Recently, there have been numerous outbreaks associated with *Salmonella* in low-moisture foods. According to the CDC, there were multistate outbreaks associated with *Salmonella* for pistachios in 2009 and 2016 and almonds in 2000 and 2003, which caused massive nationwide recalls. This study identifies the environmental and physical factors that affect modes of cross-contamination associated with *Salmonella* in order to enhance a discrete element simulation of almond processing. Almond shell pieces and kernels (200 g) were inoculated with *Salmonella Enteritidis* PT30. Subsequently, the inoculated kernels (5 g), shell pieces (5 g) and un-inoculated kernels (200 g) were conditioned at 0.20, 0.40 and 0.60 aw and mixed in a stainless steel drum (140 mm diameter) for a total number of rotations (TNR) of 5, 20, 40, and 80 revolutions. Thereafter, the contaminated samples (5 g) were retrieved, and enumerated for the transferred *Salmonella*. The maximum bacterial load transferred from shells to kernels was significantly higher (P<0.05) than that of kernels-to-kernels for 0.2 and 0.6 aw. When comparing aw, there was a significant difference between 0.2 and 0.4 (P<0.05) for both kernel-to-kernel and shell-to-kernel. This indicates that environmental and physical factors like aw and surface structure significantly affect the dry transfer of *Salmonella*. Identifying factors affecting bacterial cross-contamination modes is critical information for secondary modeling used in discrete element model simulation, which will reveal the cross-contamination pathways of *Salmonella* for an actual processing system.

**Background/Justification**

- In 2000 and 2003, there were outbreaks of *Salmonella* in California almonds, resulting in a 13 million pound recall of raw almonds in 2004 (Danyluk 2007).
- There is a lack of understanding of how this contamination occurs and the factors (environmental and physical) that have an effect on the cross-contamination of low moisture products.
- In addition, it is uncertain which areas during almond processing are the highest risk areas for cross contamination (e.g. hulling, shelling, sorting or roasting step).

**Objective**

To quantify dry cross contamination for *Salmonella* during different stages almond processing (shelling and bulk handling)

**Materials**

- The raw, shelled almond kernels treated with propylene oxide (pasteurized) were obtained.
- Raw, in-shell almonds were obtained and broken into pieces. Pieces that passed through a sieve opening of 1 cm² were used.

**Methods and Materials**

- **Inoculation**
  - *Salmonella Enteritidis* PT30 inoculum were added to almond kernels or shells (100 g total).
  - Almonds or shell pieces were hand mixed (~2 min) with inoculum in a sterile bag, and dried in a biosafety hood.

- **Conditioning**
  - After drying, the inoculated almonds or shell pieces, and un-inoculated almonds were transferred to a conditioning chamber for water activity (aw) equilibration.
  - Water activity equilibration of the almonds took about 10 days in the conditioning chambers to achieve an target aw of 0.2, 0.4, and 0.6, respectively.

- **Cross Contamination Experiment**
  - The un-inoculated conditioned almonds (200 g) were added to a stainless steel drum (140 mm diameter and 64 mm depth), and combined with 5 g of the inoculated almonds or shells pieces. The drum was rotated at 8, 16, and 24 RPM.
  - Four grams samples of almond kernels were extracted from the drum at specific time intervals at 4, 16, 20, and 40 total number of rotation.

- **Enumeration**
  - Transferred *Salmonella* were enumerated on Trypticase Soy Agar with Yeast Extract (0.6% w/v) supplemented with ferric ammonium citrate (0.05% w/v) and sodium thiosulfate (0.03% w/v) after 48 hr of incubation at 35°C.

- **Statistical Analysis**
  - An equation was used to represent the Log(CFU/g) transferred to clean almond kernels dependent on concentration and distance.
  - Statistical difference was determined by fitting the data to the nonlinear equation, and determining if the two parameters, r (rate constant) and Cₚ (asymptotic value), were statistically different by a student’s t-test (P<0.05).

**Results**

- The raw, shelled almond kernels treated with propylene oxide (pasteurized) were obtained.

**References**


**Conclusion**

- Water activity showed a significant effect on cross contamination for *Salmonella* during almond kernel-to-kernel contamination for 0.4 aw. However, water activity was not a significant factor on transfer using shell pieces.
- There was not a statistical difference in the transfer rate of bacteria when comparing transfer from kernel-to-kernel and shell-to-kernel for only 0.2 and 0.4 aw (P > 0.05).
- There was a statistical difference between the asymptotic value reached by kernel-to-kernel and shell-to-kernel cross contamination for 0.2 and 0.6 aw (P<0.05).
- Overall, water activity and inoculation method are considered as critical to evaluate dry transfer of *Salmonella* during almond processing.

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