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Case Studies: Skin and Respiratory Symptoms in Peanut Inspectors with Peanut Dust and Endotoxin Exposure

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Introduction

The National Institute for Occupational Safety and Health (NIOSH) provided technical assistance at a peanut grading room in response to a request from a state health department for an evaluation of respiratory and skin symptoms among peanut inspectors. Reported symptoms included dermal (skin rash, burning/itching skin); respiratory (cough, shortness of breath, respiratory tract irritation, nosebleeds); and flu-like symptoms after being exposed to “bad” peanuts. We evaluated the workplace during two site visits 10 months apart.

Background

Harvested peanuts are processed from September through December at the facility where they are cleaned, dried, graded, and sold. Throughout this period, 8 to 10 peanut inspectors and aides process peanut samples and operate grading machines in the grading room. The grading room is approximately 30 feet long by 20 feet wide with an 8-foot ceiling and has two entranceways: one interior doorway, kept closed when not in use, which accesses a front office area, and an exterior doorway at the back of the building. The room is equipped with an air-conditioning unit that obtains room air through a supply grill near the floor at one end of the room and recirculates the air back to the room through seven ceiling-mounted diffusers. Nine peanut grading machines are located in the grading room with, some machines fitted with inertial dust collectors for collecting large particulates (cyclones).

During the first visit, the cyclones discharged dust back into the grading room. During the second site visit, the cyclones on the foreign material and presizer machines were fitted with PVC piping connected to exhaust vents outside the building (Figure 1). A freestanding ventilation unit located beneath the work counter recirculated room air through a filter of undetermined efficiency.

Periodically throughout the day, peanut inspectors collect peanut samples from 10-ton open top wagons. Inspectors carry each sample to the grading room where it is weighed and the data logged into the computer. Each sample, which weighs 1500 to 1800 grams, is then placed into the foreign material machine to separate the peanuts from miscellaneous debris.

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After debris removal, inspectors take 500 grams of peanuts from each sample for processing in the presizing, shelling, shaking, and splitting machines. Inspectors handle the samples when placing peanuts into the machines and when performing manual grading tasks at the large work counter in the center of the grading room. Gloves and other personal protective equipment are generally not worn during this process.

Prior Government Agency Response

The State Division of Public Health, the State Department of Agriculture, and offices and centers within the Food and Drug Administration (FDA) and U.S. Department of Agriculture (USDA) initiated an investigation in response to reports of health problems among peanut inspectors who worked in the grading room during the 2007 peanut season. The epidemiologic investigation by the State Division of Public Health found that the peanut inspectors at the peanut facility began experiencing skin irritation and respiratory symptoms in October. Inspectors related their symptoms to handling peanuts from one particular grower, reporting that these peanuts had an unusual odor. Nine inspectors with symptoms were seen by an infectious disease physician who suggested that the symptoms were consistent with exposure to a chemical agent such as a mycotoxin. None of the peanut inspectors were hospitalized, but symptoms continued after initially handling that particular shipment of peanuts. As a result, the agencies' investigations focused on the peanuts from that specific grower, even though no health problems were reported by that grower's employees or by other employees of the processing company that handled peanuts from that grower. Because of employee health concerns, the peanut facility's grading room was shut down from mid-November until the last week of December 2007.

The multi-agency investigation, which began prior to NIOSH involvement, included laboratory analyses of suspect peanut samples for mold; mycotoxins (including trichothecene mycotoxins, aflatoxin, *Stachybotrys* toxins, T-2 toxin, zearalenone, deoxynivalenol, ochratoxin, and cyclopiazonic acid); pesticides, and other chemicals. Although several genera of mold were identified in samples of the suspect peanuts, the types and amounts of mold contamination were not unusual. Trichothecene mycotoxins were detected in an initial screening sample; however, the results of this initial testing were only preliminary, as the screening tests had not been validated for inshell peanuts. Confirmatory tests for tricothecene mycotoxins were negative. Additional analyses of multiple samples did not identify mycotoxins. Analyses did not indicate the presence of pesticides or other chemicals in the peanuts.

Methods

We held confidential medical and occupational interviews with seven peanut inspectors at the facility during our first site visit. One additional inspector was later interviewed by phone. Subsequent to the site visit, we reviewed medical records of 13 peanut inspectors and reports of laboratory analyses from the FDA.

Because peanut grading had been suspended prior to our 2007 site visit, we were unable to observe actual grading room operations or conduct exposure monitoring; however, we collected a dust sample from the air-conditioner filter in the grading room and several peanut shells that contained visible crystalline-like structures. Approximately 2 weeks after the site visit, the State Department of Agriculture provided us with a plastic bag containing peanuts from storage bins that were graded when employee symptoms began ("suspect peanuts") and a separate bag containing other peanuts ("comparison peanuts").

We sent air-conditioner dust and peanuts from each bulk sample to be analyzed for endotoxin (a component of the cell membrane of Gram-negative bacteria). Samples were analyzed using the limulus amebocyte lysate (LAL) assay, kinetic chromogenic method.[1] For these analyses, nine endotoxin units (EU) were equivalent to one nanogram of endotoxin.

The peanut shells that contained crystalline-like structures were prepared and analyzed by polarized light microscopy according to NIOSH Method 9002.[2] Stainless steel thermal desorption tubes that contained three beds of sorbent material were used to perform qualitative headspace analyses of VOCs emitted by suspect and comparison peanuts.

We performed a second site visit during the next grading season to observe the grading process and conduct air sampling for endotoxin. We collected personal breathing zone (PBZ) air samples on eight peanut inspectors inside the grading room. For comparison, we collected a general area (GA) air sample outdoors, approximately 3 feet above the ground and 30 feet from the entrance to the grading room. A second GA sample was collected in the office employees' lunchroom. The lunchroom was selected for background sampling because it was in the same building as the grading room and had not been associated with health problems.

Air samples were collected with endotoxin-free, three-piece 37-mm closed-face cassettes preloaded with 0.45-micron poresize polycarbonate membrane filters. Endotoxin analysis was performed using the LAL assay, kinetic chromogenic method. For air sample analysis, 15 endotoxin units (EU) were equivalent to one nanogram of endotoxin. We used an ART Instruments model HHPC-6 hand-held airborne particle counter (ART Instruments, Grants Pass, Ore.) in the grading room, the lunchroom, and outdoors. Particle count data were reported during three 21-sec periods in the morning, and three 21-sec periods during the afternoon.

Results

Exposure Assessment

During a demonstration of the grading machines in 2007, we noted that the machines generated and released dust into the grading room air. We were shown single-strap dust masks that were provided to peanut inspectors for voluntary use. These were not NIOSH-approved respirators and would not provide adequate protection against airborne particulate exposure. No respiratory protection program was in place.

During the first site visit, the air-conditioner filter in the grading room had a thick layer of dust. Peanut inspectors stated that the filter had not been changed during the preceding grading season. Analysis of the dust sample collected from the filter found 1,500,000 EUs per gram (EU/gram), which suggests endotoxin-containing dust had been released in or near the grading room. Because no one knew how long the filter had been in use, we could not determine when the contaminated dust had been deposited on the filter. Analysis for endotoxin in the samples of suspect and comparison peanuts showed that the suspect peanuts contained less endotoxin than the comparison peanuts. The endotoxin concentration in the suspect peanut sample was 260 EU/gram; the concentration in the comparison sample was 1400 EU/gram. We do not know, however, if the suspect peanuts that were submitted for analysis were representative of the peanuts thought to be associated with employees' symptoms. Qualitative volatile organic compound (VOC) analysis detected no obvious differences between the two samples of peanuts. Qualitative microscopic analysis of peanut shells did not identify any unusual characteristics.

During the second site visit, none of the peanut inspectors working during the initial site visit were employed in the grading room. The new staff stated that they had not noticed any unusual odors, nor had they experienced health problems. The lead peanut inspector during the second site visit stated that approximately one-third of the peanuts that had been graded during the preceding few days were from the grower of the suspect peanuts the prior year. The lead peanut inspector also noted that the air-conditioner filter had been changed several times since our initial site visit. Respiratory protection was voluntary, and none of the employees wore respiratory protection in the grading room. No peanut inspectors were observed wearing gloves or hearing protection. Employees did not eat or drink in the grading room.

The results of PBZ air sampling for endotoxin are presented in Table I. Time-weighted average (TWA) concentrations are reported for the actual sampling periods. The geometric mean PBZ concentration was 320 endotoxin units per cubic meter (EU/m^3). The range was 170 to 680 EU/m^3. Area samples indicated TWA concentrations of 9.8 EU/m^3 in the lunchroom and 380 EU/m^3 outdoors.

The highest TWA exposure to endotoxin occurred near the B-side foreign materials machine where miscellaneous debris was separated from the peanut samples. This was one of two foreign material machines that had been retrofitted with PVC pipe to discharge dust outdoors. However, openings in the metal duct near the cyclones on these machines allowed the cyclones to discharge partly into the room, rather than discharging entirely outdoors.

Airborne dust was not visible at the foreign material machines or elsewhere in the grading room on the sampling date. As shown in Table II, particle count data suggest that fewer airborne particles were present in the grading room than were measured outdoors and in the office lunchroom, which is located in another part of the building. During the site visit, tractors and wagons generated visible airborne dust that appeared to result in the relatively high outdoor particle counts.

Medical Assessment

We interviewed eight peanut inspectors (six of nine fulltime and two of 16 part-time employees) who worked at the peanut facility during our first site visit. For this evaluation, full-time employees were defined as working more than 15 days during the 2007 season in the grading room.

Of the eight interviewed peanut inspectors, the average age was 41 years (range: 20 to 66 years), and the average number of years worked as an inspector was 9 (range: 1 to 25 years). Of the six full-time employees, the average number of days worked was 35 (range: 29 to 39 days). The two part-time employees worked 3 and 4 days. No employees worked at other peanut grading sites after the peanut grading room was shut down. Seven employees were female, and seven were current smokers. No employees wore protective gloves; dust masks provided for workers were rarely worn.

Employees reported grading peanuts having an odd odor, and within the following 2 weeks, six of the eight employees reported skin, eye, nose, and throat irritation; seven reported headaches; six reported diarrhea (four of the six also had nausea, vomiting, or loss of appetite); and five reported flulike symptoms (including fatigue, body aches, chills, cough, and shortness of breath). One employee reported respiratory symptoms that existed prior to the 2007 peanut season.

We reviewed medical records of 13 peanut inspectors, including records of the eight interviewed employees. All 13 employees were diagnosed with "toxic exposure" or "occupational exposure consistent with an irritant chemical" by at least one physician. Twelve employees reported skin burning, itching, or rash, and most reported this was the first symptom to occur; 10 had skin findings on initial medical examination. Two employees were referred for dermatological consultation. Diagnoses in those with persistent rash included contact dermatitis (one employee) and fungal infection of the scalp (one employee); two were referred for further evaluation by an allergist.

Twelve employees reported respiratory symptoms and 10 were seen by a pulmonologist. Of these 10, all underwent chest X-rays (all with normal results) and pulmonary function testing. Seven displayed obstructive or restrictive lung changes on pulmonary function testing and were diagnosed with one or more of the following: reactive airways disease, chronic obstructive pulmonary disease, emphysema, chronic tobacco abuse, or asthma. Because of the smoking history of these employees, we were unable to assess if the abnormal lung findings were due to the effects of smoking, workplace exposures, or both.

Six peanut inspectors had blood analyses for total IgE and blood immunoassay testing for hypersensivity pneumonitis (referred to as the Farmer's Lung Panel). Two of six employees had elevated total IgE indicating allergy. No employees had detectable reactions to the Farmer's Lung Panel.

Discussion

Even though a definitive causal relationship cannot be established, results of air and dust sampling and medical evaluations suggest that exposure to endotoxin during the 2007 grading season may have contributed to the acute respiratory and flu-like symptoms experienced by the employees. The acute skin symptoms experienced by peanut inspectors were most consistent with a chemical exposure; endotoxin may have a role in skin symptoms.[3]

The persistent nature of symptoms in some employees was puzzling. Generally, in an acute exposure, once a person is removed from the exposure to either endotoxin or mycotoxin, the symptoms slowly get better and resolve within a few days to a few weeks.[4–6] One possibility is that employees carried dust on their clothing and shoes into their cars and homes, and so continued having some exposure and symptoms. Another possibility is that co-existing health conditions may have increased susceptibility, worsened symptoms, and caused longer recuperation times. Some employees who are “allergic” individuals, or have a propensity to develop allergies, may have developed an allergy to an unidentified causative agent in the peanut dust.

The high prevalence of respiratory symptoms reported among full-time peanut inspectors suggests that the exposure was an irritant compound because all persons would be equally susceptible, unlike an allergenic compound, which would affect only allergic individuals. The wide range of biological activity associated with endotoxin exposure including inflammatory, hemodynamic, and immunological responses could explain the respiratory and flu-like symptoms among the employees. The high prevalence of acute skin symptoms could be explained by skin exposure to an irritant compound, which could include chemicals sprayed on the plants and soil as pesticides, plant residues on the peanut samples that could cause acute urticarial skin symptoms, or mycotoxins. Although intense efforts by USDA and FDA were taken to find mycotoxins or unusual fungal species in the peanut samples, none were found, and the peanuts were released for further processing. It is possible that the sample of suspect peanuts subjected to this testing did not contain the same contaminant as the peanuts implicated in the peanut inspectors' symptoms.

Microorganisms in organic agricultural dust include Gram-negative bacteria, which are characterized by the presence of endotoxins in the outer bacterial cell wall membrane. Endotoxins, lipopolysaccharide complexes, are released when the bacteria die and disintegrate. Exposure to endotoxins can lead to symptoms of cough, wheeze, shortness of breath, chest tightness, and conjunctivitis. Continued or repeated exposure can result in chronic health effects including chronic bronchitis, reactive airway dysfunction syndrome, asthma, chronic airways obstruction, hypersensitivity pneumonitis, and emphysema.[7] NIOSH has published information on agricultural dust exposures and organic dust toxic syndrome.[8] The presence of endotoxins in air samples collected in 2008 suggests that airborne endotoxin exposure is likely during peanut grading and other activities where peanut crops are handled or processed. Endotoxins concentrations in all PBZ air samples appear to exceed the proposed 8-hr TWA exposure limit of 90 EU/m^3 recommended by the Dutch Expert Committee on Occupational Standards.[9]

Conclusion

Analysis of peanut bulk samples and air-conditioner dust in the initial peanut season and area and PBZ air samples in the following season provides evidence that peanut inspectors are at risk of exposure to airborne endotoxin during routine operations in peanut grading rooms. Although airborne endotoxin concentrations in grading rooms can vary between seasons, crops, and locations, air samples collected in the grading room indicate that exposure to airborne endotoxin may exceed levels that have been associated with symptoms of cough, wheeze, shortness of breath, chest tightness, mucous membrane irritation, and signs of acute airflow obstruction.[10–12]

The acute respiratory and flu-like symptoms reported in the initial site visit by peanut inspectors and the associated medical findings are consistent with endotoxin exposure. However, the persistence of symptoms reported by some employees after being removed from exposure does not fit with recognized endotoxin- or mycotoxin-related illness. We suspect that this may have resulted from “take-home” contamination (i.e., endotoxin in peanut dust that was carried home on employees' clothing) and may have resulted in continued exposure to endotoxin while away from work. In addition, some employees may have been more susceptible to pulmonary and skin disorders or had co-existing pulmonary or skin disease.

Recommendations

Engineering Controls

1. We recommended that the facility install or modify the ductwork on all cyclone-equipped machines to discharge dust entirely outdoors. If working properly, the cyclone dust collectors installed on some of the grading machines should capture coarse dust; however, cyclones will not capture fine particles. Unless ducted outdoors, these fine dust particles will be released into the peanut grading room, where the dust may be inhaled by grading room employees. A simple way to reduce exposure to agricultural dust and endotoxin would be to install ductwork on the cyclones to discharge fine particles outdoors.

2. We also recommended that an air-conditioner filter maintenance program be instituted. The filter should be changed routinely and documented in a maintenance log.

Administrative Controls

We recommended that facility management conduct employee training at the beginning of each peanut grading season to educate employees on best work practices to limit dust exposure, proper hygiene (e.g., employees should not bring food or drink into the peanut grading room), personal protective equipment use, and potential hazards of organic dust exposure. They should also encourage employees to report all potential work-related skin and respiratory symptoms to their supervisors. Because the work relatedness of skin and respiratory diseases may be difficult to establish, employees with possible work-related health problems should be fully evaluated by a physician, preferably one familiar with occupational conditions.

In addition, we also recommended that the facility management:

1. Establish an employee-management health and safety committee or working group to develop an action plan. Those involved in the work can best set priorities and

assess the feasibility of our recommendations for the specific situations in the peanut grading room.

2. Review and monitor injury/illness logs of all grading locations periodically (e.g., monthly) during peanut grading season to identify work-related skin and respiratory illness. Although we are not aware of health problems among peanut inspectors during previous seasons or at other locations, it is possible that symptoms have occurred but were not recognized. If respiratory illness is reported, the work location should undergo an environmental evaluation to characterize endotoxin exposure. Managers should report clusters of illness to their state health department to identify public health risks that may be associated with the handling and grading of peanuts. This information would enable public health agencies to develop interventions to ensure the safe handling and processing of peanuts.

3. Conduct exposure characterization for endotoxin in peanut grading rooms to characterize exposures. These results will help determine if additional engineering controls may be needed in addition to the cyclone dust collector exhaust systems that are on some machines.

Personal Protective Equipment

We recommended that management provide peanut inspectors with NIOSH-approved N95 particulate filtering facepiece respirators in the context of a respiratory protection program when exposure to organic dust cannot be avoided.[13] To reduce skin exposure to skin irritants and allergens, disposable non-latex, powder-free gloves should also be provided for peanut inspectors.

Management should also implement education and training of employees on the hazards of agricultural dust exposure and the possible hazard of taking contamination home on work clothes. Employees should not wear contaminated clothing from work to home.

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Figure 1. Peanut grading machine with retrofitted exhaust ventilation duct in 2008

Table I
Air Sampling Results for Endotoxin (October 2008)

Job Title	Location	Time (min)	Concentration (EU/m^3)^A	TWA Concentration (EU/m^3)^B
Inspector	Weigh-in	0830−1141 (191)	360	260
		1330−1657 (207)	160	
Aide	Grain analysis computer	0823−1141 (198)	220	200
		1335−1658 (203)	190	
Inspector	A-side	0825−1142 (197)	380	340
		1331−1658 (207)	300	
Inspector	A-side sheller	1023−1143 (80)	860	550
		1336−1517 (101)	310	
Aide	A-side	0852−1141 (169)	470	470
Aide	B-side foreign materials	0829−1141 (192)	780	680
		1322−1656 (214)	590	
Inspector	B-side splitter	0827−1141 (194)	200	170
		1313−1658 (225)	140	
Lead Inspector	B-side presizer	0820−1143 (203)	290	210
		1314−1654 (220)	140	
—	Lunchroom area sample	0930−1651 (441)	9.8	9.8
—	Outdoor area sample	0838−1650 (492)	380	380
Dutch Expert Committee on Occupational Standards 8-hour TWA exposure limit^C				200

^{A}EU/m^3: Endotoxin units per cubic meter of air. 15 EUs = 1 nanogram endotoxin.

^{B}TWA concentration for the morning and afternoon sampling periods.

^{C}Prior to adopting the 200 EU/m^3 limit as an economically feasible limit for the agricultural industry, the Dutch Committee proposed a health-based 8-hr TWA limit of 50 EU/m^3.

Table II

Average Number of Particles per Liter of Air by Particle Size

	Location			
	Grading Room	**Lunchroom**	**Outdoor**	
Particle Size (*μ*m)	**(n = 7)**	**(n = 5)**	**(n = 5)**	**(n = 1)[A]**
0.3	10, 000	37, 000	63, 000	72, 000
0.5	3100	4300	4000	9400
1.0	4300	2900	1100	10, 000
3.0	2300	840	490	4900
5.0	310	43	35	840
10.0	310	22	30	1600

Note: Each value is the arithmetic mean of n counts, where n = number of measurements.

[A]This measurement is reported separately because of the apparent difference between the size distribution of particles in this outdoor measurement vs. that of the other five outdoor measurements.