Survival of *Salmonella* Enteritidis Phage Type 30 on Inoculated Almonds Stored at −20, 4, 23, and 35°C

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ABSTRACT

To evaluate the survival of *Salmonella* on raw almond surfaces, whole almond kernels were inoculated with *Salmonella* Enteritidis phage type (PT) 30 collected from a 24-h broth culture or by scraping cells from an agar lawn. Kernels inoculated with lawn-collected cells to 8, 5, 3, and 1 log CFU per almond after a 24-h drying period were stored for 161 days at 23 ± 3°C. Calculated rates of reduction were similar for the four inoculum levels (0.22, 0.28, 0.29, and 0.22 log CFU/month, respectively). Kernels inoculated to 7.1 or 8.0 log CFU per almond after drying were stored for 171 or 550 days, respectively, at selected temperatures, including −20 ± 2°C, 4 ± 2°C, 23 ± 3°C, and 35 ± 2°C. No significant reductions of *Salmonella* were observed during storage at −20 and 4°C over 550 days. At 35°C, a biphasic survival curve was observed, with calculated reductions of 1.1 log CFU/month from days 0 to 59 and no significant reduction from days 59 to 171. At 23°C, reductions of 0.18 and 0.30 log CFU/month were calculated for 171 and 550 days of storage, respectively. When combined with data from the study of inoculum levels, an overall average calculated reduction at 23°C was 0.25 ± 0.05 log CFU/month. Significantly greater reductions were observed during the 24-h drying period when broth-collected cells were used as the inoculum, suggesting that cells collected from agar lawns were more resistant to drying. However, after initial drying, the rates of reduction at 23°C did not differ significantly between the inoculum preparation methods. *Salmonella* Enteritidis PT 30 survives for long periods on almond kernels under a variety of common storage conditions.

Dry foods are generally considered a minimal risk for foodborne illness because their water activity is too low to support the growth of most microorganisms. Although growth of *Salmonella* does not occur in low water activity foods, the long-term survival of this organism in chocolate, hard cheese, dried eggs, infant dried milk, and salami has been well documented (6).

The ability to survive dry conditions may have been a contributing factor in outbreaks of salmonellosis associated with low water activity foods. Outbreaks linked to chocolate (14, 23), cheddar cheese (15), powdered milk (38), carmine (28), and paprika and paprika-powdered potato chips (29) provide examples in which foods with low water activities have served as vectors for *Salmonella* infection.

The culinary definition of nuts is very broad and includes botanically defined nuts (e.g., acorn, chestnut, filberts), seeds (e.g., Brazil nuts, sesame, legumes (e.g., peanuts), and drupes (e.g., almonds, coconuts, macadamia, pecans, pistachios, and walnuts) (1, 25, 34). Nuts have water activities that are generally less than 0.7 with corresponding moistures of 3.8% (macadamia) to 12.1% (chestnut) (8). Nuts are not commonly associated with foodborne outbreaks; however, the sesame product halva (32) has been linked to outbreaks of salmonellosis, along with desiccated coconut (31), a savory snack coated with peanut butter (24, 36), peanut butter (35), in-shell peanuts (26), and raw almonds (12, 19).

Few data are available on the survival of bacterial pathogens on nuts. During traceback investigations of a 2000 to 2001 raw almond outbreak, the outbreak strain, *Salmonella* Enteritidis phage type (PT) 30, was isolated from almonds 8 months after harvest (19), suggesting the long-term survival of the organism in this product. *Salmonella* was detected in inoculated pecan halves for 16 to 32 weeks by plate count methods when inoculated at 5 log CFU/g and stored at 21°C (10). In peanut butters and spreads, *Salmonella* was detected for 24 weeks by plating when inoculated at 5.8 log CFU/g and for 6 weeks by enrichment of 25-g samples when inoculated at 1.5 log CFU/g (11). On pecan halves and in-shell pecans (10) and in peanut butter and peanut butter spread (11), *Salmonella* was found to survive better under refrigeration than at ambient or elevated temperatures.

After hulling and shelling, almonds may be fumigated for insect control and stored for up to a year before further processing and shipping (22). Long-term storage temperatures range from 4°C to ambient temperature, but after processing and packaging, almonds are generally distributed and sold at ambient temperature. Consumers may store almonds at ambient, refrigerating, or freezing temperatures for an additional 1 to 2 years (2).

The objective of this study was to evaluate the survival of *Salmonella* Enteritidis PT 30 on the surface of almond kernels that were (i) inoculated at different levels, (ii) stored at various temperatures, and (iii) inoculated by different inoculum preparation methods.

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MATERIALS AND METHODS

Almond kernels. Propylene oxide (PPO)–treated and untreated (raw) California variety almond kernels (20 to 23 almonds per 28 g) were provided by the Almond Board of California, Modesto, Calif., or Blue Diamond Almonds, Sacramento, Calif., and were stored at ambient temperature (23 ± 3°C) in sealed plastic bags.

Culture and growth conditions. Salmonella Enteritidis PT 30 (ATCC BAA-1045), isolated from recalled 2000 to 2001 outbreak-associated almonds, was stored at −80°C in tryptic soy broth (TSB; Difco, Becton Dickinson, Sparks, Md.) supplemented with 15% glycerol (Fisher, Fair Lawn, N.J.). Prior to each experiment, the frozen culture was streaked onto tryptic soy agar (TSA, composed of TSB and 1.5% granulated agar; Difco, Becton Dickinson) and incubated at 37°C for 24 h. An isolated colony was transferred to TSB and incubated at 37°C for 24 h. At two consecutive 24-h intervals, a single loopful of the culture was transferred into fresh media.

Inoculum preparation. An inoculum was prepared by scraping cells from an agar lawn as previously described (13). An overnight culture (1 ml) was spread onto three large TSA plates (150 by 15 mm) and incubated at 35 ± 2°C for 24 h to produce a bacterial lawn. A sterile cotton swab was wetted with 0.1% peptone solution (Difco, Becton Dickinson) and used to collect the cells from the three inoculated TSA plates. Cells were transferred to 25 ml of 0.1% peptone solution in a sterile 50-ml conical centrifuge tube (BD Biosciences, Bedford, Mass.). Prior to inoculating the almonds, appropriate numbers of 25-ml preparations were pooled and thoroughly mixed for a minimum of 1 min with a magnetic stir bar and stir plate. The inoculum was kept on the stir plate until all almond samples had been inoculated (up to 0.25 h). Inoculum levels were adjusted, as appropriate, by serial dilution in 0.1% peptone solution.

To prepare an inoculum collected from a broth culture, 10 μl of an overnight culture was transferred into 30 ml of TSB and incubated at 35 ± 2°C for 24 ± 2 h. The inoculum was placed into a sterile 50-ml conical centrifuge tube and centrifuged at 3,000 × g for 15 min (Allegra 6, Beckman Coulter, Fullerton, Calif.). The cells were washed twice by decanting the supernatant and suspending the cell pellet in 30 ml of Buttermilk’s phosphate buffer (BPB). Washed cells were suspended in 0.1% peptone solution at half of the original culture volume.

The level of Salmonella in the inoculum was determined by serial dilution in BPB and then plating onto both TSA and bis-muth sulfite agar (BSA; Difco, Becton Dickinson).

Almond inoculation. Almonds were inoculated as previously described (13). Almond samples (400 ± 1 g) were weighed into polyethylene bags (Bitran, 30.5 by 30.5 cm; Com-Pac Int., Carbondale, Ill.), and 25 ml of the pooled inoculum was added. Populations on wet almonds were determined during an hour of inoculation by plating on TSA or were estimated by calculating the total population in 25 ml of inoculum and dividing by 400 g of almonds.

Each bag was closed and inverted by hand for 1 min to mix thoroughly. Almonds were poured out of the bag and spread onto two sheets (46 by 57 cm) of filter paper (Fisherbrand Qualitative P8, Fisher), which had been folded in half and placed on a metal drying rack set inside a large lidded plastic tub. Almonds were held in the tub for 24 ± 3 h at 23 ± 3°C with the lid ajar to allow the inoculum to dry. Almonds were visibly dry in approximately 1 h. For experiments requiring more than 400 g of almond kernels, multiple 400-g batches were prepared as necessary, and all of the almonds were pooled into one polyethylene bag (Bitran, 40.6 by 40.6 cm). The bag was inverted by hand for 1 min to mix the pooled almonds thoroughly before storing.

After 24 h, a weight of almonds sufficient for the study was placed into polyethylene zipper-top bags. The bags were sealed and placed into a larger polyethylene bag inside a plastic container. In initial studies, these closed containers were directly transferred to storage, and in a subsequent study, the containers were held at 23 ± 3°C for 7 days before being stored at the appropriate temperature to allow equilibration of the moisture added during inoculation.

Inoculum concentration. To evaluate the effect of inoculum concentration, PPO-treated almonds were inoculated to approximately 8, 5, 3, and 1 log CFU per almond after drying. Inoculated kernels were stored at 23 ± 3°C for up to 161 days.

Storage conditions. To evaluate the impact of storage temperature, two separate storage studies were carried out. In the initial study, PPO-treated almonds were inoculated to 7.1 log CFU per almond after drying and stored at 4 ± 2°C, 23 ± 3°C, and 35 ± 2°C for up to 171 days (approximately 6 months). During this experiment, consumer inquiries were received about the relative safety of almonds stored in the freezer. Therefore, in a subsequent storage study, raw almonds inoculated to 8.0 log CFU per almond after drying were stored at −20 ± 2°C, 4 ± 2°C, and 35 ± 3°C, and storage time was increased to 550 days (approximately 18 months). Raw rather than PPO-treated almonds were used for this second study because the background population (3 log CFU per almond or less on TSA) was significantly below the inoculum level and did not interfere with plate counts of Salmonella on TSA.

A freezer temperature of −20 ± 2°C was selected for evaluation in this study because home and retail freezers are typically maintained at or below −18°C (3). The 35°C storage temperature was eliminated in the second study because almonds are only occasionally exposed to such a high temperature.

Comparison of inoculum preparation methods. To evaluate the impact of inoculum preparation on the survival of Salmonella, raw almonds were inoculated with either lawn-collected or broth inoculum and then stored at 23 ± 3°C for up to 550 days.

Enumeration. Salmonella Enteritidis PT 30–inoculated almonds were removed from storage, and each bag was first inverted by hand for 20 s to mix thoroughly. In the initial storage study, a slightly modified mechanical shaking method was used for recovery of Salmonella from almonds (25). Three recovery methods—hand shaking, mechanical shaking, and stomaching—were subsequently compared for preparing almond samples prior to plating. The hand shaking method is a modification of procedures described in the Food and Drug Administration (FDA) Bacteriological Analytical Manual (BAM) (4), with 10 almond kernels (11 to 14 g) rather than 50-g samples. Almonds (10) and 10 ml of BPB were added to a 532-ml Whirl-Pak bag (Nasco, Modesto, Calif.) and shaken vigorously 50 times through a 30-cm arc; the shaken sample was left standing for 3 to 5 min and then shaken an additional five times before serial dilution. The mechanical shaking method consisted of placing 10 almond kernels into a sterile 125-ml Erlenmeyer flask with 10 ml of BPB. The flask was covered with aluminum foil and placed on a rotary shaker at 150 rpm for 15 min (25). In the stomaching method, 10 almond kernels were placed into a 532-ml Whirl-Pak bag with 10 ml of BPB and stomached for 2 min (Stomacher 3500 Lab Blender, Seward, Thetford, UK).

Serial dilutions of the liquid surrounding the shaken or stom-
almonds were made in BPB, and then 0.1 ml was plated onto TSA and BSA. In addition to plating 0.1 ml of the lowest dilution, 0.25 ml was plated onto each of four petri dishes to improve the detection limit to 1 CFU per almond.

The volume of almonds and diluent was not significantly different before and after stomaching (data not shown). Because the almonds were not liquefied during stomaching, the calculated CFU per milliliter of plated solution was considered equivalent to the CFU per almond.

**Confirming Salmonella colonies.** When populations of Salmonella on TSA dropped to the levels of the background population (less than or equal to 2 or 3 log CFU per almond for PPO-treated or raw almonds, respectively), presumptive Salmonella colonies were confirmed by selecting individual colonies, streaking them onto BSA, and incubating them at 35 ± 2°C for 48 h. For the inoculum level study, colonies typical of Salmonella on BSA were confirmed by the BBL Enterotube II (BBL, Becton, Dickinson, Sparks, Md.). For the broth inoculum study, colonies characteristic of Salmonella were selected from BSA plates and stabbed and streaked into lysine iron agar slants (Difco, Becton Dickinson) and triple sugar iron slants (Difco, Becton Dickinson) and incubated at 35 ± 2°C for 24 h. Those slants with reactions that were typical of Salmonella were confirmed by the Salmonella latex test (Oxoid, Ogdensburg, N.Y.). The Salmonella count was adjusted, as appropriate, on the basis of these results.

**Enrichment.** When counts fell below the limit of detection (1 CFU per almond), enrichment for Salmonella was conducted by a modification of the FDA BAM method (5). Almond samples (10 almonds and 10 ml of BPB) were shaken or stomached and, in some cases, plated onto TSA or BSA before the residual was added to 180 ml of lactose broth (Difco, Becton Dickinson) in a sterile stainless steel blender jar (Waring Products, Torrington, Conn.). Samples were blended at low speed for 2 min and held for 24 h at 35 ± 2°C (5). Two typical Salmonella colonies were selected from BSA, which was streaked from secondary enrichments of Rappaport-Vassiliadis R10 (Difco, Becton Dickinson) and tetrathionate (Difco, Becton Dickinson), and these colonies were stabbed and streaked onto triple sugar iron and lysine iron agar slants. Salmonella was confirmed from triple sugar iron slants by a latex agglutination test.

**Determining the reduction per month.** When significant population declines were observed, the reduction of Salmonella per month of storage was calculated by determining the linear regression for the survival curves, calculating the reduction per day, and multiplying this number by 30.4, which is the average number of days in a month (365 days/12 months).

**Statistics.** Data were subjected to statistical analysis software (JMP Version 5.1.2, SAS, Statistical Analysis Systems Institute, Cary, N.C.) for analysis of variance and the Tukey-Kramer honestly significant difference test. Differences between mean values were considered significant at P < 0.05.

**RESULTS AND DISCUSSION**

**Comparison of stomaching and shaking for recovery of Salmonella Enteritidis PT 30 from almonds.** A small but significant (P < 0.05) improvement in recovery of Salmonella from almonds was observed with stomaching (9.1 ± 0.02 log CFU per almond) compared with hand shaking (8.8 ± 0.1 log CFU per almond) or mechanical shaking (8.7 ± 0.1 log CFU per almond). Populations on TSA or BSA were not significantly different (P > 0.05) for any recovery method. The initial survival studies (for almonds held at 23°C for 161 days or at 4, 23, and 35°C for 171 days) were carried out with mechanical shaking; therefore, Figures 1 and 2 represent data obtained by mechanical shaking. However, on the basis of the data obtained above, the stomaching method was chosen to recover Salmonella from almonds for the subsequent storage study (−20, 4, and 23°C for 550 days); Table 1 represents recovery data obtained by stomaching.

**Effect of inoculum concentration on the survival of Salmonella Enteritidis PT 30 on almonds.** Almonds were inoculated to target populations of approximately 8, 5, 3, and 1 log CFU per almond after a 24-h drying period. Populations of Salmonella on the wet almonds corresponded to the inoculum levels estimated by calculation and were 0.8 to 1.5 log CFU per almond higher than after 24 h of drying (data not shown). In most cases, counts on BSA were slightly but not significantly (P > 0.05) lower than counts on TSA. Because PPO-treated almonds were used, the
### TABLE 1. Survival of Salmonella Enteritidis PT 30 on almond kernels stored at 23, 4, and −20°C and inoculated by lawn-collected inoculum or broth inoculum

<table>
<thead>
<tr>
<th>Time (day)</th>
<th>23°C lawn inoculum</th>
<th>4°C lawn inoculum</th>
<th>−20°C lawn inoculum</th>
<th>23°C broth inoculum</th>
<th>4°C broth inoculum</th>
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<tr>
<td></td>
<td>TSA</td>
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<td>TSA</td>
<td>BSA</td>
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<tr>
<td>Inoculum</td>
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<tr>
<td>a</td>
<td>10.8 ± 0.0</td>
<td>10.8 ± 0.0</td>
<td>7.7 ± 0.2</td>
<td>7.6 ± 0.2</td>
<td>9.3 ± 0.0</td>
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<tr>
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<tr>
<td>0</td>
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<td>7</td>
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<td>7.4 ± 0.2</td>
<td>4.4 ± 0.5</td>
</tr>
</tbody>
</table>

*a* Values are expressed as log CFU per milliliter; values are the average of one sample from each of three experiments (*n* = 3).

*b* For all lawn inoculum samples, the same inoculum was used, and the dry and 0-day values represent the same control samples used for all temperatures.

*c* Values are expressed as log CFU per almond; values are the average of duplicate samples from each of three experiments (*n* = 6).

*d* Broth inoculum; values are the average of one sample from each of three experiments (*n* = 3).

*e* Ten-gram samples (3 of 3) positive upon enrichment.
background population on TSA was consistently 2.0 log CFU per almond or less. Background colonies were not detected at any time on BSA, and for this reason, only BSA data are shown in Figure 1. *Salmonella* was detected at all times by plating, except at 161 days, when counts on almonds initially inoculated to approximately 10 CFU per almond fell below the limit of detection (1 CFU per almond). However, *Salmonella* could be recovered by enrichment of all nine 10-almond samples. Similar reductions of 0.22, 0.28, 0.29, and 0.22 log CFU per month ($R^2$ values of 0.88, 0.85, 0.88, and 0.95, respectively) were calculated for initial inoculum levels of 8, 5, 3, and 1 log CFU per almond, respectively.

Few studies have compared the influence of different inoculum levels on the survival of pathogens in dry foods. For produce surfaces, greater decreases in survival have been observed in some cases with lower inoculum levels (16, 33), whereas in other cases, survival was independent of initial inoculum density (39). Although Burnett et al. (11) used high (5.7-log CFU/g) and low (1.5-log CFU/g) levels of *Salmonella* to inoculate peanut butter and peanut butter spreads, their methods did not allow a comparison of the rates of decline during storage.

Laboratory studies are often criticized for using high inoculum levels that relate more to restrictions in methodology and detection limits than predicted contamination levels. Data from this study suggest that, for almonds, survival at high populations is a reasonable predictor of behavior at low levels of contamination.

**Effect of storage temperature on the survival of *Salmonella Enteritidis* PT 30 on almonds.** Almonds are grown in the central valley of California, where normal daytime highs can range from 12°C in the winter to over 36°C in the summer months (30). Almond handlers may store untreated almonds for up to 12 months in two controlled environments, refrigerated (4°C) or near 20°C, or they may store them for shorter periods at ambient temperatures. Shipping and retail handling are usually at ambient temperatures. It is estimated that consumers store almonds for an additional 12 months in the freezer or refrigerator or at ambient temperatures (2).

Two separate studies were performed to evaluate the impact of temperature on the survival of *Salmonella* inoculated onto almonds. Levels of *Salmonella* 24 h after inoculation were 7.1 and 8.0 log CFU per almond in the first (171-day) and second (550-day) storage study, respectively. In most cases, counts on BSA were slightly but not significantly lower than counts on TSA (Table 1). *Salmonella* counts on BSA and TSA exceeded background populations at all times.

Stable populations of *Salmonella* were observed on almonds stored at −20°C over 550 days (Table 1). No reduction of *Salmonella* occurred during the 18-month study. Statistically, some data points were significantly different from each other ($P < 0.05$); however, a downward trend was not observed. Similarly, no decline in *Salmonella* was observed on almonds stored at 4°C in either the first 6-month study (Fig. 2) or the second 18-month study (Table 1).

At 23°C storage, *Salmonella* declined at a rate of 0.30 log CFU per month ($R^2 = 0.97$) in the first study (Fig. 2) and at a rate of 0.18 log CFU per month ($R^2 = 0.96$) in the second study (Table 1). When combined with data from the study of inoculum levels (Fig. 1), an overall average calculated reduction at 23°C was 0.25 ± 0.05 log CFU per month.

At 35°C, a biphasic survival curve was observed (Fig. 2). The rate of reduction that was calculated from days 0 to 59 was 1.1 log CFU per almond ($R^2 = 0.90$). A consistent population was observed from days 59 to 171.

Temperature-dependent survival has been reported for *Salmonella* in a number of other studies. Five-strain cocktails of *Salmonella* survived better at 5°C than at 21°C when inoculated into peanut butter or peanut butter spreads (11). Similarly, populations of three serovars of *Salmonella* independently inoculated onto pecan halves (10) declined most rapidly at 21°C, whereas populations remained relatively stable at −18, −7, and 5°C. Improved survival of *Escherichia coli K*-12 inoculated onto pecan halves (7) was documented at storage temperatures of −7, 0, and 14°C when compared with 21 and 30°C, although populations declined at all temperatures. In contrast, identical slow reductions were observed at 6 and 18 to 20°C for a cocktail of two strains of *Salmonella Enteritidis* (unknown PT) inoculated into halva (a sweetened product made from ground sesame seed) (27). Because of their relatively high fat level, nuts and nut products are ideally stored at lower temperatures to prevent oxidative rancidity, but this action may consequently enhance the survival of microorganisms, including foodborne pathogens.

**Influence of inoculum preparation on the survival of *Salmonella Enteritidis* PT 30 on almonds.** Initial inoculum populations were 10.8 log CFU/ml for lawn-collected cells and 9.3 log CFU/ml for broth-collected cells. Estimated populations on wet almonds were 9.7 and 8.1 log CFU/g for lawn- and broth-collected methods, respectively. After 24 h of drying, the populations were 8.0 and 4.4 log CFU per almond, with calculated reductions of 1.7 and 3.7 log CFU per almond, for lawn- and broth-collected inocula, respectively. These data confirmed communications with other researchers who had experienced difficulty when inoculating almonds to high population levels with broth-collected cells. Preliminary attempts in this laboratory to inoculate almonds with cells grown in aqueous slurries of almond hulls also failed to yield high populations of *Salmonella* on almonds (data not shown). However, the survival of *Salmonella Enteritidis* PT 30 was generally improved on drying hulls as incubation time in a wet hull slurry was extended from 2 to 7 days (37). This improvement suggests that in broth culture, the cells in very late stationary phase are better able to survive drying than are those in early stationary phase, although this behavior was not confirmed on almond kernels.

Reductions of *Salmonella* for broth-collected inoculum from days 0 to 224 were 0.33 log CFU per month ($R^2 =$
0.95). This rate of reduction was higher but not significantly different ($P > 0.05$) from that observed for the lawn-collected inoculum, which suggests that differences in inoculum preparation primarily affect sensitivity to desiccation rather than the survival of dried cells. Although the population decreased to below 1 CFU per almond after day 224, 10-g samples were positive upon enrichment for 18 months.

Developing inoculation and recovery methods for any product requires a number of decisions, including the type of product analyzed, conditions for preparing inoculum, procedure for inoculation, and conditions for retrieval of inoculated organisms (9). The decision to use lawn-collected cells for almonds was based on our previous experience with developing a method for inoculating and recovering *Salmonella* on the surface of tomatoes (18). Although the natural mode of contamination of almonds with *Salmonella* is unknown, the presence of planktonic cells is less likely in almond production, harvesting, and processing environments. Inoculation with lawn-collected cells should present a worst-case scenario for evaluating the risk associated with consumption of almonds. The ability to produce a stable population of *Salmonella* on almonds is beneficial for the evaluation of intervention strategies in which reductions of several logs need to be demonstrated.

Previous studies that have inoculated nuts or nut products with *Salmonella* have used a broth-collected inoculum (10, 11, 27). Observed variability in counts obtained shortly after inoculation of these products could be due to differences in substrate (solid surface, spread, or powder), different strains of *Salmonella*, or different inoculum preparation methods (growth in broth or on agar and carrier solution). Loss of viability shortly after inoculation is thought to be due to osmotic stresses, chemical composition (including presence of antimicrobials), or water activity of the dry product (21).

Methods for preparing the inoculum are rarely evaluated when developing techniques for inoculating microorganisms onto foods. In this study, when an inoculum was prepared by growing cells to a lawn rather than in a broth, the organism was observed during the initial 24-h drying period. This suggested that broth cultures were not as well adapted to survive the stress of drying. Further investigations into the differences between these two preparation methods may provide an understanding of the mechanisms that are important for *Salmonella* to develop a tolerance to drying stresses. This knowledge should aid in understanding the behavior of this organism in dried foods as well as in the environment. The natural level of contamination of *Salmonella* on almonds is thought to be very low in most cases (20). Under the conditions evaluated in this study, inoculum density did not influence the survival of *Salmonella* on almonds, with refrigerator and freezerer temperatures effectively stabilizing populations during an 18-month study. These data will be critical to the design of future studies with almonds or other nuts and are important to the development of risk assessment models for this product.

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