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Evaluation of Microwave Oven Heating and Salad Dressings to Control *Listeria monocytogenes* on Diced Ham and Turkey Breast

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ABSTRACT

This study evaluated the antilisterial effects of salad dressings on inoculated and stored diced cured ham and uncured turkey breast, without or with prior microwave oven heating of the deli meats. Product pieces (1.5 × 1.5 × 1.5 cm) were inoculated (2.1 ± 0.1 log CFU/cm^2) with *Listeria monocytogenes* (10-strain mixture) and stored (7°C) aerobically in bags to simulate home storage. Ham (storage days 0, 7, 14) and turkey breast (storage days 0, 5, 9) samples were left untreated or were immersed (5 or 10 min, 25 ± 2°C) in sunflower oil + vinegar, extra virgin olive oil + lemon juice, commercially available salad dressings (vinaigrette and thousand island) or distilled water (DW), and each immersion treatment was applied to deli meat samples that were previously exposed or not exposed to microwave oven heating (30 or 45 s). When the salad dressing treatments were applied without prior microwave oven heating of the ham and turkey breast samples, *L. monocytogenes* reductions obtained were 0.3–0.8 and 0.2–0.6 log CFU/cm^2, higher, respectively, than those obtained for DW-treated samples. When the deli meats were first heated in the microwave oven and then exposed to the salad dressings, pathogen reductions increased from 0.5–1.2 or 0.2–0.8 (without microwave heating) to 3.4–5.5 or 2.9–5.7 (with 45 s microwave heating) log CFU/cm^2 for ham and turkey breast, respectively. Pathogen reductions were not ($P \geq 0.05$) different for samples with 5 and 10 min of immersion in most salad dressing treatments. Use of microwave oven heating and certain salad dressings in sequence may contribute to the reduction of *L. monocytogenes*, if present, on diced deli meats consumed with salads especially important if these are consumed by at-risk populations.

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INTRODUCTION

Deli meats have been involved in a number of listeriosis outbreaks in the United States *(4, 5, 6, 7, 19)*, and have been identified as the highest predicted relative risk for listeriosis among 23 categories of ready-to-eat foods, based on a risk assessment conducted by the U.S. Food and Drug Administration and the U.S. Department of Agriculture Food Safety and Inspection Service *(30)*. Although many foodborne illness outbreaks have been associated with eating outside the home, it has been reported that foodborne illness is three times more likely to originate in consumer homes than in commercial cafeterias *(2),* because of poor food hygiene practices, improper temperature control and inappropriate refrigerator management *(14, 15, 31)*. *Listeria monocytogenes* is difficult to control in the home because it may be present in a wide variety of foods, including vegetables, seafood, dairy products, and meat and poultry products, and because it grows at refrigerator temperatures *(22)*. As deli meats are ready-to-eat products and, hence, do not need reheating before consumption, products potentially contaminated with *L. monocytogenes* represent a risk for consumers, especially those with a suppressed immune system. Thus, control strategies that could be applied in the home are needed, to reduce the risk of illness in high-risk populations.

Chemical antimicrobials, such as benzoate, lactate, diacetate, sorbate, acetic acid, and lactic acid, are widely used in food processing *(27)*. In recent years, however, there has been an increasing demand by consumers for the use of natural antimicrobial systems to maintain food safety. Commercial dressings for salads, such as thousand island dressing, and vinaigrettes (vinegar or lemon juice mixed with oil), are widely used in the United States for preparation of vegetable salads *(24)* and cooked fish *(28)*, and have a good safety record because they contain acetic or citric acid as ingredients *(1)*. Antimicrobial effects of salad dressings have been documented in vegetables *(23, 24)*, egg or milk mayonnaise *(20, 21)*, stuffed mussels *(16)* and frankfurters *(25)*. This indicates that exposing foods to salad dressings prior to consumption could potentially inactivate microbial contamination, including contamination with foodborne pathogens.

Microwave ovens are remarkably popular for food preparation in the home *(10, 11)* because of their speed of heating and convenience *(12)*. According to the U.S. Department of Agriculture Food Safety and Inspection Service, more than 90% of homes in America have at least one microwave oven *(29)*. Control of *L. monocytogenes* using microwave heating has previously been reported in lamb and quail meat *(8)* and frankfurters *(13, 25)*. The objective of this study was to evaluate the antilisterial effects of salad dressings on inoculated and stored diced cured ham and uncured turkey breast, without or with prior exposure of the deli meats to microwave oven heating. The study was conducted on diced ham and turkey breast as these products are likely to be used in the preparation of salads.

MATERIALS AND METHODS

Products and product inoculation

Commercially manufactured cured ham and uncured turkey breast were purchased from a local supermarket. The ingredients of the cured ham included water, salt, sugar, sodium phosphate, sodium erythorbate, and sodium nitrite, while the formulation of the uncured turkey breast consisted of turkey breast meat, turkey broth, modified food starch, salt, sugar, sodium phosphate, and flavoring. A 10-strain mixture of *L. monocytogenes*, including NA-1 (serotype 3b, pork sausage isolate); N-7150 (serotype 3a, meat isolate); 558 (serotype 1/2, pork meat isolate); N1-227, R2-500 and R2-764 (serotype 4b, food isolates); N1-225, R2-501 and R2-763 (serotype 4b, clinical isolates); and R2-765 (serotype 4b, environmental isolate), was used for product inoculation. Strains N1-225, N1-227, R2-500, R2-501, R2-763, R2-764 and R2-765 were kindly provided by Dr. Martin Wiedmann (Cornell University, Ithaca, NY) *(9)*. The strains were individually cultured, harvested, washed, and habituated in ham or turkey breast homogenate for 3 days at 7°C, as described previously *(17, 18)*. On the day of the experiment, the 10 strains were combined and serially diluted in freshly prepared ham or turkey breast *(17, 18)* homogenate to a concentration of 4–5 log CFU/ml.

Before inoculation, ham and turkey breast products were sliced (Hobart 2712 12" Semi Automatic Slicer, Hobart Mfg. Co., Troy, OH) and manually diced into pieces of 1.5 × 1.5 × 1.5 cm. Batches of 18 pieces of each product were immersed in 200 ml of the diluted inoculum for 5 min, with intermittent shaking. The pieces were then transferred to a tray covered with sterile aluminum foil and placed in a biosafety cabinet for 15 min to allow for cell attachment and drying of the excess liquid inoculum. The inoculated (2.1 ± 0.1 log CFU/cm^2) samples were placed into zip-top type vacuum bags (18 pieces per bag; Zip Vak, 15 × 20 cm, nylon/EVA copolymer, Winpak Winnipeg, MB, Canada), vacuum-packaged (Hollymatic Corp., Countryside, IL), and then opened to remove six pieces for day 0 testing. The bags with the remaining 12 pieces were reclosed and stored at 7°C for up to 14 (ham) or 9 (turkey breast) days. This procedure simulated opening of a vacuum-packaged product by a consumer, removing some of the pieces for consumption, reclosing the bag and storing the rest in a home refrigerator for consumption on another day.

Product treatments

Salad dressing and microwave oven treatments were applied to ham samples on days 0, 7 and 14 of storage (7°C) and to turkey breast samples on days 0, 5 and 9. For treatment with salad dressings, six pieces of diced ham or turkey breast were transferred to Whirl-Pak® bags (15 × 23 cm; Nasco, Modesto, CA) containing one of the following treatments: (i) no treatment (control); (ii) sterile distilled water (DW; 20 ml); (iii) sunflower oil (18 ml; Kroger®, Kroger Co., Cincinnati, OH) mixed with vinegar (2 ml; Private Selection®, Inter-American Products, Inc. Cincinnati, OH) (pH 2.50); (iv) extra virgin olive oil (18 ml; Star®, Star Fine Foods, Fresno, CA) mixed with lemon juice (2 ml; Kroger®) (pH 3.50); and one of two commercial salad dressings: (v) vinaigrette (20 ml; Kraft®, Kraft Foods Global Inc., Northfield, IL; pH 3.30), and (vi) thousand island (20 ml; Kraft®; pH 3.44). Each of the DW or salad dressing treatments were applied for 5 or 10 min (25 ± 2°C), and to deli meat samples previously exposed or not exposed to 30 or 45 s of microwave oven (Amana, model Radarange AM-C5143AAW, Newton, IA) heating (1100 Watts, 2450 MHz, high power). The 45 s microwave heating treatment was not applied to day 0 samples, as their contamination levels were low. Microwave oven exposure was applied to batches of six pieces of diced ham or turkey breast immersed in 150 ml of DW (to allow for more even heating and to prevent hot/

TABLE 1. Mean (± standard deviation) pH values of diced ham samples inoculated with *Listeria monocytogenes* and stored aerobically at 7°C for 14 days. On days 0, 7 and 14 of storage, samples were left untreated or were immersed for 5 or 10 min in distilled water or salad dressings, without or with prior microwave heating of the deli meats for 30 or 45 s

		No microwave heating		With 30 s microwave heating		With 45 s microwave heating	
Storage day	Treatment	5 min	10 min	5 min	10 min	5 min	10 min
0	Control	6.42 ± 0.04		NA		ND	ND
	Microwave 30 s	NA		6.38 ± 0.03		ND	ND
	Distilled water	6.40 ± 0.04	6.38 ± 0.04	6.40 ± 0.04	6.41 ± 0.04	ND	ND
	Sunflower oil + vinegar	5.41 ± 0.10	5.29 ± 0.08	5.50 ± 0.03	5.33 ± 0.09	ND	ND
	Extra virgin olive oil + lemon juice	6.05 ± 0.07	5.85 ± 0.03	5.83 ± 0.07	5.73 ± 0.09	ND	ND
	Vinaigrette	5.39 ± 0.16	5.35 ± 0.05	5.42 ± 0.05	5.26 ± 0.05	ND	ND
	Thousand island	5.68 ± 0.15	5.57 ± 0.05	5.58 ± 0.09	5.59 ± 0.05	ND	ND
7	Control	6.43 ± 0.06		NA		NA	
	Microwave 30 s	NA		6.40 ± 0.07		NA	
	Microwave 45 s	NA		NA		6.41 ± 0.09	
	Distilled water	6.45 ± 0.05	6.43 ± 0.05	6.42 ± 0.07	6.41 ± 0.13	6.37 ± 0.07	6.38 ± 0.04
	Sunflower oil + vinegar	5.43 ± 0.12	5.36 ± 0.09	5.45 ± 0.04	5.31 ± 0.11	5.30 ± 0.05	5.28 ± 0.06
	Extra virgin olive oil + lemon juice	6.04 ± 0.07	5.92 ± 0.08	5.84 ± 0.12	5.83 ± 0.15	5.88 ± 0.09	5.86 ± 0.08
	Vinaigrette	5.35 ± 0.15	5.42 ± 0.07	5.34 ± 0.13	5.26 ± 0.12	5.34 ± 0.07	5.21 ± 0.13
	Thousand island	5.53 ± 0.15	5.54 ± 0.09	5.50 ± 0.14	5.53 ± 0.14	5.50 ± 0.12	5.54 ± 0.04
14	Control	5.79 ± 0.26		NA		NA	
	Microwave 30 s	NA		5.86 ± 0.23		NA	
	Microwave 45 s	NA		NA		5.88 ± 0.34	
	Distilled water	5.88 ± 0.24	5.85 ± 0.35	5.93 ± 0.24	5.86 ± 0.18	5.80 ± 0.28	5.83 ± 0.24
	Sunflower oil + vinegar	5.24 ± 0.36	5.06 ± 0.06	4.86 ± 0.17	4.98 ± 0.10	5.10 ± 0.12	4.93 ± 0.14
	Extra virgin olive oil + lemon juice	5.50 ± 0.24	5.53 ± 0.12	5.39 ± 0.13	5.08 ± 0.22	5.29 ± 0.20	5.27 ± 0.11
	Vinaigrette	5.01 ± 0.20	4.91 ± 0.14	4.96 ± 0.16	4.90 ± 0.16	4.96 ± 0.25	4.96 ± 0.13
	Thousand island	5.09 ± 0.17	5.11 ± 0.10	5.04 ± 0.18	5.02 ± 0.17	5.11 ± 0.20	5.24 ± 0.10

NA: Not applicable; ND: Not done

cold spots) in sterile bowls (346 cm^3). The salad dressing immersion treatments were applied to samples within 5–10 s following the 30 or 45 s microwave treatment, when the two treatments were applied in sequence. Thus overall, the treatments evaluated in this study, for each of the two deli meat products and on three storage days (0, 7, and 14 for ham, and 0, 5, and 9 for turkey breast), included six immersion treatments (none, DW, sunflower oil + vinegar, extra virgin olive oil + lemon juice, vinaigrette, and thousand island), two immersion times (5 and 10 min), and three microwave oven heating times (0, 30, and 45 [except for day 0 samples] s).

Microbiological, chemical and physical analyses

After treatment with salad dressings, without or with prior microwave heating of the deli meat samples, the six product pieces were transferred into a filter bag (15 × 23 cm; WhirlPak®) containing 20 ml of maximum recovery diluent (comprised of 0.85% NaCl and 0.1% peptone). The samples were vertically shaken 30 times within approximately 30 s *(3)*, serially diluted in 0.1% buffered peptone water (Difco, Becton Dickinson, Sparks, MD), and plated on tryptic soy agar (Difco, Becton Dickinson) supplemented with 0.6% yeast extract (Acumedia, Lansing, MI; TSAYE) and PALCAM agar (Difco, Becton Dickinson) for enumeration of total microbial populations and *L. monocytogenes*, respectively *(3)*. Colonies were manually counted after incubation of plates at 25°C for 72 h (TSAYE) and 30°C for 48 h (PALCAM agar). Following microbial analysis, the ham and turkey breast samples suspended in maximum recovery diluent were pummeled (2 min; Masticator, IUL Instruments, Barcelona, Spain), and pH measurements of the homogenate were taken with a digital pH meter with a glass electrode (Denver Instruments, Arvada, CO). Water activities (AquaLab model series 3, Decagon Devices Inc., Pullman, WA) of untreated inoculated samples (day 0) were also measured.

TABLE 2. Mean (± standard deviation) pH values of diced turkey breast samples inoculated with *Listeria monocytogenes* and stored aerobically at 7°C for 9 days. On days 0, 5 and 9 of storage, samples were left untreated or were immersed for 5 or 10 min in distilled water or salad dressings, without or with prior microwave heating of the deli meats for 30 or 45 s

		No microwave heating		With 30 s microwave heating		With 45 s microwave heating	
Storage day	Treatment	5 min	10 min	5 min	10 min	5 min	10 min
0	Control	6.36 ± 0.02		NA		ND	ND
	Microwave 30 s	NA		6.41 ± 0.05		ND	ND
	Distilled water	6.39 ± 0.04	6.38 ± 0.02	6.40 ± 0.04	6.42 ± 0.07	ND	ND
	Sunflower oil + vinegar	5.42 ± 0.10	5.36 ± 0.04	5.44 ± 0.16	5.33 ± 0.13	ND	ND
	Extra virgin olive oil + lemon juice	5.93 ± 0.17	5.87 ± 0.08	5.79 ± 0.05	5.76 ± 0.09	ND	ND
	Vinaigrette	5.47 ± 0.07	5.39 ± 0.08	5.42 ± 0.12	5.29 ± 0.06	ND	ND
	Thousand island	5.54 ± 0.08	5.45 ± 0.05	5.45 ± 0.16	5.30 ± 0.11	ND	ND
5	Control	6.18 ± 0.17		NA		NA	
	Microwave 30 s	NA		6.27 ± 0.11		NA	
	Microwave 45 s	NA		NA		6.33 ± 0.09	
	Distilled water	6.14 ± 0.25	6.16 ± 0.24	6.26 ± 0.12	6.31 ± 0.13	6.36 ± 0.08	6.30 ± 0.05
	Sunflower oil + vinegar	5.37 ± 0.10	5.41 ± 0.07	5.33 ± 0.04	5.32 ± 0.11	5.35 ± 0.09	5.21 ± 0.10
	Extra virgin olive oil + lemon juice	5.95 ± 0.17	5.80 ± 0.20	5.72 ± 0.12	5.64 ± 0.15	5.69 ± 0.07	5.52 ± 0.15
	Vinaigrette	5.38 ± 0.23	5.46 ± 0.23	5.32 ± 0.13	5.18 ± 0.12	5.35 ± 0.08	5.10 ± 0.15
	Thousand island	5.41 ± 0.10	5.36 ± 0.06	5.42 ± 0.14	5.31 ± 0.14	5.31 ± 0.08	5.28 ± 0.10
9	Control	5.94 ± 0.14		NA		NA	
	Microwave 30 s	NA		6.40 ± 0.29		NA	
	Microwave 45 s	NA		NA		6.32 ± 0.12	
	Distilled water	6.33 ± 0.28	6.32 ± 0.40	5.94 ± 0.40	6.43 ± 0.26	6.22 ± 0.09	6.38 ± 0.21
	Sunflower oil + vinegar	5.69 ± 0.17	5.72 ± 0.17	5.57 ± 0.22	5.51 ± 0.24	5.67 ± 0.19	5.39 ± 0.24
	Extra virgin olive oil + lemon juice	5.91 ± 0.09	5.98 ± 0.06	5.80 ± 0.16	5.76 ± 0.14	5.84 ± 0.25	5.83 ± 0.22
	Vinaigrette	5.60 ± 0.15	5.46 ± 0.13	5.45 ± 0.13	5.50 ± 0.17	5.65 ± 0.32	5.33 ± 0.22
	Thousand island	5.47 ± 0.17	5.40 ± 0.17	5.56 ± 0.14	5.47 ± 0.12	5.48 ± 0.17	5.47 ± 0.23

Statistical analysis

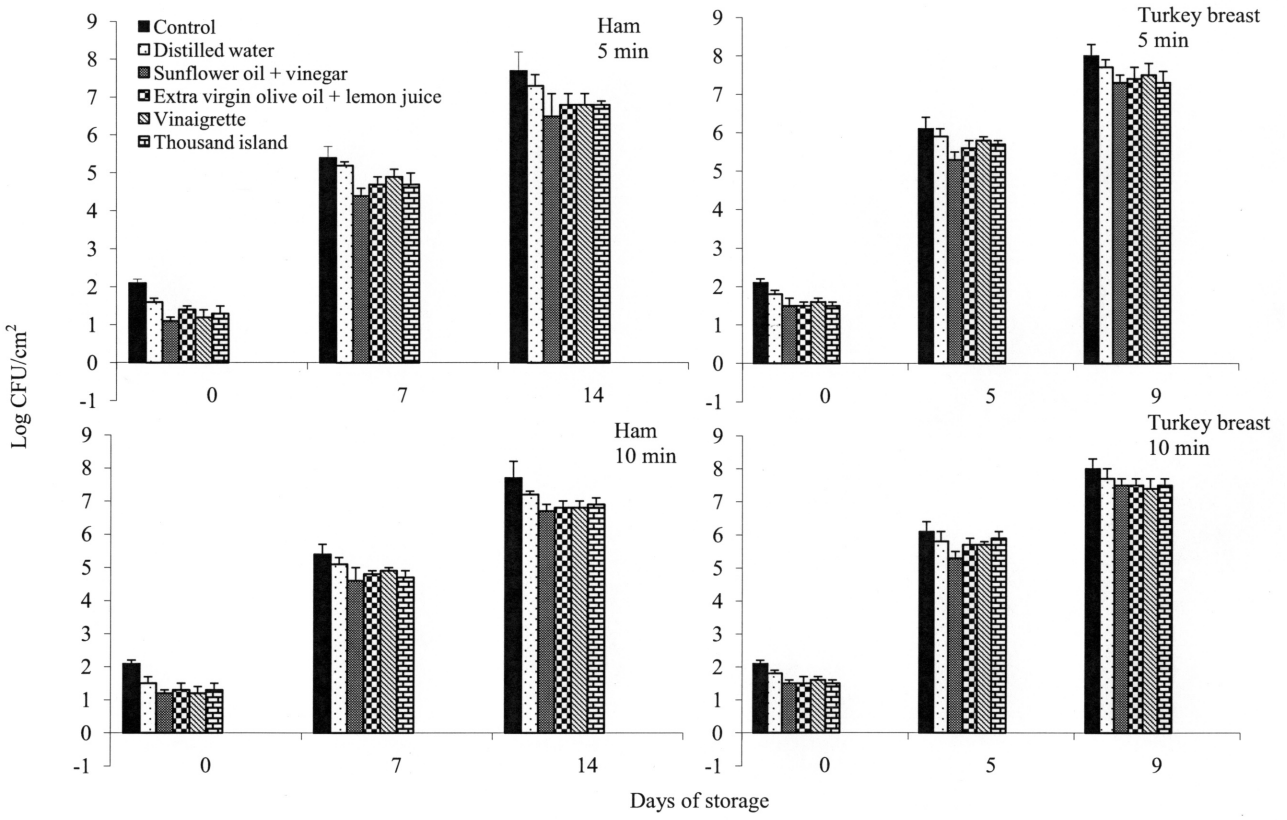
The experimental unit (sample) in this study consisted of six pieces of diced ham or turkey breast. The study was repeated twice, using different lots of the ham and turkey breast. For each replication, three samples for each treatment were analyzed at each sampling time for each product. Total microbial and *L. monocytogenes* counts were converted into log CFU/cm^2 by taking into consideration the surface area (81 cm^2) of the six pieces of diced ham or turkey breast and the volume (20 ml) of maximum recovery diluent added to the samples for microbial analysis. The pH and microbiological data (log CFU/cm^2) were analyzed using the Mixed Model Procedure of SAS® version 9.1 (SAS Institute, Cary, NC) to analyze the survivors and reductions of each treatment. For each product and each analysis day, independent variables included immersion treatment (none, DW, sunflower oil + vinegar, extra virgin olive oil + lemon juice, vinaigrette, or thousand island), immersion time (5 or 10 min), and microwave treatment (without, or with 30 or 45 s microwave heating) and interactions of immersion treatment × immersion time, immersion treatment × microwave treatment, and immersion treatment × immersion time × microwave treatment. Means and standard deviations for microbiological data were calculated, and the mean differences were separated with the least significant difference procedure at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Physical and chemical properties of ham and turkey breast

The initial (day 0) water activity and pH of the untreated inoculated diced ham and turkey breast samples were 0.975 ± 0.004 and 6.42 ± 0.04, and 0.979 ± 0.002 and 6.36 ± 0.02, respectively. The pH values of samples of both products decreased significantly ($P < 0.05$) following immersion in the

FIGURE 1. Mean populations of *Listeria monocytogenes* (± standard deviation; log CFU/cm^2) on diced ham and turkey breast inoculated and stored aerobically at 7°C for 14 or 9 days, respectively, and left untreated or immersed for 5 or 10 min in distilled water, sunflower oil + vinegar, extra virgin olive oil + lemon juice, vinaigrette or thousand island.



salad dressings (Tables 1 and 2). On day 0 of storage, immersion of samples in each of the four salad dressings for 5 or 10 min, without prior microwave heating of the deli meats, reduced ($P < 0.05$) the pH of ham and turkey breast by 0.37–1.13 and 0.43–1.00 units, respectively, compared to the controls (pH 6.42 and 6.36 for ham and turkey breast, respectively). The pH of samples treated with extra virgin olive oil + lemon juice was higher ($P < 0.05$) than that of samples treated with the other three salad dressings (Tables 1 and 2). These results are similar to those of our previous study *(25)*, which showed that immersion of frankfurters in various salad dressings reduced the pH of the product by 0.17–0.43 units. Salad dressings are known to act as acidifiers when applied to vegetables or egg mayonnaise *(1, 26)*. In the present study, ham samples stored at 7°C for 14 days had a lower ($P < 0.05$) pH than day 0 samples (Table 1), whereas turkey breast samples did not ($P \geq 0.05$) show large changes in pH values for most treatments as storage progressed (Table 2). Overall, microwave heating did not ($P \geq 0.05$) have large effects on the pH values of ham and turkey breast samples.

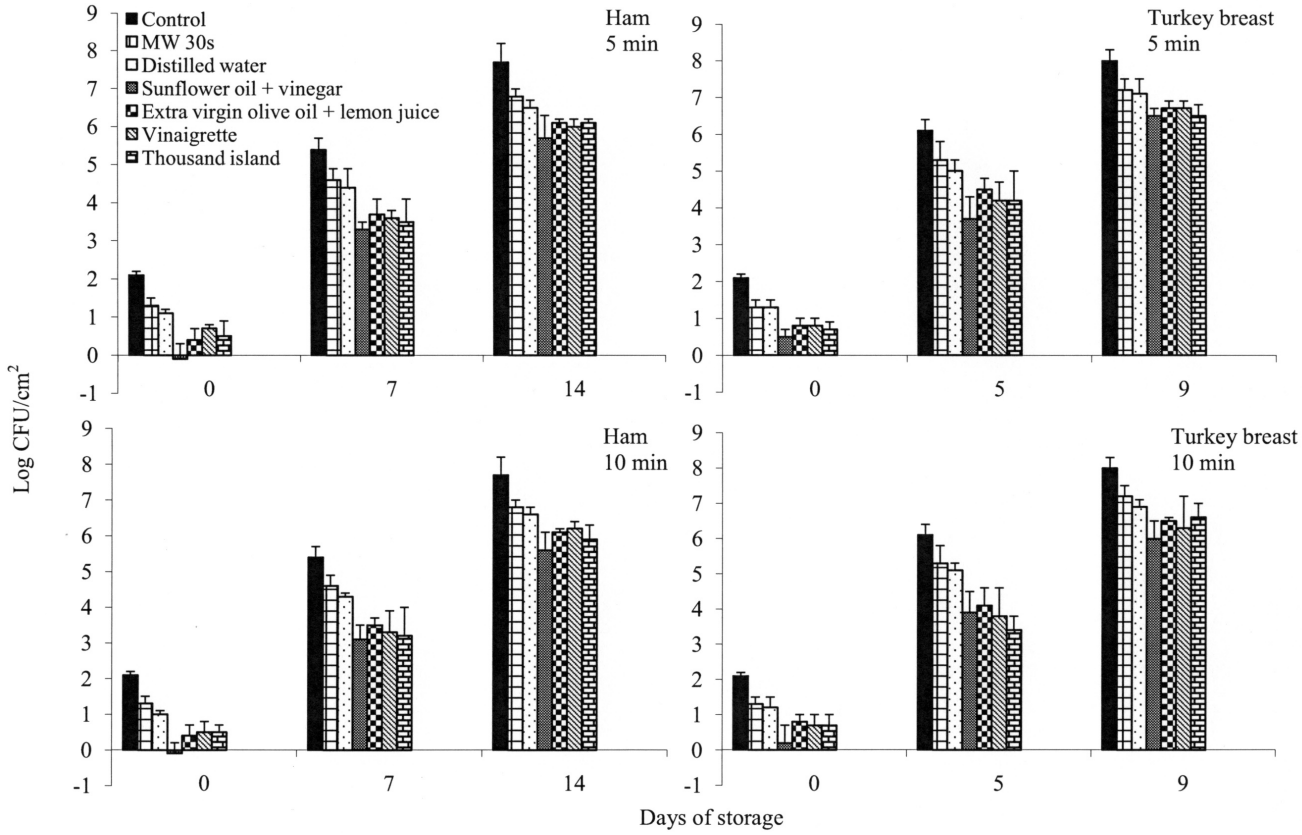
Microbial growth on ham and turkey breast during aerobic storage at 7°C

Initial (day 0) *L. monocytogenes* (Fig. 1 and 2) and total microbial (data not shown) counts on inoculated diced ham and turkey breast samples were 2.1 ± 0.1 and 2.2 ± 0.1 log CFU/cm^2, respectively. During aerobic storage at 7°C, *L. monocytogenes* grew to 7.7 and 8.0 log CFU/cm^2 on ham and turkey breast control samples, respectively (Fig. 1-3). On day 0 and day 7 (ham) or day 5 (turkey breast), total microbial counts on TSAYE (data not shown) were similar ($P \geq 0.05$) to those observed on PALCAM agar, indicating that the majority of colonies found on TSAYE were *L. monocytogenes*. Total microbial populations reached 8.1 and 8.2 log CFU/cm^2 on ham and turkey breast control samples, respectively, by the end of storage at 7°C. On day 14 (ham) or day 9 (turkey breast), total microbial counts on TSAYE were approximately 0.2–1.0 log CFU/cm^2 higher than the counts on PALCAM agar plates for most treatments of the two products, indicating the potential presence of spoilage microflora, such as lactic acid bacteria and yeasts *(17, 18)*.

Antilisterial effects of salad dressings without prior microwave heating of ham and turkey breast

On day 0 of storage, immersion of ham or turkey breast samples in each of the four salad dressings for 5 or 10 min reduced pathogen numbers by 0.7–1.0 and 0.5–0.6 log CFU/cm^2, respectively (Fig. 1). These reductions were higher, but not significantly different ($P \geq 0.05$) from those obtained when the products were immersed in DW (0.5–0.6 and 0.3 log CFU/cm^2 for ham and turkey breast, respectively). In a previous study *(25)*, immersion of inoculated frankfurters in sunflower or extra virgin olive oil with lemon juice or vinegar, or four commercial salad dressings, reduced initial

FIGURE 2. Mean populations of *Listeria monocytogenes* (± standard deviation; log CFU/cm²) on diced ham and turkey breast inoculated and stored aerobically at 7°C for 14 or 9 days, respectively, and left untreated or immersed for 5 or 10 min in distilled water, sunflower oil + vinegar, extra virgin olive oil + lemon juice, vinaigrette or thousand island, with prior microwave heating (MW) of the deli meats for 30 s.



L. monocytogenes populations by 0.5–0.9 log CFU/cm², which is in agreement with the findings of the present study. Pathogen reductions were not different ($P \geq 0.05$) between 5 or 10 min of immersion of samples in the salad dressings (Fig. 1).

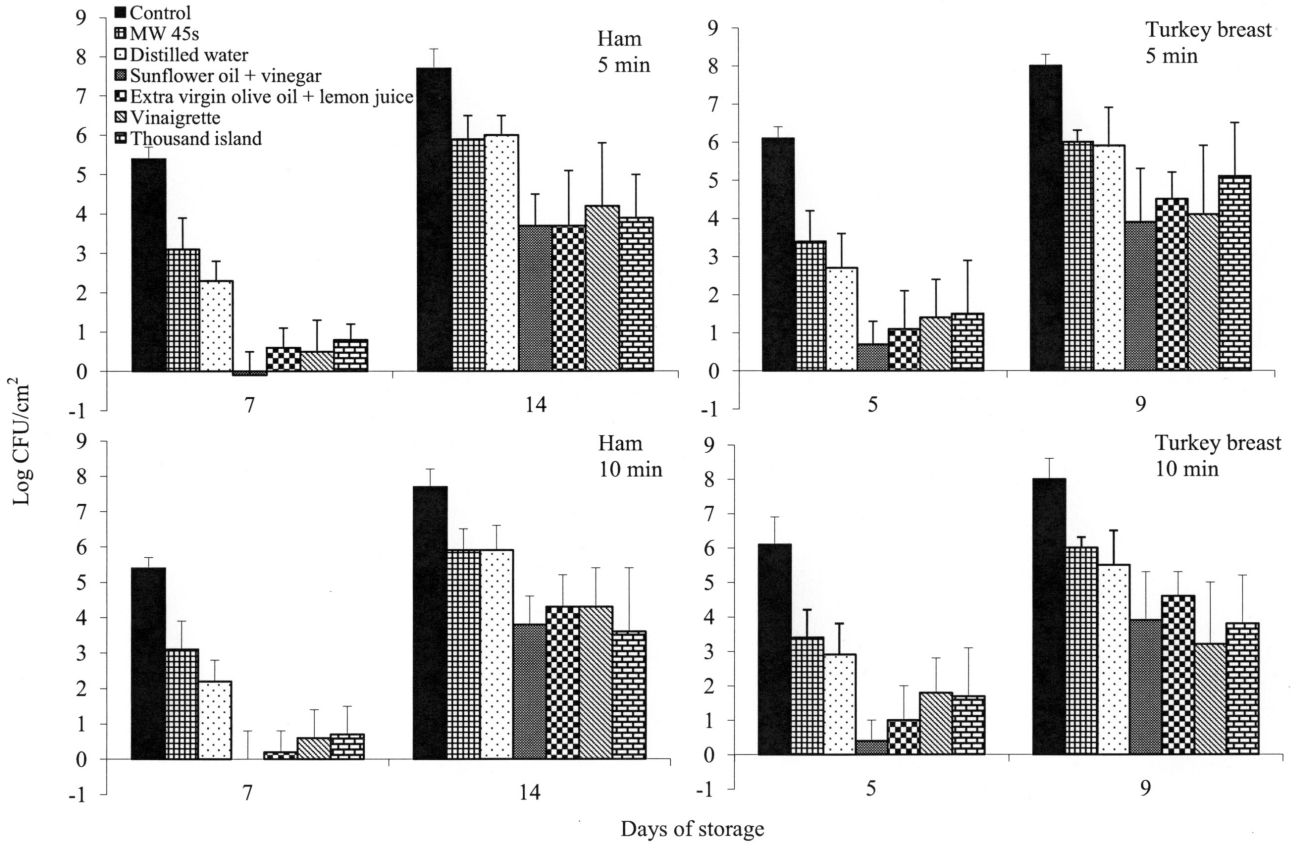
As previously indicated, as storage time progressed from day 0 to day 14 (ham) or day 9 (turkey breast), *L. monocytogenes* contamination levels increased from 2.1 to 7.7 or 8.0 log CFU/cm², respectively. Reductions in pathogen counts following exposure of stored samples to the salad dressings were similar to those obtained for day 0 samples (Fig. 1). Among the four salad dressing treatments, sunflower oil + vinegar generally caused slightly ($P \geq 0.05$) higher reductions on the two products at all storage times, and pathogen numbers were reduced by 1.0–1.2 and 0.6–0.8 log CFU/cm² on ham and turkey breast, respectively (Fig. 1). As for day 0 samples, reductions in pathogen levels were similar ($P \geq 0.05$) for 5 or 10 min exposure to the salad dressings.

Antilisterial effects of salad dressings with prior microwave heating of ham and turkey breast

As expected, microwave heating of the deli meats resulted in reductions of *L. monocytogenes* populations (Fig. 2 and 3). Microwave treatment for 30 s (without immersion in salad dressings) reduced pathogen counts by 0.8–0.9 or 0.8 log CFU/cm² on ham and turkey breast samples, respectively (Fig. 2), whereas treatment for 45 s increased the reductions to 1.8–2.3 and 2.0–2.7 log CFU/cm², respectively (Fig. 3). The average surface temperatures of samples of ham or turkey breast immediately after microwaving for 30 or 45 s were 52 and 62.5°C, respectively, as measured with a Temp Testr® IR laser thermometer (Oaklon, Gainesville, FL). As previously reported *(10, 11, 12)*, reductions of microbial counts by microwaving are due to heat generation.

Immersion (5 or 10 min) of ham or turkey breast samples in DW after microwave heating of the deli meats caused additional pathogen reductions of only 0.1–0.3 (30 s) and 0.1–0.8 (45 s) log CFU/cm², irrespective of product storage day. In comparison, samples immersed in salad dressings after 30 or 45 s of microwave heating resulted in lower ($P < 0.05$) numbers of pathogen survivors compared to those of corresponding DW-treated samples. Specifically, for stored samples of ham and turkey breast, microwave heating for 30 s followed by treatment with salad dressings reduced *L. monocytogenes* counts by a total of 1.4–2.3 and 1.3–2.7 log CFU/cm², respectively (Fig. 2). When the salad dressing treatments were preceded by a 45 s microwave treatment, total reductions of 3.4–5.5 and 2.9–5.7 log CFU/cm² were obtained for ham and turkey breast samples, respectively (Fig. 3). The enhanced pathogen destruction obtained by applying the microwave and salad dressing treatments in sequence, as compared to each treatment applied individually, suggested that the cells were sensitized or injured

FIGURE 3. Mean populations of *Listeria monocytogenes* (± standard deviation; log CFU/cm^2) on diced ham and turkey breast inoculated and stored aerobically at 7°C for 14 or 9 days, respectively, and left untreated or immersed for 5 or 10 min in distilled water, sunflower oil + vinegar, extra virgin olive oil + lemon juice, vinaigrette and thousand island, with prior microwave heating (MW) of the deli meats for 45 s.



during the heat treatment, thus making them more susceptible to the low pH effects of the salad dressing treatments.

Microwave heating of day 0 ham and turkey breast samples for 30 s followed by treatment with sunflower oil + vinegar for 10 min resulted in the lowest pathogen numbers (-0.1 and 0.2 log CFU/cm^2, respectively) compared with samples treated with the other three salad dressings (Fig. 2). Microwave heating of day 7 and day 14 ham samples for 30 or 45 s followed by immersion in the salad dressings resulted in total reductions of 1.5–2.3 (Fig. 2) or 3.4–5.5 log CFU/cm^2 (Fig. 3), respectively. Similarly, on day 5 and day 9 of storage, total reductions of 1.3–2.4 (Fig. 2) or 2.9–5.7 log CFU/cm^2 (Fig. 3) were obtained on turkey breast samples that were exposed to the salad dressing treatments after microwave heating for 30 or 45 s, respectively. Maximum total pathogen reductions of 5.5 and 5.7 log CFU/cm^2 were observed on day 7 (ham) and day 5 (turkey breast), respectively, for samples that were heated in the microwave oven for 45 s and then immersed in sunflower oil + vinegar (5 or 10 min) (Fig. 3). Pathogen reductions were similiar ($P \geq 0.05$) with 5 and 10 min of immersion for most of the salad dressing treatments applied to stored product samples; only 9-day old-turkey breast samples treated with thousand island dressing had higher ($P < 0.05$) total reductions at 10 min (4.2 log CFU/cm^2) than at 5 min (2.9 log CFU/cm^2).

The results of this study show that microwave oven heating and salad dressing treatments applied in sequence resulted in higher reductions of *L. monocytogenes* on deli meats, compared with individual treatments. Microwave heating for 45 s followed by exposure to salad dressings, especially sunflower oil + vinegar, may contribute to reduction of *L. monocytogenes* contamination on deli meat products, such as ham or turkey breast, in the home environment. Salad dressings tested in this study reduced pathogen numbers by approximately 1.0–5.0 log CFU/cm^2, depending on product storage time, when exposure to salad dressings was preceded by a 45 s microwave oven treatment. It is recommended that consumers consider using microwave oven heating and salad dressings to prepare diced ham or turkey breast for use in salads, especially if they are at risk for listeriosis.

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