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Food Safety Needs Assessment for North American Pecan Shellers

ABSTRACT

The United States is a leading producer of pecans globally. Despite significant contributions to the nation's gross domestic product, little food safety guidance currently exists for pecan shellers. This survey identified typical food safety practices for a subset of North American pecan shellers. A 24-question Qualtrics online survey was distributed to shellers directly or through Cooperative Extension, commodity group, or association avenues. More than half of pecan shellers had a food safety plan in place (56.5%, 13/23) and treated in-shell pecans with hot water or steam (56.5%, 13/23), but these practices tended to be associated with operation size. A majority of the shellers conditioned in-shell pecans in water (73.9%, 17/23), but the time varied between <1 h (50.0%, 8/16), 1–2 h (6.3%; 1/16), 3–4 h (12.5%; 2/16), and >4 h (31.2%, 5/16). Of the shellers that condition in-shell pecans, 58.8% (10/17) reported using a sanitizer in the conditioning water. Chlorine-based sanitizers (chlorine dioxide, sodium hypochlorite, and calcium hypochlorite) were the most commonly used in conditioning water. Most shellers did not use a kill-step to treat pecan kernels (82.6%, 19/23). Findings from this survey can lead to the development of targeted food safety resources for use by the pecan industry.

INTRODUCTION

The United States and Mexico account for 90% of the world's pecan exports: in 2022 alone, the United States produced 275 million lb, valued at US$493 million *(21, 24)*. Mexico and China are leading importers of U.S.-grown, in-shell pecans, whereas the European Union, Canada, and Israel tend to be the largest markets for shelled U.S. pecans *(21)*. Pecans are the third favorite nut by American consumers, with two thirds of households regularly purchasing pecans, 58.3% of which are purchased raw and shelled *(8)*.

The U.S. Food and Drug Administration (FDA) does not consider pecans to be a commodity that is frequently consumed raw and has therefore excluded pecan growers from the requirements of the Standards for Growing, Harvesting, Packing, and Holding of Produce for Human

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Consumption Rule, also called the Produce Safety Rule (21 CFR 112) *(25)*. In addition, many pecan shellers are excluded from the requirements of the Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food Rule (21 CFR 117) *(26)*. Although this may be the case, outbreaks of salmonellosis have been associated with similarly handled tree nuts, such as almonds and pistachios, resulting in significant changes in food safety requirements for these commodities *(9, 10, 13)*. Although pecans have not been implicated in any significant outbreaks of foodborne illness, the similarities in production practices between pecans and other previously implicated nuts should be considered as potential risk factors.

Pecans, like almonds and pistachios, are harvested by mechanically shaking the trees and collecting fallen nuts from the ground. This contact with the ground could provide a potential route of initial pathogen contamination, especially in orchards that use silviculture techniques that include grazing animals throughout the orchard *(11)*. In-shell nuts are then conditioned by soaking in water to facilitate cracking efficiency, which results in larger kernel pieces *(12)*. Without appropriate water management, this conditioning step could exacerbate contamination in the field by facilitating cross-contamination to previously uncontaminated pecans soaking in the water. Following the conditioning step, nuts are cracked and the shells are removed before packaging *(12)*. As with most commodities, the introduction of foodborne hazards may occur at multiple stages throughout production and handling. Although pecans may be excluded from certain federal mandates such as the Produce Safety Rule and the Preventative Controls for Human Food Rule, some states, such as Oklahoma, have certain requirements for the handling and shelling of pecans due to the potential for contamination during harvest *(19)*.

A survey was created and disseminated to North American pecan shellers to determine frequently implemented food safety practices used by pecan shellers. These data provide insight into typical practices throughout the industry. This information can provide educators and commodity associations with information related to knowledge gaps that may be used to guide the development of resources targeting pecan shellers. In addition, this survey may be used to guide researchers to develop more effective food safety interventions that are in-line with current industry practice.

METHODS

An online survey was developed and administered through Qualtrics survey software, (version July 2022–January 2023, Qualtrics, Seattle, WA). The survey received blanket approval as an Agricultural and Natural Resources Extension Evaluation Tool for use with human participants by the University of Georgia Institutional Review Board, PROJECT00000044.

The survey was developed by food safety and agricultural economic specialists, with the aim to evaluate food safety practices in pecan shelling facilities in North America. Questions were composed to address shelling operation demographics, pecan handling, and food safety practices. Demographic questions included location (state or country), operation size (annual shelling volume), number of employees, and revenue from pecan shelling operations. Questions regarding pecan handling and food safety practices included food safety plans, sanitation practices, pecan conditioning steps, water use, and treatment/kill-step of pecans (Supplemental 1). The survey was designed with the "skip logic" function that directed respondents to or past specific questions based on the answers of a previous question to obtain more information regarding operational practices that may not occur at all operations. The survey consisted of 24 questions in total. The survey was reviewed by 10 external food safety and agricultural economic specialists not involved in this publication to ensure that the questions and survey structure were adequately organized to measure the food safety practices and potential needs.

A survey respondent was required to meet the following inclusion criteria: (1) self-identifies as a pecan sheller, (2) owns/works at a pecan shelling entity located in North America, and (3) has a managerial role. As acknowledged in the introduction of the Qualtrics survey, only one survey response per pecan shelling entity was allowed. To ensure duplicate responses were not submitted, the "prevent multiple submissions" function was used when distributing the survey through Qualtrics.

Responses were collected on 5 September 2022 until 11 January 2023. To date, a U.S. pecan sheller directory does not exist; as such, various North American pecan-affiliated lists and communications were used to reach the target population. The survey was distributed through direct communication, member newsletters, and listservs with the National Pecan Shellers Association, the Georgia Pecan Growers Association, Oklahoma Pecan Growers Association, North Carolina Pecan Growers Association, Mississippi Pecan Growers Association, Western Pecan Growers Association, Texas Pecan Growers Association, and the Louisiana Pecan Growers Association. The survey was made available by the provided link or QR code. Although the survey was drafted to focus on shellers located in the United States or those that contribute to the U.S. pecan market, the intent was to access the most pecan shelling facilities in North America so responses from Mexico were included in the analysis. Partially completed surveys were omitted from the results.

Incomplete surveys were removed before statistical analysis. Statistical analysis was conducted using RStudio version 4.2.3. Descriptive statistics were used to describe respondent demographics (e.g., size of packing operations, revenues) and responses to survey questions. Ranking

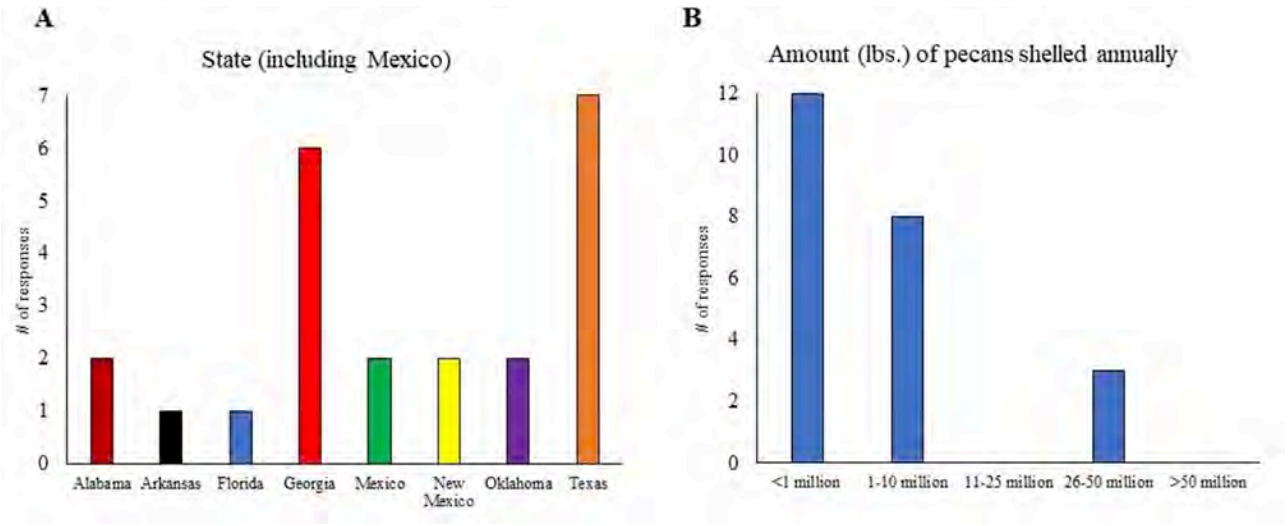

FIGURE 1. Demographic distribution of the sheller survey respondents (n = 23) based on U.S. state and Mexico (A) and the annual volume (lb) of the pecan shelling operation (B).

of food safety concerns was evaluated using the method described in Bakin et al. *(1)* by inversely weighting rankings to ranked priorities. Weighted scores were calculated for each concern by summing the weighted rankings across responses.

RESULTS

North American pecan sheller demographics

In total, 23 completed surveys were collected from pecan shellers. Responses included shellers from seven states in the United States (Alabama, Arkansas, Florida, Georgia, New Mexico, Oklahoma, and Texas) and two states from Mexico *(Fig. 1)*. The states that were most represented with pecan shelling operations were Texas (7/23) and Georgia (6/23). Survey respondents identified primarily as owners/managers of the shelling operation. Of the 23 responses, 52.2% (12/23) of them shelled <1 million lb annually, 34.8% (8/23) shelled between 1 and 10 million lb annually, and 13.0% (3/23) shelled between 26 and 50 million lb annually. The percentage of a firm's revenue from pecan shelling operations varied from <US$50000 to >US$5 million, with the highest being >US$5 million (17.4%, 4/23) followed by US$1000000 to US$4999999 (13%, 3/23) and <US$50000 (13%, 3/23). Most (90.0%, 18/20) of the pecan shellers who responded to the survey operate with fewer than 100 full-time employees while using a combination of part-time and seasonal employees, but three of the respondents preferred not to provide this information. Shellers most often source pecans from multiple sources whether that be from orchards owned by the organization or from third-party growers or a co-op of growers.

Food safety practices and programs

A majority (53.5%, 13/23) of shellers reported having a food safety plan in place to support compliance of regulatory or third-party audit requirements. These third-party audit schemes included SQF, Global GAPs, Primus, and AIB. When these responses were separated by operation size or output, there was an apparent difference in the operations that have food safety plans for shelling activities *(Fig. 2)*. For the operations that shell <1 million lb of pecans annually, 25.0% (3/12) had a food safety plan in place. In comparison, 87.5% (7/8) and 100% (3/3) of operations that shell 1–10 and 26–50 million lb of pecans annually, respectively, had a food safety plan.

For most shelling operations, 69.6% (16/23) sanitized shelling and packing equipment daily, 17.4% (4/23) sanitized weekly, and 13.0% (3/23) sanitized as needed. The sanitizers used in sanitation programs varied: 34.8% (8/23) of shellers used multiple sanitizers in their operations. Sanitizers included chlorine-based sanitizers such as sodium hypochlorite and chlorine dioxide, quaternary ammonia, alcohol-based sanitizers, and dimethyl ethers.

Conditioning water

Conditioning is conducted during the shelling process to increase the efficacy of kernel halves during cracking. Based on the results of the survey, 73.9% (17/23) of pecan shellers reported using this step in their shelling operations. The amount of time pecans spent in conditioning water varied from <1 h (50%, 8/16), 1–2 h (6.3%, 1/16), 3–4 h (12.5%, 2/16) to >4 h (31.2%, 5/16). One of the respondents that identified as using a conditioning step did not provide a length of time. Of the operations that use conditioning water, 58.8% (10/17) used a sanitizer in their conditioning water. Chlorine-based sanitizers such as sodium hypochlorite (40.0%, 4/10), chlorine dioxide (30.0%, 3/10), and calcium hypochlorite (20%, 2/10) were the most commonly used sanitizers in conditioning water, with one operation reporting using peroxyacetic acid (PAA; *Fig. 3*). When evaluating the use of sanitizers compared with the hot water sterilization

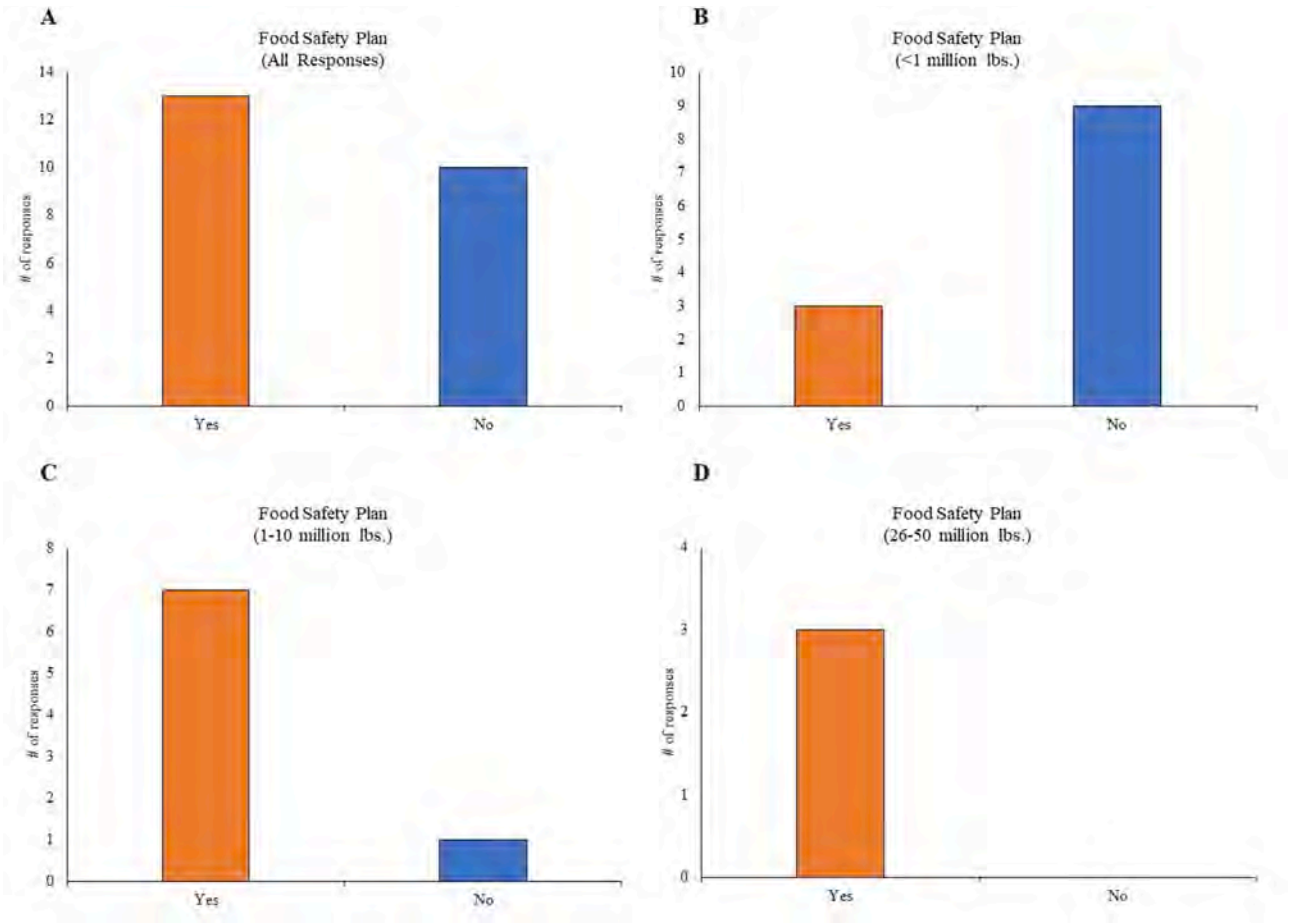

FIGURE 2. Number of operations that have food safety plans for all pecan operations (A), operations that shell <1 million lb of pecans annually (B), operations that shell 1–10 million lb annually (C), and operations that shell 26–50 million lb annually (D).

techniques of in-shell pecans, all operations that did not use sanitizers in their conditioning process used a hot water sterilization treatment of in-shell pecans.

Sanitizer monitoring occurred at varying frequencies, with some operations measuring once to as many as four times a day. Attributes such as temperature, pH, sanitizer level, and turbidity were also measured in some shelling operations (11/17). More than half (52.9%, 9/17) of the shellers recirculated water used for conditioning; that is, the same water was used between batches of pecans. Most shellers reported establishing conditioning water change schedules based on visual cues, such as turbidity; the other common responses were sanitizer levels or on set schedule.

In-shell sterilization and kernel treatment

The use of hot water/steam sterilization of in-shell pecans to treat foodborne pathogens before shelling was found to be a common practice: 56.5% (13/23) of shellers use this treatment in their operation. When these responses were separated by operation size or output, there was an apparent difference in the operations that used hot water or steam sterilization *(Fig. 4)*. For the operations that shelled <1 million lb of pecans annually, 25.0% (3/12) used a hot water/steam sterilization treatment. In comparison, 87.5% (7/8) and 100% (3/3) of operations that shelled 1–10 and 26–50 million lb of pecans annually, respectively, use a hot water/steam sterilization treatment in their operations. The most common temperature of the water used for the hot water/steam treatment was between 150 and 200°F (65.6–93.3°C), with 76.9% (10/13) of operations using this temperature and 23.1% (3/13) of operations using a temperature between 201 and 250°F (93.9–121.7°C). For the operations that used the 150–200°F temperature, treatment time varied between 1–3 min (30.0%, 3/10), 4–5 min (20.0%, 2/10), 6–8 min (20.0%, 2/10) and >8 min (30.0%, 3/10; *Fig. 5*). For operations that used the 201–250°F temperature, treatment times were either 1–3 min (66.7%, 2/3) or 6–8 min (33.3%, 1/3). The majority (82.6%, 19/23) of the shellers did not use any other further sterilization treatment on pecans outside of the use of a hot water treatment for in-shell pecans. Propylene oxide (PPO; 13.0%, 3/23) and a PAA-based treatment (4.3%, 1/23) were reported as the treatments used outside of hot water to treat pecan kernels.

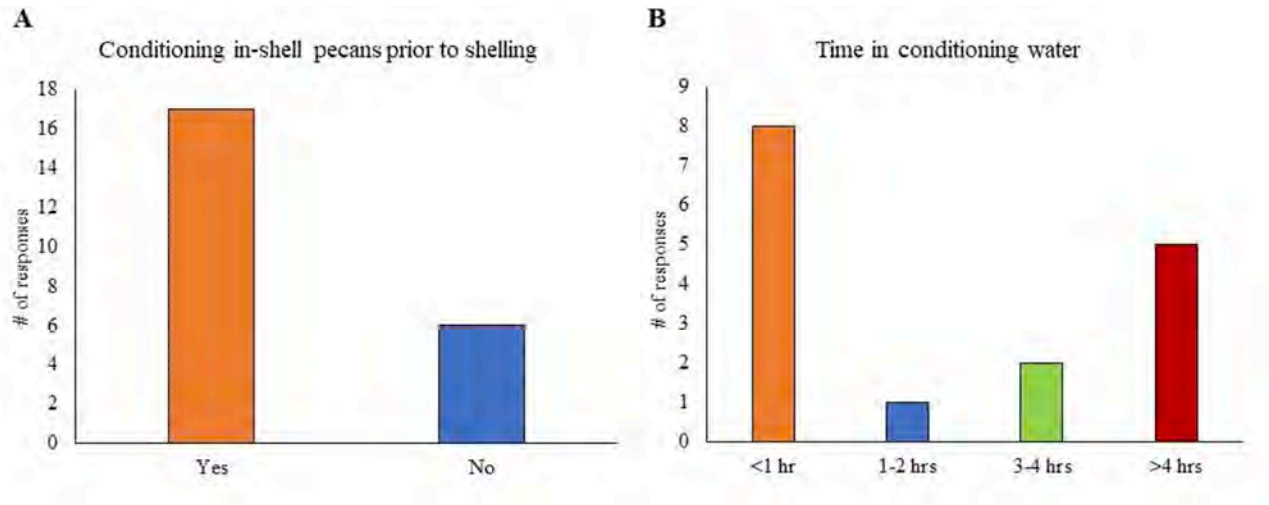

FIGURE 3. Number of operations that have a conditioning step before shelling (A) and number of responses for the length of time in-shell pecans are conditioned (B).

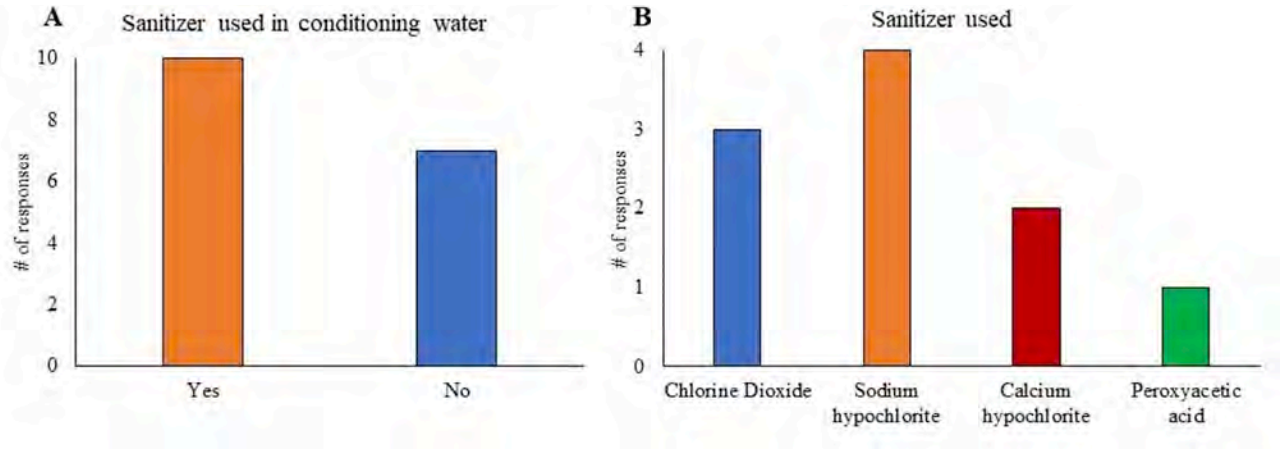

FIGURE 4. Number of operations that use sanitizers in conditioning water (A) and type of sanitizers used (B).

DISCUSSION

Although pecans are not covered by the FDA's Food Safety Modernization Act Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Human Food Rule and the Produce Safety Rule, pecans are commonly consumed raw, stressing the importance of best practices of safe handling of pecans *(16)*. The results of the survey provided valuable insight into food safety practices for pecan shellers in North America. A previous risk assessment used results from a survey performed by the National Pecan Shellers Association (NPSA) in 2013, with 22 responses from shellers, and was determined to represent the majority of U.S. pecan shellers *(12)*. The current survey had 23 respondents who finished the survey, with all but 2 being located in the United States; these 2 were firms located in Mexico. Based on the responses of the demographic questions, the majority of the operations that participated in the survey could be categorized as a "small" operation based on annual shelling (<1 million lb) and the number of employees (<50). The results of the survey suggest that the operations that shelled <1 million lb of pecans are less likely to have a food safety plan in place *(Fig. 2)*. Many food safety plans are created to support regulatory requirements or a third-party audit program (SQF, Primus, etc.) required from a buyer. These audits often require that employees be trained to carry out tasks that are associated with implementing food safety requirements *(23)*. Because many of the operations rely on a seasonal workforce that incurs high turnover from year to year, it is extremely important that these employees be trained on food safety practices and procedures to prevent

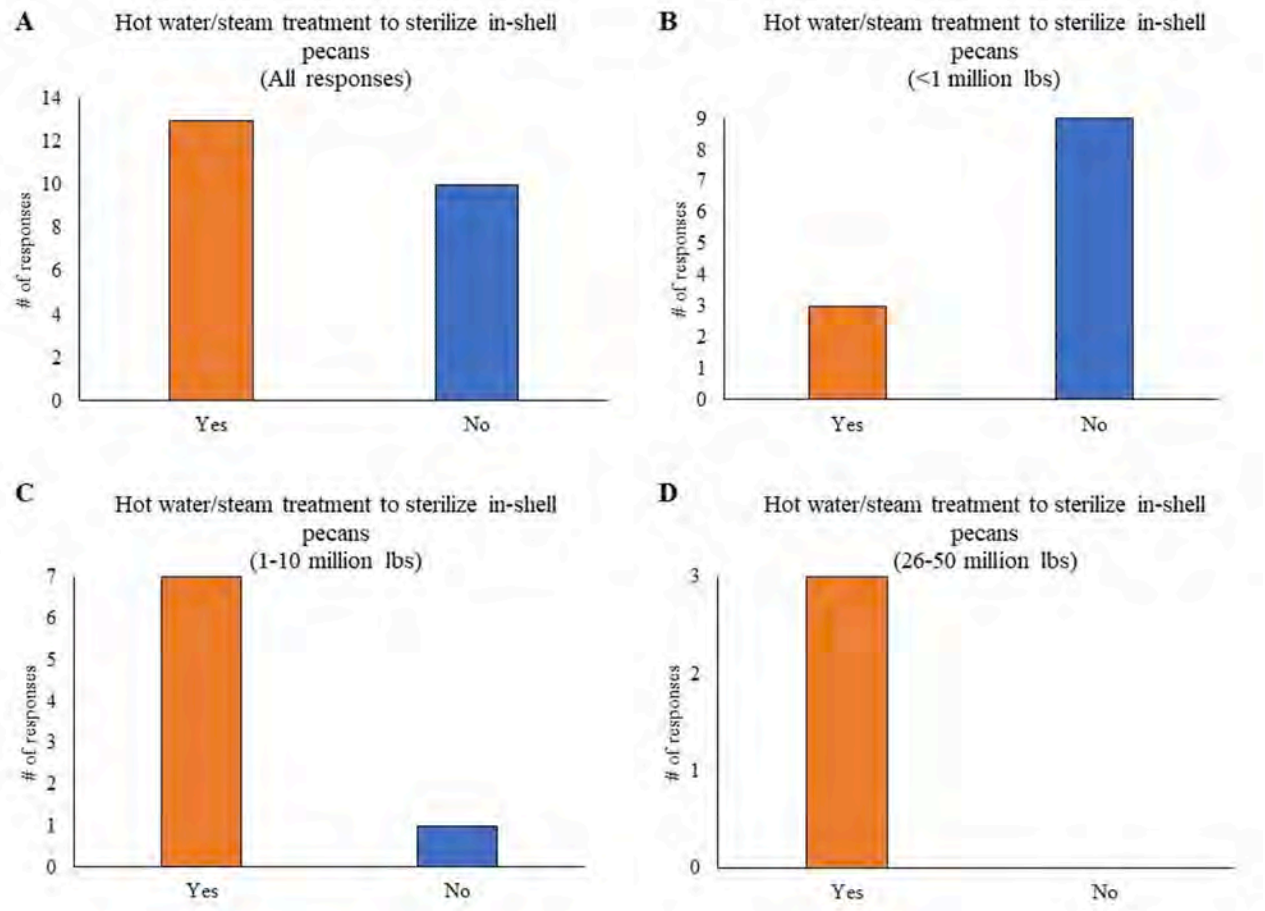

FIGURE 5. Number of responses of operations that use hot water/steam sterilization of in-shell pecans before shelling for all pecan operations (A), operations that shell <1 million lb of pecans annually (B), operations that shell 1–10 million lb annually (C), and operations that shell 26–50 million lb annually (D).

potential contamination events. It is essential that pecan shellers have access to materials that can be used to train employees on food safety practices regardless of the size of the operation.

A majority of the pecan shellers use a conditioning step in their operation. The conditioning step involves soaking in-shell pecans to obtain an optimal moisture content of the pecan kernel to maximize the number of intact kernel halves during the shelling process *(20)*. Based on the results of the survey, the conditioning step could be anywhere from <1 h to >4 h, depending on the operation. This presents potential issues with sanitizer efficacy in conditioning water over a long period if the sanitizer is not measured and replenished over the course of the conditioning process. The survey results indicate that a majority of the pecan shellers who used sanitizers in their conditioning water used a chlorine-based sanitizer (chlorine dioxide, sodium hypochlorite, or calcium hypochlorite). Studies have shown that low free chlorine levels may contribute to bacterial survival and that increased organic load, which can be measured as chemical oxygen demand (COD), can negatively impact free chlorine levels *(4, 18)*. Likewise, studies have shown that as chlorine demand increases by increased COD levels the free chlorine levels often decline over the course of a production period if they are not monitored and maintained at effective concentrations by adding more sanitizer to the system *(3, 17)*. Previous research has determined that in-shell pecans can become contaminated with foodborne pathogens in the field during harvest *(2, 7, 11)*; thus, the need for sanitizers in conditioning water, in the absence of a hot water or steam sterilization step, is critical to reduce incoming pathogens. In fact, the Oklahoma State Department of Health requires that in-shell pecans undergo a bactericidal process by either using a thermal treatment by hot water immersion for 2 min; a flow of hot water for 5 min at 170°F (77°C); or hot air at 180°F (82°C) for 20 min or if a thermal treatment is not used by immersing pecans in a 1000 ppm chlorine bath or an equivalent sanitizer *(19)*.

More than half of the shelling operations use some form of hot water or steam process to treat in-shell pecans, although

the use of the process seemed to be determined by the annual shelling output, because only 25.0% of shellers who shell <1 million lb of pecans use one of these processes. Previous research has determined that hot water treatments at 176 and 194°F (80 and 90°C) for 3–5 min were effective at achieving a 5-log CFU/g reduction of *Salmonella enterica* and *Escherichia coli* O157:H7, whereas a treatment at 158°F (70°C) for 5 min was effective at achieving a 5-log CFU/g reduction of *Listeria monocytogenes* on in-shell pecans *(15)*. Steam was also found to be an effective treatment at reducing the *Salmonella* surrogate *Enterococcus faecium* by 5-log CFU/g at 194°F (90°C) for 15 s, while also delaying the rancidity of the kernel and potentially extending shelf life *(14)*. This is an effective way to reduce pathogen levels while still maintaining quality. For many operations, implementation of these processes may be cost prohibitive, but there are designs and plans available for small-scale shellers to adapt a single-pass chlorinated water treatment for inshell pecans at a low cost within their operation *(19)*. Although a majority of the shellers use some form of hot water or steam, the results were not as high as previously reported by the survey conducted by the NPSA in 2013 that was used to develop a risk assessment of salmonellosis for pecan consumption in the United States *(12)*, finding that 77% (17/22) use a hot water or steam process to treat in-shell pecans, compared with 56.5% in this survey. These numbers may vary because the NPSA only distributed the survey to their members, who are often the larger shellers that are more likely to have a hot water or steam process in place, whereas this survey was distributed through various outlets that might reach smaller shelling operations.

Outside of treating in-shell pecans with a hot water or steam process, most shellers do not use any treatment on the pecan kernel after shelling to reduce potential contamination. Although this may be the case, pecan kernels generally undergo a drying process that often includes the use of hot air at approximately 140°F (60°C), which could result in a slight pathogen reduction *(6)*. This is generally not seen as a control step because the time may vary and is dependent on obtaining the desired final kernel moisture of 4% *(20)*. Of the operations that use a process to treat kernels, PPO and PAA were the primary treatments used. PPO has been found to be an effective treatment at reducing *Salmonella* and *E. coli* on pecan and other tree nuts *(5, 22)*. Although PPO treatment may be effective at reducing pathogenic load, it is not often a logistical or financially viable option for smaller pecan shellers, because this would require significant resources to implement this system in their operation or cost to send to a third-party facility to perform the treatment. Although not as effective as PPO, PAA as a treatment of pecan kernels was found to reduce up to 2.4 log CFU/g of *Salmonella* at 40 µg/mL. Oil roasting is a process in which pecans are moved through heated oil, which alters the flavor and texture of the kernel, and has been found to reduce up to 3.5 log CFU/g of *Salmonella* on pecan kernels when treated for 30 s at 260°F (127°C) *(6)*. Surprisingly, oil roasting was not identified as a treatment step used by shellers. This may be due to oil roasting not occurring at the shelling facility or only being performed if requested by buyers. Available and effective alternative treatments to eliminate pathogens on the surface of pecans should be evaluated for use by pecan shellers.

CONCLUSIONS

Pecans are frequently consumed either as an ingredient or raw by consumers in the United States. Therefore, best practices to ensure food safety are critical for the continued safety of consumers of raw, shelled pecans. The results of the survey provided insight into food safety and quality trends that are based on the size of an operation and its capacity to implement certain control measures. To provide shellers with an understanding of best practices, the development of food safety guidance documents and employee trainings may be needed. Likewise, the use and monitoring of sanitizers to prevent cross-contamination during conditioning should be encouraged, particularly if hot water or steam sanitation processes are not used to further reduce microbial hazards.

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