



## CONTAMINATION, SURVIVAL, AND ELIMINATION OF *SALMONELLA* ON PRE-HARVEST AND POST-HARVEST PECANS

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Outbreaks of salmonellosis have been linked to consumption of peanut butter and almonds. Tree nuts other than almonds have not been implicated as vehicles of salmonellosis. However, the presence of *Salmonella* on a small percentage of samples of Brazil nuts, cashew nuts, hazel nuts, macadamia nuts, pecans, pistachios, and walnuts has been documented. Pistachios, hazel nuts, and a granola product containing pecans thought to be contaminated with *Salmonella* were recalled from the U.S. market in 2009. Pinenuts contaminated with *Salmonella* were recalled in January 2010.

Pre-harvest and post-harvest pecans are exposed to environments that impose some level of risk of contamination with foodborne pathogens. Pecans that have fallen to the ground several days preceding harvest may absorb water. This water may contain *Salmonella*, *Escherichia coli* O157:H7, or other pathogens originating from wild or domestic animal feces, inadequately composted manure, irrigation water, or run-off water. Cleaning pecans may involve immersion in water and cross contamination with foodborne pathogens. Wetting of inshell nuts may result from leaks in roofs or walls of storage facilities, thereby resulting in potential contamination or development of high-moisture environments that favor the growth of mycotoxigenic molds and foodborne pathogens. Conditioning pecans also creates an environment which may result in cross-contamination.

Analysis for *E. coli* in pecans has shown that the percent of samples collected from orchards grazed with cattle is six-fold higher than that of samples collected from non-grazed orchards (Marcus and Amling, 1973). The practice of grazing cattle and other ruminant and non-ruminant animals in pecan orchards is highly discouraged, yet still exists. Pre-harvest contact of pecans with animal feces or water containing feces could potentially result in contamination with foodborne pathogens. There is very little known about the survival characteristics of *Salmonella* and other foodborne pathogens in pecan orchard soil. Until more is known, it is highly advisable to not graze animals in pecan orchards.

Studies done in our laboratory in the 1970s showed that *Salmonella* can survive on dry inshell pecans and pecan halves for several weeks (Beuchat and Heaton, 1975). Survival was enhanced by storing nuts at freezing or refrigeration temperatures. These studies also showed that middle septum tissue contained components that are toxic to *Salmonella*. Information on long-term survival of *Salmonella* on pecans and survival characteristics on high-moisture nutmeats and inedible components would be useful when assessing safety risks associated with variations in moisture content during pre-harvest and post-harvest handling.

We did a study with three major objectives. The first objective was to determine water infiltration characteristics of inshell pecans as affected by the variety of nut and extent of shell damage. The second objective was to determine if *Salmonella* will grow on high-moisture nutmeats and inedible components. The third objective was to determine survival characteristics of *Salmonella* in water-saturated pecan orchard soil. Reported here are preliminary results of these studies.

## MATERIALS AND METHODS

Inoculum for all studies consisted of a mixture of five *Salmonella* serotypes: Anatum, Enteritidis, Oranienburg, Sundsvall, and Tennessee. Inshell nuts were inoculated by immersing in a suspension of the pathogen. High-moisture nutmeats, inedible nut components, and orchard soil were inoculated by adding suspensions of cells to the test material.

Inoculated inshell pecans were dried and stored at -4, 39, 70, and 99°F (-20, 4, 21, and 37°C, respectively) for up to 78 weeks (approximately 18 months) before analyzing for the presence and population of *Salmonella*. High-moisture nutmeats and inedible components (shucks, shells, and middle septum tissue) were stored at 39, 70, 86, and 99°F for up to 48 hours or 8 days, respectively. The viability of *Salmonella* in an aqueous extract of shucks held at 70 and 99°F for up to 24 hours was monitored.

Pecan orchard soil from four Georgia counties (Crisp, Lowndes, Mitchell, and Peach) was saturated with water or pecan shuck extract, inoculated with *Salmonella*, and stored at 70 and 99°F. Soil was analyzed for *Salmonella* over a 49-day period.

## RESULTS AND DISCUSSION

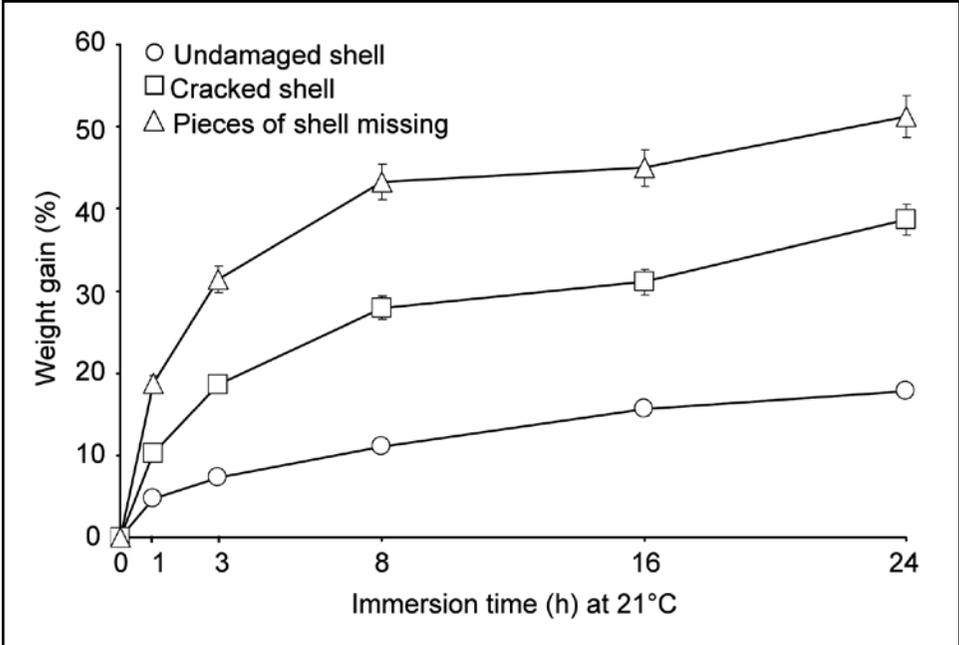
The rate of uptake of water, and presumably *Salmonella* and other microorganisms it may contain, varied among the six varieties (Elliott, Desirable, Moneymaker, Schley, Sumner, and Stuart) tested. Uptake was not necessarily correlated size, shape, or volume of the nuts. Not surprisingly, uptake of water was much more rapid if the shell was cracked or if pieces of the shell were missing (Figure 1). Immersion of undamaged pecans in a suspension of *Salmonella* results in rapid infiltration of the pathogen and migration to the kernel. After drying the nuts and storing them at 39°F for up to 5 weeks, *Salmonella* could be

detected on the kernel surface.

Long-term storage studies showed that *Salmonella* survives well on/in inshell pecans stored at -4 and 39°F for 78 weeks. Death of some *Salmonella* occurred on nuts stored at 70 and 99°F. These studies emphasize the importance of preventing damage of nuts during harvesting and handling. Uptake of *Salmonella* by damaged, as well as undamaged, pecans can result in contamination of the kernel and survival of the pathogen during storage at conditions commonly used in the pecan industry.

*Salmonella* does not grow on nutmeats held at 39°F. The pathogen can grow, however, on high-moisture pecan halves, medium pieces, and granules stored at 70, 86, and 99°F. Growth was most abundant on granules, followed by pieces and halves, in that order. Increased rates of growth were attributed in part to increased amounts of internal nutmeat tissue accessible to *Salmonella*. These observations highlight the importance of not allowing high-moisture nutmeats or inshell pecans to remain in cleaning, conditioning, flotation, or drying areas in shelling plants.

*Salmonella* can grow on the surface of high-moisture shucks held at 70, 86, and 99°F and on shells at 86 and 99°F (Figure 2). Growth did not occur on shucks or shells held at 39°F or on high-moisture middle septum tissue at 39 - 99°F. Observations concerning the apparent toxicity of middle septum tissue

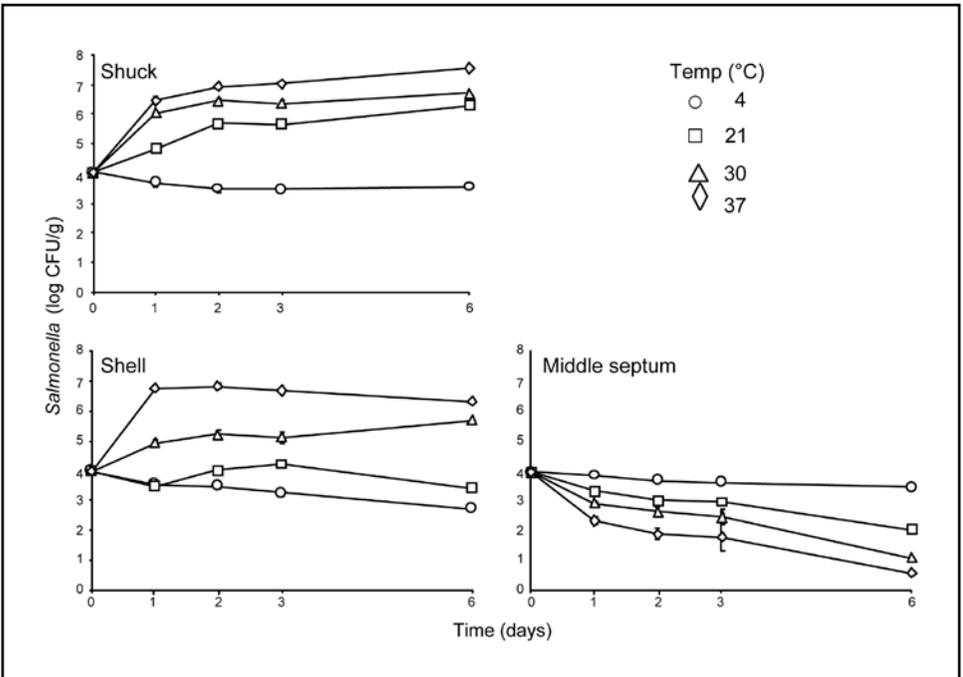


**Figure 1.** Weight gains due to uptake of water by undamaged Desirable var. inshell pecans, pecans with cracked shells, and pecans with pieces of the shell missing

to *Salmonella* are in agreement with our earlier studies.

*Salmonella* has been reported to grow in slurries of almond hulls and shells (Uesugi and Harris, 2006) and in almond orchard soil containing aqueous extract of hulls (Danyluk et al., 2007). In contrast, our study shows that aqueous extract of pecan shucks is toxic to *Salmonella*. The pathogen did not die in water held at 70 or 99°F for 48 h. However, reductions of more than 4 log CFU/g (10,000 colony-forming units per gram) occurred in shuck extract held under the same conditions. The disparate behavior of *Salmonella* on the surface of water-saturated shucks versus suspending cells in a water extract of the shucks is attributed to several factors. A low concentration of water-soluble nutrients and the acidic pH of the extract, perhaps together with high concentrations of polyphenolic compounds and other antimicrobials in the extract, may have resulted in death of *Salmonella*.

*Salmonella* did not grow in water- or shuck extract-saturated orchard soil during the 49-day storage period. The pathogen slowly died throughout storage, reaching undetectable levels (<1 CFU/25 g) within 49 days. Trends showed that death may have been more rapid at 99°F than at 70°C and in shuck extract-saturated soil compared to water-saturated soil. Studies are now underway to determine if and how long *Salmonella* survives in dry pecan orchard soil.



**Figure 2.** Survival and growth of *Salmonella* in high-moisture (water-saturated) pecan shucks, shells, and middle septum tissues stored for up to 6 days at 39, 70, 86, and 99°F (4, 21, 30, and 37°C, respectively).

## REFERENCES

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