°C for 44 to 48 h were streaked on MOXP agar and incubated at 37°C for 44 to 48 h. Plates were incubated at 37°C for 44 to 48 h before examining for presumptive-positive *L. monocytogenes* colonies. Up to five colonies were selected for confirmation using the API *Listeria* assay (bioMérieux) and Microbact *Listeria* 12L assay (Oxoid).

The number of mesophilic aerobic microorganisms (total counts) in salad dressings was determined by surface plating undiluted and serially diluted samples on TSAP. Colonies were counted after incubating plates at 30°C for 24 h.

Lactic acid bacteria were enumerated by surface plating undiluted and serially diluted samples on deMan Rogosa Sharpe (MRS) agar (BBL/Difco, Becton Dickinson). Plates were overlaid with molten (48 to 50°C) MRS agar and incubated at 37°C. Colonies were counted after incubating plates for 5 and 7 days.

Yeast and mold populations were determined by surface plating undiluted and diluted samples on dichloran rose bengal chloramphenicol agar (BBL/Difco, Becton Dickinson). Plates were incubated at 25°C for 5 days before colonies were counted.

Statistical analysis. Three replicate experiments using three lots of each salad dressing manufactured on three different days over a 4-month period were conducted. Data were analyzed with the general linear model of the Statistical Analysis System procedure (SAS Institute, Cary, N.C.). The least significant difference test was used to determine significant differences ($P \leq 0.05$) in log populations of pathogens, total counts, lactic acid bacteria, and yeasts and molds in each dressing or groups of dressings as affected by storage time. Significant differences between populations of each microorganism or group of microorganisms detected in the 10 dressings at each storage time were also determined. Mean pH values of dressings stored for a given time as well as pH values of each salad dressing stored for different times were compared for significant differences using the least significant difference test.

RESULTS AND DISCUSSION

The pH of TSBG (7.3 ± 0.2) decreased to 4.68 ± 0.03 within 24 h after inoculation with *Salmonella* or *E. coli* O157:H7. The pH of brain heart infusion broth supplemented with 1% glucose (7.4 ± 0.2) was decreased to 4.44

TABLE 1. *Acid content and pH of salad dressings*[a]

Salad dressing	Total and aqueous phase acids (%)[b]												
	Citric		Malic		Lactic		Acetic		Phosphoric		Total		
	T	AP	T	AP	T	AP	T	AP	T	AP	T	AP	pH
Ranch													
Full-fat 1											0.92	2.02	3.69
Full-fat 2	0.11	0.31	0.07	0.20	0.12	0.34	0.05	0.14	0.51	1.44	0.88	2.48	3.30
Full-fat 3	<0.11	<0.11	0.09	0.17	0.09	0.18	0.27	0.55	0.45	0.59	0.74	1.47	3.21
Reduced-fat 1											1.31	2.01	3.48
Reduced-fat 2	0.04	0.05	0.07	0.10	0.69	0.94	0.10	0.14	0.04	0.05	0.71	0.97	3.55
Reduced-fat 3	<0.11	<0.11	0.08	0.13	0.05	0.08	0.42	0.70	0.37	0.62	0.91	1.52	3.06
Blue cheese													
Full-fat 1	0.18	0.49	ND	ND	0.13	0.35	0.62	1.67	0.30	0.81	1.01	2.73	3.89
Full-fat 2	<0.11	<0.11	0.10	0.21	0.23	0.51	0.54	1.18	0.35	0.76	1.22	2.64	3.39
Reduced-fat 1	0.07	0.10	0.05	0.07	0.53	0.76	0.27	0.39	0.40	0.57	1.06	1.52	3.59
Reduced-fat 2	<0.11	<0.11	0.14	0.22	0.22	0.34	0.58	0.92	0.33	0.52	1.30	2.05	3.13

[a] Values were provided by the manufacturers of salad dressings. Mean values were calculated for samples representing three lots from which salad dressings were obtained for use in the study. Total aqueous phase acid was calculated as acetic acid. Absence of values indicates that none were provided by the manufacturer.

[b] T, total acids; AP, aqueous phase acids, ND, none detected.

± 0.11 within 24 h after inoculation with *L. monocytogenes*. Decreases are attributed largely to fermentation of glucose. These cells would likely have undergone some degree of habituation to acidic pH *(10)*. The use of acid-adapted cells rather than unadapted cells established a more robust physiological state to enable survival upon exposure to the harsh acidic environment imposed by the salad dressings into which they were inoculated. The initial populations of *Salmonella*, *E. coli* O157:H7, and *L. monocytogenes* were 5.3 to 5.9 log CFU/g (high inoculum) for the death rate study and 2.4 to 2.5 log CFU/g (low inoculum) for the challenge study.

Proximate composition of salad dressing. Salad dressings were arbitrarily assigned numbers to indicate that they were manufactured by different companies. Shown in Table 1 are the acid content and pH of the salad dressings evaluated in the study. These values were provided by the manufacturers. The pH of three lots of salad dressings on the day they were inoculated with pathogens was measured in our laboratory. Ranges in pH values of three lots of full-fat ranch, reduced-fat ranch, full-fat blue cheese, and reduced-fat blue cheese dressings were 2.87 to 3.72, 2.82 to 3.19, 3.08 to 3.87, and 2.83 to 3.49, respectively. These pH values differed somewhat from the values provided by the manufacturers (Table 1), perhaps reflecting changes in pH that occurred as a result of equilibration of acidulants in dressing components between the date of manufacture and the date of inoculation. The lowest mean concentrations of acetic acid in the aqueous phase of samples from three lots of full-fat ranch, reduced-fat ranch, full-fat blue cheese, and reduced-fat blue cheese dressings were 0.14, 0.14, 1.18 and 0.39%, respectively. Citric, malic, lactic, and phosphoric acids also contributed to the low pH of dressings. Table 2 shows the moisture, protein, sodium benzoate, and potassium sorbate contents of salad dressings. Also listed are sugar and salt contents (total and aqueous phase). Data were provided by manufacturers of the salad dressings.

Studies on *Salmonella.* Populations of *Salmonella* recovered from salad dressings inoculated with high (5.7 log CFU/g) and low (2.4 log CFU/g) populations of the pathogen and stored at 25°C for up to 6 days are shown in Table 3. Populations determined by direct plating were significantly reduced ($P \leq 0.05$) by ≥0.9 log CFU/ml within 30 min after inoculation (day 0) and by >4.7 log CFU/ml within 24 h of storage. On day 0, retention of viability in dressings receiving the high inoculum was highest in blue cheese reduced-fat 2 dressing (4.8 log CFU/ml) and lowest in ranch reduced-fat 3 dressing (4.1 log CFU/ml). Retention of viability of *Salmonella* in salad dressings receiving a low inoculum was highest in blue cheese full-fat 2 and lowest in ranch full-fat 2 and blue cheese full-fat 1 on day 0. Even with a range in the number of *Salmonella* recovered from the 10 salad dressings on day 0, populations detected differed by only 0.7 log CFU/ml in dressings inoculated with 5.7 log CFU/ml and by 0.4 log CFU/ml in dressings inoculated with 2.4 log CFU/ml; ranges in reductions were 0.9 to 1.6 log CFU/ml and 1.0 to 1.4 log CFU/ml within 30 min in dressings inoculated with high and low inocula, respectively. Regardless of the inoculum level, *Salmonella* was not detected by direct plating any of the 10 salad dressings 24 h after inoculation, indicating reductions of >4.7 log CFU/ml.

Data for individual dressings within each of the four types of dressings (i.e., ranch full-fat, ranch reduced-fat, blue cheese full-fat, and blue cheese reduced-fat) were composited and analyzed to determine if the death rate of *Salmonella* (initial population, 5.7 log CFU/g) is influenced by differences in basic composition. Results are shown in Table 4. Populations detected in the four types of dressings within 30 min after inoculation (day 0) with a high number

TABLE 2. *Proximate composition and preservative content of salad dressings*[a]

Salad dressing	Moisture (%)	Protein (%)	Fat (%)	Sugars (%)[b]		Salt (%)[b]		Sodium benzoate (%)	Potassium sorbate (%)
				T	AP	T	AP		
Ranch									
Full-fat 1	45.8	1.76	47.0			1.99	4.35		
Fall-fat 2	35.5	1.74	56.8	2.46	6.94	1.68	4.74	0.01	0.29
Full-fat 3	50.3	0.80	38.3	5.08	10.09	2.73	5.42	<0.01	0.20
Reduced-fat 1	64.0					2.34	3.90		
Reduced-fat 2	73.8	0.63	6.04	4.76	6.47	2.01	2.73	0.11	0.11
Reduced-fat 3	60.0	0.70	14.0	4.72	7.87	3.03	5.06	<0.01	0.14
Blue cheese									
Full-fat 1	37.0	1.90	52.8	4.30	11.6	2.09	5.64	0.11	0.14
Full-fat 2	46.2	1.58	44.3	2.80	6.06	2.72	5.90	<0.01	0.28
Reduced-fat 1	70.1	2.21	5.98	5.02	7.16	2.12	3.03	0.05	0.15
Reduced-fat 2	63.1	1.73	21.6	6.14	9.74	2.86	4.51	0.01	0.04

[a] Values were provided by the manufacturers of salad dressings. Mean values were calculated from samples representing three lots from which salad dressings were obtained for use in the study. Absence of values indicates that none were provided by the manufacturer.
[b] T, total; AP; aqueous phase.

of *Salmonella* (5.7 log CFU/g) were not significantly different ($P \leq 0.05$). Retention of viability in dressings receiving a low inoculum (2.4 log CFU/g), however, was significantly higher in reduced-fat ranch and reduced-fat blue cheese dressings than in full-fat ranch dressing on day 0.

Shown in Table 5 are the numbers of samples of three

TABLE 3. *Populations of* Salmonella *recovered from inoculated salad dressings on Hektoen enteric agar supplemented with pyruvate (HEP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on:				
		Day 0	Day 1	Day 2	Day 3	Day 6
Ranch						
Full-fat 1	A 5.7 A	ABC 4.7 B	A ND[b] C		A ND C	A ND C
	a 2.4 a	ab 1.1 b	a ND b	a ND b	a ND b	a ND b
Full-fat 2	A 5.7 A	BCD 4.3 B	B ND C		A ND C	A ND C
	a 2.4 a	b 1.0 b	a ND b	a ND b	a ND b	a ND b
Full-fat 3	A 5.7 A	CD 4.2 B	B ND C		A ND C	A ND C
	a 2.4 a	b 1.1 b	a ND b	a ND b	a ND b	a ND b
Reduced-fat 1	A 5.7 A	ABC 4.7 B	B ND C		A ND C	A ND C
	a 2.4 a	ab 1.3 b	a ND b	a ND b	a ND b	a ND b
Reduced-fat 2	A 5.7 A	ABCD 4.5 B	B ND C		A ND C	A ND C
	a 2.4 a	ab 1.2 b	a ND b	a ND b	a ND b	a ND b
Reduced-fat 3	A 5.7 A	D 4.1 B	B ND C		A ND C	A ND C
	a 2.4 a	ab 1.3 b	a ND b	a ND b	a ND b	a ND b
Blue cheese						
Full-fat 1	A 5.7 A	AB 4.7 B	B ND C		A ND C	A ND C
	a 2.4 a	b 1.0 b	a ND b	a ND b	a ND b	a ND b
Full-fat 2	A 5.7 A	D 4.2 B	B ND C		A ND C	A ND C
	a 2.4 a	a 1.4 b	a ND b	a ND b	a ND b	a ND b
Reduced-fat 1	A 5.7 A	BCD 4.3 B	B ND C		A ND C	A ND C
	a 2.4 a	ab 1.3 b	a ND b	a ND b	a ND b	a ND b
Reduced-fat 2	A 5.7 A	A 4.8 B	B ND C		A ND C	A ND C
	a 2.4 a	ab 1.3 b	a ND b	a ND b	a ND b	a ND b

[a] Populations of *Salmonella* recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inocula. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).
[b] ND, none detected (< 1.0 log CFU/ml) by direct plating.

TABLE 4. *Populations of* Salmonella *recovered from four types of inoculated salad dressings on Hektoen enteric agar supplemented with pyruvate (HEP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on: Day 0	Day 1	Day 2	Day 3	Day 6
Ranch (full-fat 1, 2, 3)	A 5.7 A	A 4.4 B	A ND[b] C		A ND C	A ND C
	a 2.4 a	b 1.1 b	a ND c	a ND c	a ND c	a ND c
Ranch (reduced-fat 1, 2, 3)	A 5.7 A	A 4.4 B	A ND C		A ND C	A ND C
	a 2.4 a	a 1.3 b	a ND c	a ND c	a ND c	a ND c
Blue cheese (full-fat 1, 2)	A 5.7 A	A 4.5 B	A ND C		A ND C	A ND C
	a 2.4 a	ab 1.2 b	a ND c	a ND c	a ND c	a ND c
Blue cheese (reduced-fat 1, 2)	A 5.7 A	A 4.5 B	A ND C		A ND C	A ND C
	a 2.4 a	a 1.3 b	a ND c	a ND c	a ND c	a ND c

[a] Populations of *Salmonella* recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inoculum. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] ND, none detected (<1.0 log CFU/ml) by direct plating.

TABLE 5. *Detection of* Salmonella *in salad dressings by direct plating and enrichment*

Salad dressing	Initial population (log CFU/g)[a]	Detection by direct plating and enrichment on[b]: Day 0 dp	Day 0 en	Day 1 dp	Day 1 en	Day 2 dp	Day 2 en	Day 3 dp	Day 3 en	Day 6 dp	Day 6 en	Day 8 dp	Day 8 en	Day 15 dp	Day 15 en
Ranch															
Full-fat 1	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Full-fat 2	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Full-fat 3	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 1	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 2	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**		0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 3	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Blue cheese															
Full-fat 1	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Full-fat 2	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 1	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 2	5.7	**3/3**		0/3	0/3			0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**2/3**	0/1	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3

[a] Initial populations were calculated from the number of CFU in inocula.

[b] Salad dressings were stored at 25°C for up to 15 days. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Values indicate the number of replicate samples in which *Salmonella* was detected by direct plating or enrichment of the number of samples analyzed. Absence of values indicates that salad dressings were not analyzed. Detection limits were 1.0 log CFU/ml of salad dressing analyzed by direct plating and 1 CFU/25 ml of salad dressing analyzed by enrichment. Bold values indicate the maximum storage time (days) at which *Salmonella* was detected in each dressing inoculated with the pathogen at populations of 5.7 or 2.4 log CFU/g. dp, direct plating; en, enrichment.

analyzed by direct plating and one, two, or three analyzed by enrichment for each combination of test parameters that were positive for *Salmonella.* Detection limits were 1.0 log CFU/ml for samples that were direct plated and 1 CFU/25 ml for enriched samples. Bold values indicate the maximum storage time at which *Salmonella* was detected in each dressing inoculated with the pathogen at populations of 5.7 or 2.4 log CFU/g. Values for all days on which samples were analyzed are presented. Within 24 h, all salad dressings initially inoculated with *Salmonella* at populations of 5.7 or 2.4 log CFU/g contained <1 CFU/25 ml.

The initial and maximum mean pH values of three lots of uninoculated salad dressings and salad dressings inoculated with either high or low numbers of *Salmonella, E. coli* O157:H7, and *L. monocytogenes* within the 15-day storage period are shown in Table 6. The highest initial pH values for the three lots of ranch full-fat, ranch reduced-fat, blue cheese full-fat, and blue cheese reduced-fat dressings manufactured by three companies and inoculated with *Salmonella* were 3.53, 3.72, 3.87, and 3.49, respectively. There were some significant ($P \leq 0.05$) differences in the initial pH values of the 10 dressings. This held true for the maximum pH of uninoculated and inoculated dressings during the 15-day storage period. The maximum pH values of all dressings increased during the 15-day storage period, regardless of the presence of *Salmonella*; however, most of these pH values were not significantly different ($P > 0.05$) than respective initial values. Analysis of composites of pH values for each of the four types of salad dressings revealed that the blue cheese full-fat dressings had a significantly higher ($P \leq 0.05$) initial pH than the blue cheese reduced-fat dressings. Uninoculated and inoculated blue cheese full-fat dressing had significantly higher maximum pH values than those of ranch-type dressings and blue cheese reduced-fat dressing during the 15-day storage period. The initial pH of the four types of dressing did not differ significantly from the maximum pH during storage, regardless of inoculation with *Salmonella.*

Our observations on the rapid death of *Salmonella* in shelf-stable, dairy-based, pourable salad dressings are not dissimilar to those reported by others for salmonellae in commercial mayonnaise. Lock and Board *(5)* reported reductions in *Salmonella* Enteritidis of ca. 4.5 log CFU/g of commercial mayonnaise (pH 4.2) stored at 20°C for 24 h. Erickson and Jenkins *(1)* showed that *Salmonella* Enteritidis inoculated into four commercial mayonnaise products (pH 3.3 to 3.9) was reduced by 5 to 6 log CFU/g within 24 h at 26.6°C. A mixture of *Salmonella* Enteritidis and *Salmonella* Typhimurium was reduced by ca. 5 log CFU/g of cholesterol-free, reduced-calorie mayonnaise within 24 h at 23.9°C *(3).*

Studies on *E. coli* O157:H7. Populations of *E. coli* O157:H7 recovered from salad dressings inoculated with high (5.9 log CFU/g) and low (2.4 log CFU/g) populations of the pathogen and stored at 25°C for up to 6 days are shown in Table 7. In only three salad dressings (ranch full-fat 1, ranch reduced-fat 1, and blue cheese full-fat 1) was *E. coli* O157:H7 initially at 5.9 log CFU/ml detected by direct plating 3 days after inoculation, indicating reductions of 5.9 log CFU/ml in 7 of the 10 products. Reductions of ≥3.5 log CFU/ml occurred in all dressings within 3 days. Regardless of the level of inoculum, the pathogen was not detected by direct plating (<1.0 log CFU/ml) in dressings stored for 6 days or longer, indicating a reduction of 5.9 log CFU/ml in all dressings. With the exceptions of ranch full-fat 1 and blue cheese full-fat 1 dressings, regardless of the inoculum level, significant reductions ($P \leq 0.05$) in *E. coli* O157:H7 occurred within 30 min after inoculation. Significant reductions in populations occurred in dressings analyzed on subsequent days of storage.

Data for individual dressings within each of the four types of dressings were composited to determine if the death rate of *E. coli* O157:H7 is influenced by differences in basic composition. Significant ($P \leq 0.05$) reductions (≥1.3 log CFU/ml) in populations occurred within 30 min (day 0) after inoculation of ranch-type dressings but not blue cheese dressings inoculated with *E. coli* O157:H7 at a population of 5.9 log CFU/g; significant reductions (≥0.8 log CFU/ml) occurred within 30 min in all four types of dressings inoculated at a population of 2.4 log CFU/g (Table 8). Significant reductions occurred in dressings stored for longer periods, regardless of inoculum level. At 6 days, an initial population of 5.9 log CFU/g was reduced to <1.0 log CFU/ml.

Table 9 shows the numbers of samples out of three analyzed by direct plating and one, two, or three analyzed by enrichment that were positive for *E. coli* O157:H7 for each combination of test parameters. Detection limits were 1.0 log CFU/ml by direct plating and 1 CFU/25 ml by enrichment. Bold values indicate the maximum storage time at which *E. coli* O157:H7 was detected in each dressing inoculated with the pathogen at populations of 5.9 or 2.4 log CFU/g. Values for all days on which samples were analyzed are shown. In no instance was the pathogen detected in salad dressings stored for ≥8 days after inoculation, regardless of the inoculum level. In only one dressing (ranch full-fat 1) was *E. coli* O157:H7 detected 6 days after inoculation. The pathogen survived for 3 days but not 6 days in ranch full-fat 2, ranch full-fat 3, ranch reduced-fat 1, blue cheese full-fat 1, and blue cheese reduced-fat 2 dressings, and for 1 day but not 2 days in four of the other five dressings. In a given salad dressing inoculated with 5.9 log CFU/g, the number of days of storage on which *E. coli* O157:H7 was detected exceeded or was equal to the number of days of storage on which the pathogen was detected in dressings inoculated with 2.4 log CFU/g. This indicates that the rate of inactivation is not logarithmic and that a few cells in the inoculum, regardless of initial number inoculated into dressings, were more tolerant than others to the stress environment imposed by the dressings. Nevertheless, initial populations of 5.9 and 2.4 log CFU/ml decreased to undetectable (<1 CFU/25 ml) levels by enrichment in less than 8 and 6 days, respectively, in all 10 dressings.

The initial and maximum mean pH values of three lots of uninoculated salad dressings and salad dressings inoculated with *E. coli* O157:H7 over the 15-day storage period are shown in Table 6. The maximum pH values of all in-

TABLE 6. *Initial and maximum mean pH values of three lots of uninoculated salad dressings and salad dressings inoculated with* Salmonella, E. coli *O157:H7, or* L. monocytogenes *and stored at 25°C for up to 15 days*[a]

	Dressings inoculated with *Salmonella*			Dressings inoculated with *E. coli* O157:H7			Dressings inoculated with *L. monocytogenes*		
		Maximum pH[b]			Maximum pH[b]			Maximum pH[b]	
Salad dressing	Initial pH	Uninoculated	Inoculated	Initial pH	Uninoculated	Inoculated	Initial pH	Uninoculated	Inoculated
Ranch									
Full-fat 1	AB 3.54 A	B 3.70 A	B 3.69 A	AB 3.54 B	B 3.70 AB	B 3.74 A	AB 3.54 A	B 3.70 A	B 3.72 A
Full-fat 2	DE 2.99 B	E 3.23 A	E 3.20 AB	DE 2.99 B	E 3.23 AB	DE 3.25 A	DE 2.99 B	E 3.23 A	E 3.22 A
Full-fat 3	CDE 3.12 A	D 3.32 A	D 3.32 A	CDE 3.12 B	D 3.32 AB	D 3.33 A	CDC 3.12 A	D 3.32 A	D 3.34 A
Reduced-fat 1	ABC 3.37 A	C 3.51 A	C 3.51 A	ABC 3.37 A	C 3.51 A	C 3.52 A	ABC 3.37 A	C 3.51 A	C 3.52 A
Reduced-fat 2	ABC 3.38 B	C 3.54 AB	C 3.55 A	ABC 3.38 B	C 3.54 AB	C 3.55 A	ABC 3.38 B	C 3.54 AB	C 3.56 A
Reduced-fat 3	E 2.96 A	E 3.18 A	E 3.15 A	E 2.96 A	E 3.18 A	E 3.17 A	E 2.96 A	E 3.18 A	E 3.17 A
Blue cheese									
Full-fat 1	A 3.65 A	A 3.85 A	A 3.83 A	A 3.65 A	A 3.85 A	A 3.84 A	A 3.65 A	A 3.85 A	A 3.90 A
Full-fat 2	BCD 3.28 A	C 3.49 A	C 3.49 A	BCD 3.28 A	C 3.49 A	C 3.48 A	BCD 3.28 A	C 3.49 A	C 3.49 A
Reduced-fat 1	BCD 3.28 A	C 3.50 A	C 3.50 A	BCD 3.28 A	C 3.50 A	C 3.50 A	BCD 3.28 A	C 3.50 A	C 3.52 A
Reduced-fat 2	DE 2.98 B	E 3.22 A	E 3.20 AB	DE 2.98 B	E 3.22 A	E 3.22 A	DE 2.98 B	E 3.22 A	E 3.22 A
Ranch (full-fat 1, 2, 3)	AB 3.21 A	B 3.21 A	B 3.40 A	AB 3.21 A	B 3.41 A	AB 3.44 A	AB 3.21 A	B 3.41 A	B 3.42 A
Ranch (reduced-fat 1, 2, 3)	AB 3.23 A	B 3.41 A	B 3.40 A	AB 3.23 A	B 3.41 A	B 3.41 A	AB 3.23 A	B 3.41 A	B 3.41 A
Blue cheese (full-fat 1, 2)	A 3.46 A	A 3.67 A	A 3.66 A	A 3.46 A	A 3.67 A	A 3.66 A	A 3.46 A	A 3.67 A	A 3.69 A
Blue cheese (reduced-fat 1, 2)	B 3.13 A	B 3.36 A	B 3.35 A	B 3.13 A	B 3.36 A	B 3.36 A	B 3.13 A	B 3.36 A	B 3.37 A

[a] Within the 10 salad dressings or within the four groups of salad dressings inoculated with the same pathogen, values in the same column that are preceded by the same letter are significantly different ($P \leq 0.05$). Within pathogen, values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] Maximum pH of uninoculated and salad dressings receiving high (5.7 log CFU/ml) or low (2.4 log CFU/ml) inoculum of *Salmonella*, high (5.9 log CFU/ml) or low (2.4 log CFU/ml) inoculum of *E. coli* O157:H7, or high (5.3 log CFU/ml) or low (2.5 log CFU/ml) inoculum of *L. monocytogenes* and stored at 25°C for up to 15 days.

TABLE 7. *Populations of* E. coli *O157:H7 recovered from inoculated salad dressings on sorbitol MacConkey agar supplemented with pyruvate (SMACP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on: Day 0	Day 1	Day 2	Day 3	Day 6
Ranch						
Full-fat 1	A 5.9 A	A 4.7 AB	A 4.2 B		AB 1.5 C	A ND C
	a 2.4 a	a 1.7 a	b ND[b] b	a ND b	a ND b	a ND b
Full-fat 2	A 5.9 A	A 4.4 B	A 4.0 B		B ND C	A ND C
	a 2.4 a	abc 1.4 b	b 0.7 bc	a ND c	a ND c	a ND c
Full-fat 3	A 5.9 A	A 4.8 B	B 2.9 C		B ND D	A ND D
	a 2.4 a	abc 1.4 b	b ND c	a ND c	a ND c	a ND c
Reduced-fat 1	A 5.9 A	A 4.6 B	B 3.1 C		B 1.0 D	A ND D
	a 2.4 a	ab 1.6 b	ab 0.8 c	a ND c	a ND c	a ND c
Reduced-fat 2	A 5.9 A	A 4.3 B	C 1.0 C		B ND C	A ND C
	a 2.4 a	ab 1.6 b	b ND c	a ND c	a ND c	a ND c
Reduced-fat 3	A 5.9 A	A 4.7 B	C 0.7 C		B ND C	A ND C
	a 2.4 a	abc 1.6 b	b ND c	a ND c	a ND c	a ND c
Blue cheese						
Full-fat 1	A 5.9 A	A 5.0 AB	A 4.1 B		A 2.4 C	A ND D
	a 2.4 a	abc 1.4 b	a 1.1 bc	a ND c	a ND c	a ND c
Full-fat 2	A 5.9 A	A 4.8 B	B 2.6 C		B ND D	A ND D
	a 2.4 a	c 1.2 b	b ND b	a ND b	a ND b	a ND b
Reduced-fat 1	A 5.9 A	A 5.0 B	C ND C		B ND C	A ND C
	a 2.4 a	bc 1.3 b	b ND b	a ND b	a ND b	a ND b
Reduced-fat 2	A 5.9 A	A 4.8 B	B 2.9 C		B ND D	A ND D
	a 2.4 a	abc 1.4 b	A b 0.8 bc	a ND c	a ND c	a ND c

[a] Populations of *E. coli* O157:H7 recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inocula. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] ND, none detected (<1.0 log CFU/ml) by direct plating.

oculated ranch full-fat dressings, ranch reduced-fat 2 dressing, and blue cheese reduced-fat 2 dressing were significantly higher than respective initial pH values. In no instance was maximum pH of inoculated dressings significantly different than the maximum pH of uninoculated dressings throughout the 15-day storage period. The maximum pH values of ranch full-fat 1 and blue cheese full-fat 1 dressings inoculated with *E. coli* O157:H7 were significantly higher than those of the other eight dressings, which may have favorably influenced the retention of viability.

TABLE 8. *Populations of* E. coli *O157:H7 recovered from four types of inoculated salad dressings on sorbitol MacConkey agar supplemented with pyruvate (SMACP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on: Day 0	Day 1	Day 2	Day 3	Day 6
Ranch (full-fat 1, 2, 3)	A 5.9 A	A 4.6 B	A 3.7 C		AB 0.9 D	A ND D
	a 2.4 a	ab 1.5 b	a 0.7 c	a ND[b] c	a ND c	a ND c
Ranch (reduced-fat 1, 2, 3)	A 5.9 A	A 4.5 B	B 1.6 C		AB 0.8 CD	A ND D
	a 2.4 a	a 1.6 b	a 0.7 c	a ND c	a ND c	a ND c
Blue cheese (full-fat 1, 2)	A 5.9 A	A 4.9 A	A 3.3 B		A 1.5 C	A ND C
	a 2.4 a	b 1.3 b	a 0.9 c	a ND c	a ND c	a ND c
Blue cheese (reduced-fat 1, 2)	A 5.9 A	A 4.9 A	B 1.8 B		B ND C	A ND C
	a 2.4 a	ab 1.4 b	a 0.8 c	a ND c	a ND c	a ND c

[a] Populations of *E. coli* O157:H7 recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inoculum. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] ND, none detected (<1.0 log CFU/ml) by direct plating.

TABLE 9. *Detection of* E. coli *O157:H7 in salad dressings by direct plating and enrichment*

Salad dressing	Initial population (log CFU/g)[a]	Detection by direct plating and enrichment on[b]: Day 0 dp	Day 0 en	Day 1 dp	Day 1 en	Day 2 dp	Day 2 en	Day 3 dp	Day 3 en	Day 6 dp	Day 6 en	Day 8 dp	Day 8 en	Day 10 dp	Day 10 en	Day 15 dp	Day 15 en
Ranch																	
Full-fat 1	5.9	3/3		3/3				1/3	1/2	0/3	**1/3**	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		0/3	3/3	0/3	2/3	0/3	**1/3**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
Full-fat 2	5.9	3/3		3/3				0/3	**2/3**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	2/3	1/1	1/3	**3/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3				
Full-fat 3	5.9	3/3		3/3				0/3	**2/3**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		0/3	**3/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3			0/3	0/3
Reduced-fat 1	5.9	3/3		3/3				**1/3**	0/2	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		1/3	2/2	0/3	1/3	0/3	**1/3**	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3
Reduced-fat 2	5.9	3/3		**2/3**	0/1			0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		0/3	**1/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2			0/3	0/3
Reduced-fat 3	5.9	3/3		1/3	**2/2**			0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		0/3	**2/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2			0/3	0/3
Blue cheese																	
Full-fat 1	5.9	3/3		3/3				2/3	**1/1**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.4	2/3	1/1	1/3	2/3	0/3	3/3	0/3	**2/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Full-fat 2	5.9	3/3		**3/3**				0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	2/3	1/1	0/3	**3/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3			0/3	0/3
Reduced-fat 1	5.9	3/3		0/3	**2/3**			0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	**3/3**		0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2			0/3	0/3
Reduced-fat 2	5.9	3/3		3/3				0/3	**2/3**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.4	3/3		1/3	**2/2**	0/3	2/3	0/3	0/3	0/3	0/3	0/3	0/3	0/1	0/1	0/3	0/3

[a] Initial populations were calculated from the number of CFU in inocula.

[b] Salad dressings were stored at 25°C for up to 15 days. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Values indicate the number of replicate samples in which *E. coli* O157:H7 was detected by direct plating or enrichment out of the number of samples analyzed. Absence of values indicates that salad dressings were not analyzed. Detection limits were 1.0 log CFU/ml of salad dressings analyzed by direct plating and 1 CFU/25 ml of salad dressing analyzed by enrichment. Bold values indicate the maximum storage time (days) at which *E. coli* O157:H7 was detected in each dressing inoculated with the pathogen at populations of 5.9 or 2.4 log CFU/g. dp, direct plating; en, enrichment.

Analysis of composites of pH values of individual salad dressings within each of the four types of dressings revealed no significant differences ($P > 0.05$) in initial and maximum pH values of uninoculated or inoculated dressings.

Rates of death of *E. coli* O157:H7 in the shelf-stable, dairy-based, pourable salad dressings examined in our study were more rapid than those observed by Raghubeer et al. *(9)*, who inoculated two strains of the pathogen into a ranch salad dressing formulated and processed to be stored at refrigerated temperature. In the latter study, the pathogen inoculated into the dressing (pH 4.51) at a population of 6.4 log CFU/g was detectable (1.8 log CFU/g) after storage for 17 days at 4°C. In the same study, the pathogen inoculated initially at 6.3 log CFU/g of mayonnaise (pH 3.91) was undetectable (<0.5 CFU/g) after storage at 22°C for 4 days. The ability of *E. coli* O157:H7 to survive longer in ranch salad dressing than in mayonnaise was attributed in part to differences in pH, nutrient availability, storage temperature, and water activity. Survival of *E. coli* O157:H7 in mayonnaise and in blue cheese dressing and Thousand Island dressing prepared from mayonnaise has been studied *(13)*. When the pathogen was inoculated into mayonnaise (pH 3.65) at a population of 7 to 8 log CFU/g and stored at 25°C, it was undetectable within 3 days. Cells were detected in mayonnaise stored at 7°C for up to 35 days. An initial population of ca. 8 log CFU/g decreased to ca. 5 and 3 log CFU/g, respectively, in blue cheese dressing (pH 4.44) and Thousand Island dressing (pH 3.76) stored at 5°C for 35 days. Rates of inactivation in these laboratory-prepared dressings at ambient temperature were not reported.

Hathcox et al. *(4)* determined death rates of *E. coli* O157:H7 in reduced-calorie mayonnaise (pH 4.08) and real mayonnaise (pH 3.86 to 3.97) held at 30°C. Initial populations of 0.23 to 0.29 log CFU/g were reduced to undetectable levels within 1 and 2 days, respectively. An initial population of 2.73 log CFU/g was reduced to an undetectable level within 4 days at 30°C or 7 days at 20°C; tolerance was greater in real mayonnaise than in reduced-calorie mayonnaise. When *E. coli* O157:H7 was inoculated at a population of 6.23 log CFU/g, it was not detected by enrichment of three 0.33-g samples of reduced-calorie mayonnaise held at 5°C for 58 days and was reduced from 0.95 CFU/g of real mayonnaise held at 5°C for 79 days to an undetectable level in three 0.33-g samples at 93 days. The ability of *E. coli* O157:H7 to survive longer in mayonnaise is attributable to its higher pH and other less stressing in-

TABLE 10. *Populations of* L. monocytogenes *recovered from inoculated salad dressings on modified Oxford medium supplemented with pyruvate (MOXP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on: Day 0	Day 1	Day 2	Day 3	Day 6
Ranch						
Full-fat 1	A 5.3 A	A 4.4 A	A 4.5 A		A 3.9 AB	A ND[b] B
	a 2.5 ab	a 2.3 a	a 2.1 a	a 1.4 a	a 1.9 a	a ND a
Full-fat 2	A 5.3 A	A 4.4 AB	A 4.3 AB		ABC 2.4 BC	A ND C
	a 2.5 ab	a 2.7 a	a 2.0 abc	a 1.4 bc	bc 1.0 c	a ND c
Full-fat 3	A 5.3 A	A 4.2 A	A 4.3 A		AB 3.0 AB	A ND B
	a 2.5 ab	a 2.3 a	a 1.8 a	a 1.2 a	bc 1.2 a	a ND a
Reduced-fat 1	A 5.3 A	A 4.5 A	A 4.4 A		A 3.6 AB	A ND B
	a 2.5 ab	a 2.6 a	a 2.2 abc	a 1.3 bc	ab 1.7 abc	a ND c
Reduced-fat 2	A 5.3 A	A 4.2 A	A 4.3 AB		C 0.7 C	A ND BC
	a 2.5 ab	a 2.4 a	a 1.2 ab	a ND b	c 0.8 b	a ND b
Reduced-fat 3	A 5.3 A	A 4.0 AB	A 4.0 AB		ABC 2.6 AB	A ND B
	a 2.5 ab	a 2.4 a	a 1.5 ab	a 0.8 b	c 0.7 b	a ND b
Blue cheese						
Full-fat 1	A 5.3 A	A 4.4 A	A 3.2 AB		C ND B	A ND B
	a 2.5 ab	a 2.4 a	a 1.3 ab	a ND b	c ND b	a ND b
Full-fat 2	A 5.3 A	A 4.5 A	A 3.2 AB		B 0.9 B	A ND B
	a 2.5 ab	a 2.8 a	a 1.1 b	a 1.1 b	c 0.8 b	a ND b
Reduced-fat 1	A 5.3 A	A 4.1 AB	A 3.3 AB		C ND B	A ND B
	a 2.5 ab	a 2.4 a	a 1.2 ab	a ND b	c ND b	a ND b
Reduced-fat 2	A 5.3 A	A 4.5 A	A 3.8 A		BC 1.2 B	A ND B
	a 2.5 ab	a 2.9 a	a 1.1 b	a ND b	c 0.9 b	a ND b

[a] Populations of *L. monocytogenes* recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inocula. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] ND, none detected (<1.0 log CFU/ml) by direct plating.

trinsic factors compared with the salad dressings tested in the present study and also to storage at refrigeration temperature rather than at 25°C. Erickson et al. *(2)* reported reductions in populations of *E. coli* O157:H7 of more than 6 to 7 log CFU/g of full-fat and reduced-fat mayonnaise (pH 3.21 to 3.94) held at 25°C for 1 to 3 days. In no instance has *E. coli* O157:H7 been reported by these investigators to grow in salad dressings or mayonnaise, regardless of the level of inoculum or storage temperature.

Studies on *L. monocytogenes.* Populations of *L. monocytogenes* recovered from salad dressings inoculated with high (5.3 log CFU/g) and low (2.5 log CFU/g) populations of the pathogen and stored for up to 6 days are shown in Table 10. Regardless of inoculum level, *L. monocytogenes* was not detected (<1.0 log CFU/ml) by direct plating any of the 10 salad dressings 6 days after inoculation, indicating a reduction of >4.3 log CFU/ml in all salad dressings. Populations did not decrease significantly ($P > 0.05$) within 1 day after inoculation, regardless of inoculum level, but did decrease significantly ($P \leq 0.05$) within 3 days in ranch full-fat 2, ranch reduced-fat 2, and all blue cheese dressings inoculated with *L. monocytogenes* at a level of 5.3 log CFU/g. A significant reduction (1.5 log CFU/ml) in population of *L. monocytogenes* occurred within 3 days in ranch full-fat 2 dressing but not in the other nine dressings inoculated with a low population (2.5 log CFU/g) of the pathogen. The lack of significant differences in the initial count of 2.5 log CFU/g and none detected (<1.0 log CFU/ml by direct plating) is a result of large standard deviations among counts. By day 3, significant reductions of 2.9 and 4.6 log CFU/ml of ranch full-fat 2 and ranch reduced-fat 2 dressings, respectively, and 4.1 to >4.3 log CFU/ml of the four blue cheese dressings were observed. Considering death rates in all salad dressings, reductions of ≥1.4 log CFU/ml and >4.3 log CFU/ml occurred within 3 and 6 days, respectively. Inactivation of *L. monocytogenes*, regardless of the inoculum level, appeared to be largely unaffected by composition of the 10 salad dressings.

Data for individual dressings within each of the four types of dressing were composited and analyzed to determine if the rate of death of *L. monocytogenes* is influenced by differences in basic composition. Significant differences ($P \leq 0.05$) among the four types of dressing were not detected on day 0 (Table 11). On day 1, a significantly higher number of *L. monocytogenes* was detected in ranch full-fat dressings than in blue cheese full-fat dressings initially receiving a high inoculum (5.3 log CFU/g) and in ranch full-fat dressings than in blue cheese full-fat or blue cheese reduced-fat dressings initially receiving a low inoculum (2.5 log CFU/g). Within 3 days after inoculation with 2.5

TABLE 11. *Populations of* L. monocytogenes *recovered from four types of inoculated salad dressings on modified Oxford medium supplemented with pyruvate (MOXP)*[a]

Salad dressing	Initial population	Population (log CFU/ml) on: Day 0	Day 1	Day 2	Day 3	Day 6
Ranch (full-fat 1, 2, 3)	A 5.3 A	A 4.3 AB	A 4.4 AB		A 3.1 B	A ND[b] C
	a 2.5 a	a 2.5 a	a 2.0 ab	a 1.3 bc	a 1.4 bc	a ND c
Ranch (reduced-fat 1, 2, 3)	A 5.3 A	A 4.2 A	AB 4.2 A		AB 2.3 B	A ND B
	a 2.5 ab	a 2.5 a	ab 1.6 bc	ab 0.9 c	ab 1.0 c	a ND c
Blue cheese (full-fat 1, 2)	A 5.3 A	A 4.5 AB	B 3.2 B		B 0.8 C	A ND C
	a 2.5 a	a 2.6 a	b 1.2 b	ab 0.9 b	b ND b	a ND b
Blue cheese (reduced-fat 1, 2)	A 5.3 A	A 4.3 A	AB 3.6 A		B 1.0 B	A ND B
	a 2.5 a	a 2.6 a	b 1.1 b	b ND b	ab 0.8 b	a ND b

[a] Populations of *L. monocytogenes* recovered from inoculated salad dressings stored at 25°C for up to 6 days. Initial populations were calculated from the number of CFU in inoculum. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Absence of values indicates that salad dressings were not analyzed. Within a storage time and inoculum level, mean values in a column that are not preceded by the same letter are significantly different ($P \leq 0.05$). Mean values in the same row that are not followed by the same letter are significantly different ($P \leq 0.05$).

[b] ND, none detected (<1.0 log CFU/ml) by direct plating.

and 5.3 log CFU/g, significant reductions of ≥1.1 and ≥2.2 CFU/ml, respectively, occurred in all four types of dressings.

Table 12 shows the number of samples of three analyzed by direct plating and one, two, or three analyzed by enrichment for each combination of test parameters that was positive for *L. monocytogenes.* Detection limits were 1.0 log CFU/ml for direct plating and 1 CFU/25 ml for enrichment. Bold values indicate the maximum storage time at which *L. monocytogenes* was detected in each dressing inoculated with the pathogen at populations of 5.3 or 2.5 log CFU/g. Regardless of the inoculum level, *L. monocytogenes* was not detected in salad dressings stored for ≥8 days. The pathogen was detected by enrichment but not by direct plating of ranch full-fat 1 dressing and not by enrichment in the other nine dressings on day 6 of storage. This indicates a decrease in population of 5.3 log CFU/ml in all dressings within 6 days. With the exception of blue cheese reduced-fat 1 dressing, the pathogen was detected in inoculated dressings stored for 3 days. The time required for elimination of *L. monocytogenes* was largely unaffected by inoculum level.

Initial and maximum mean pH values of three lots of uninoculated salad dressings and salad dressings inoculated with *L. monocytogenes* within the 15-day storage period are shown in Table 6. The pH of ranch full-fat 2, ranch reduced-fat 2, and blue cheese reduced-fat 2 increased significantly during storage. The pH was not significantly ($P > 0.05$) affected by inoculation with *L. monocytogenes.* Analysis of composites of pH values of individual salad dressings within the four types of dressings analyzed revealed that the initial pH of full-fat blue cheese dressings was significantly higher than the pH of reduced-fat blue cheese dressings, but the pH of both types of blue cheese dressings was not significantly different than the pH of the two ranch type dressings. The maximum pH values of uninoculated and inoculated blue cheese full-fat dressings stored for 15 days was significantly higher ($P \leq 0.05$) than those of the other three types of dressings.

Glass and Doyle *(3)* determined inactivation rates of *L. monocytogenes* and *Salmonella* in mayonnaise (pH 3.9 to 4.3) containing different amounts of fat and acetic acid. Products inoculated with these pathogens at a population of ca. 6 log CFU/g were held at 23.9°C for up to 14 days. As observed for the shelf-stable, dairy-based, pourable salad dressings in our study, *L. monocytogenes* survived longer than *Salmonella.* No *L. monocytogenes* (per l00 g) was detected at 10 or 14 days postinoculation of reduced-calorie mayonnaise or cholesterol-free, reduced-calorie mayonnaise, respectively, made with 0.7% acetic acid in the aqueous phase *(3).* Reductions of >4 log CFU of *L. monocytogenes* per gram occurred within 3 days. Erickson and Jenkins *(1)* reported decreases in populations of *L. monocytogenes* of 8 log CFU/g of real mayonnaise dressing (pH 3.6) and sandwich spread (pH 3.3) stored for 3 days and reduced-calorie mayonnaise dressing (pH 3.9) stored for 8 days at 26.6°C. *L. monocytogenes* survived longer than *Salmonella* in test products, as it did in the salad dressings tested in our study.

Total plate counts, lactic acid bacteria, and yeasts and molds. Populations of aerobic mesophilic microorganisms (total counts) in salad dressings inoculated with *Salmonella, E. coli* O157:H7, or *L. monocytogenes* generally reflected those obtained for each pathogen during the first few days of storage, indicating colony formation by these pathogens on TSAP. On sampling days after pathogens were not detected by direct plating, total counts reflected the presence of other microflora and generally decreased to less than the limit of detection (1.0 log CFU/ml) as storage time progressed.

Populations of bacteria recovered on MRS agar, during the initial days of storage, from salad dressings inoculated with pathogens also reflected populations of the pathogens, not classical lactic acid bacteria. Once populations of pathogens were markedly reduced, lactic acid bacteria could be enumerated. Overall, counts remained low or were unaffected by the population of pathogen in the inoculum or by

TABLE 12. *Detection of* L. monocytogenes *in salad dressings by direct plating and enrichment*

Salad dressing	Initial population (log CFU/g)[a]	Detection by direct plating and enrichment on[b]: Day 0 dp	Day 0 en	Day 1 dp	Day 1 en	Day 2 dp	Day 2 en	Day 3 dp	Day 3 en	Day 6 dp	Day 6 en	Day 8 dp	Day 8 en	Day 10 dp	Day 10 en	Day 15 dp	Day 15 en
Ranch																	
Full-fat 1	5.3	3/3		3/3				2/3	0/1	0/3	**1/3**	0/3	0/3	0/2	0/2	0/3	0/3
	2.5	3/3		2/3	1/1	1/3	1/2	2/3	0/1	0/3	**1/3**	0/3	0/3	0/2	0/2	0/3	0/3
Full-fat 2	5.3	3/3		3/3				2/3	**1/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	3/3		3/3		2/3	1/1	2/3	**1/1**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Full-fat 3	5.3	3/3		3/3				**2/3**	0/1	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.5	2/3	1/1	2/3	0/1	1/3	1/2	1/3	**1/2**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
Reduced-fat 1	5.3	3/3		3/3				2/3	**1/1**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	3/3		3/3		2/3	1/1	**3/3**		0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Reduced-fat 2	5.3	3/3		3/3				1/3	**1/2**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	2/3	0/1	3/3		0/3	2/3	1/3	**3/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Reduced-fat 3	5.3	3/3		2/3	0/1			**2/3**	0/1	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.5	2/3	0/1	2/3	0/1	1/3	1/2	1/3	**2/3**	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
Blue cheese																	
Full-fat 1	5.3	3/3		2/3	1/1			0/3	**1/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	3/3		3/3		1/3	**1/2**	0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
Full-fat 2	5.3	3/3		2/3	1/1			0/3	**1/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	3/3		1/3	1/2	1/3	0/2	**1/3**	0/2	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
Reduced-fat 1	5.3	2/3	1/1	2/3	**1/1**			0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
	2.5	2/3	0/1	2/3	0/1	0/3	**2/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/2	0/2	0/3	0/3
Reduced-fat 2	5.3	3/3		3/3				1/3	**2/3**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3
	2.5	3/3		1/3	2/3	0/3	2/3	1/3	**1/2**	0/3	0/3	0/3	0/3	0/3	0/3	0/3	0/3

[a] Initial populations were calculated from the number of CFU in inocula.

[b] Salad dressings were stored at 25°C for up to 15 days. Values shown for day 0 were obtained from salad dressings analyzed within 30 min after inoculation. Values indicate the number of replicate samples in which *L. monocytogenes* was detected by direct plating or enrichment of the number of samples analyzed. Absence of values indicates that salad dressings were not analyzed. Detection limits were 1.0 log CFU/ml of salad dressing analyzed by direct plating and 1 CFU/25 ml of salad dressing analyzed by enrichment. Bold values indicate the maximum storage time (days) at which *L. monocytogenes* was detected in each dressing inoculated with the pathogen at populations of 5.3 or 2.5 log CFU/g. dp, direct plating; en, enrichment.

storage time. Populations of yeasts and molds recovered from salad dressings inoculated with each pathogen and stored for up to 15 days at 25°C were determined. Counts remained undetectable (<1.0 log CFU/ml) or low, not exceeding 2.3 log CFU/ml throughout storage for 15 days, and were unaffected by populations of pathogens inoculated into the dressings. The absence of growth of lactic acid bacteria, yeasts, and molds precludes any effects these spoilage microorganisms might have had on the survival or rate of death of test pathogens.

Retention of viability of *E. coli* O157:H7 and *L. monocytogenes* may differ among specific dressings within a basic formulation, e.g., these pathogens remained viable for a longer time in ranch full-fat 1 dressing than in ranch full-fat 2 or ranch full fat 3 dressings. Overall, however, strong evidence does not exist to conclude that the type of dressing (i.e., ranch versus blue cheese) or the level of fat in the dressings affects the rate of death of test pathogens. Changes in pH, total counts, and populations of lactic acid bacteria and yeasts and molds in salad dressings stored for up to 15 days at 25°C are unaffected by the presence of pathogens. Conversely, the lack of growth of spoilage microorganisms excludes any impact they might have otherwise had on survival or rates of death of *Salmonella, E. coli* O157:H7, or *L. monocytogenes.*

This study demonstrates that the death rate of *Salmonella, E. coli* O157:H7, and *L. monocytogenes* in 10 commercially manufactured shelf-stable, dairy-based, pourable full-fat and reduced-fat ranch and blue cheese salad dressings stored at 25°C is rapid. *Salmonella* died most rapidly, followed by *E. coli* O157:H7. *L. monocytogenes* exhibited the highest resistance among the three test pathogens to the adverse environments imposed by salad dressings. Dressings inoculated with *Salmonella, E. coli* O157:H7, or *L. monocytogenes* at populations of 5.3 to 5.9 log CFU/g were undetectable (<1 CFU/25 ml) by enrichment within 1, 8, and 8 days, respectively. All dressings were able to effect a >4.7 log CFU/ml reduction in *Salmonella* within 24 h, ≥3.5 and >4.9 log CFU/ml reductions in *E. coli* O157:H7 within 3 and 6 days, respectively, and ≥1.4 and >4.3 log CFU/ml reductions in *L. monocytogenes* within 3 and 6 days, respectively. Elimination of the pathogens in dressings inoculated with 2.4 to 2.5 log CFU/g occurred within the same or less storage time.

Typically, the distribution pattern from the manufacturer to retail or food service establishments is at least 14

days for shelf-stable, dairy-based, pourable salad dressings. Results of this study show that large populations of the pathogens tested would die before unopened bottles of dressings reach the consumer. Likewise, large populations of *Salmonella*, *E. coli* O157:H7, or *L. monocytogenes* that may contaminate dressings after containers are opened in food service or home settings would die rapidly at 25°C. Results show that shelf-stable, dairy-based, pourable full-fat and reduced-fat ranch and blue cheese salad dressings produced by three different manufacturers and stored at 25°C should not be considered as potentially hazardous foods (time-temperature control for safety foods) as defined by the FDA Food Code *(12).*

ACKNOWLEDGMENT

This study was supported, in part, by the Association for Dressings and Sauces, Atlanta, Ga.

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