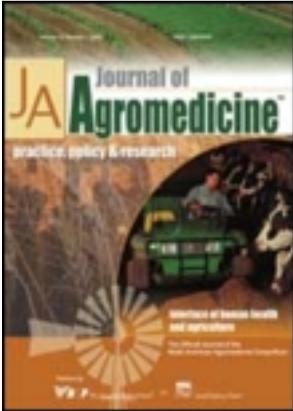


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Journal of Agromedicine

Publication details, including instructions for authors and subscription information:

<http://tandfprod.literatumonline.com/loi/wagr20>

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Available online: 21 Sep 2008

To cite this article: Steven E. Lacey PhD, Lorraine M. Conroy ScD, John E. Franke PhD, Richard A. Wadden PhD, Donald R. Hedeker PhD & Linda S. Forst MD (2006): Personal Dust Exposures at a Food Processing Facility, *Journal of Agromedicine*, 11:1, 49-58

To link to this article: http://dx.doi.org/10.1300/J096v11n01_06

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ABSTRACT. A field study was performed to quantify personal dust exposures at a food processing facility. A review of the literature shows very little exposure information in the food processing industry. The processing area consisted of a series of four rooms, connected by a closed-loop ventilation system, housed within a larger warehouse-type facility. Workers were exposed to various fruit and vegetable dusts during the grinding, sieving, mixing and packaging of freeze-dried or air-dried products. Eight two-hour periods were monitored over two days. Personal total suspended particulate samples were collected on 37 mm PVC filters with 5 μm pore size according to National Institute for Occupational Safety and Health (NIOSH) Method 0500. The filters were analyzed gravimetrically. The two-hour task sampling personal dust exposures ranged from 0.33-103 mg/m^3 . For each worker, an eight-hour time weighted average (TWA) concentration was calculated, and these ranged from 3.08-59.8 mg/m^3 . Although there are no directly appropriate occupational exposure limits that may be used for comparison, we selected the Threshold Limit Value (TLV) for particulates not otherwise classified (PNOC) of 10 mg/m^3 for inhalable particles. Neglecting the respiratory protection used, five out of eight of the worker time-weighted averages exceeded the TLV. It should be noted that the TLV is based on the inhalable fraction and in this study total suspended particulate was measured; additionally, the TLV is applicable for dusts that are insoluble or poorly soluble, and have low toxicity, which may have limited protective ability in this case due to the irritant nature of certain dusts (e.g., jalapeno peppers, aloe vera). Sieving resulted in significantly higher exposure than grinding and blending. Measuring area concentrations alone in this environment is not a sufficient method of estimating personal exposures due to work practices for some operations. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2006 by The Haworth Press, Inc. All rights reserved.]

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The authors want to recognize the assistance of graduate students L. Berman, L. Clark, A. Carollo, T. Dyson, L. Ellington, R. Jimenez, K. Kennedy, J. Paulin, T. Schoonover, and Dr. S. Erdal. They also greatly appreciate the assistance provided by the facility management and employees.

Funding/Support: Research supported by CDC/NIOSH Grant #T42/CCT4100424-08 (Pilot Projects); Researcher supported by CDC/NIOSH Grant #U06/CCU516863-03, CDC/NIOSH Grant # T42/CCT4100424-08 (Industrial Hygiene), and the University of Illinois at Chicago Division of Environmental and Occupational Health Sciences.

KEYWORDS. Dust exposure, food processing, food dust

INTRODUCTION

Operations in the food processing industry create an environment where workers may be exposed to a variety of organic dusts. Specific information on the size of this industry is not explicitly available, but data from the Bureau of Labor Statistics suggest that 20,000 to 60,000 workers in the U.S. are involved in food processing related activities, excluding bakers and meat processors.¹

Health effects from handling food products and exposure to organic food dusts are noted in the literature. Dermatological symptoms noted include itching, erythema, eczema, edema, desquamation, urticarial rashes, and vesicular dermatitis, primarily of the hands, forearms, face and neck.²⁻¹⁶ The grinding, sieving, mixing, and packaging of various dried food products may result in: dyspnea, nose bleeds, sinusitis; chronic cough, phlegm and bronchitis; eye, nose, and throat irritation; headaches; burning sensation of the skin; weight loss; and pulmonary function decrements resulting in decreased Forced Expiratory Flow (FEF) at 25 and 50%.¹⁷⁻²² Similar respiratory symptoms have been noted in potato processing workers and hemp, flax, cotton, jute, and sisal workers.^{23,24}

Limited air sampling has been reported for this industry. Four studies reported area total dust concentrations ranging from less than 0.5 mg/m³ to 95.5 mg/m³ in spice, dried-foods, animal feed, and potato processing facilities.^{17-19,25} One study reported personal dust concentrations as high as 153 mg/m³.²⁵

Area sampling at a spice processing plant reported a mean total dust concentration in the work area of 2.9 mg/m³, with a range of 0.5 mg/m³ to 10.1 mg/m³.¹⁷ Statistically significant reduction in lung function was noted in across-shift measurements for FEF₂₅ (-15.2), FEF₅₀ (-8.3), FEV₁ (-3.0), and FVC (-2.0). Area sampling data from a facility that processed coffee, tea, spices, confectionary, dried fruits, cocoa, and flour reported a total dust concentration range of 2.9 mg/m³ to 31.2 mg/m³, with a respirable dust range of 0.33 mg/m³ to 3.2 mg/m³.¹⁸ Again, reduction in across-shift ventilatory

capacity was noted: FEF₂₅ (-12.1 to -26.7), FEF₅₀ (-5.1 to -21.6), FEV₁ (-1.3 to -9.9), and FVC (-1.9 to -3.7). The percentage of workers reporting acute symptoms during work shift included: cough (25.5 to 57.5%), dyspnea (33.9 to 44.5%), throat irritation (36.5 to 56.5%), throat dryness (27.5 to 60.3%), eye irritation (30.3 to 54.7%), nose dryness (16.0 to 47.8%), nose bleeding (16.9 to 40.2%), and headache (28.3 to 46.2%). A study at an animal food processing facility reported a total dust concentration range of 0.77 mg/m³ to 10.62 mg/m³, with a respirable fraction range of 0.34 mg/m³ to 2.94 mg/m³.¹⁹ In the same study, in rooms where product was transferred from container to container, the total dust concentration average was 35.59 mg/m³, and the respirable fraction average was 2.07 mg/m³. Cross shift lung function testing again showed decrements in capacity: FEF₂₅ (-11.5), FEF₅₀ (-9.8), FEV₁ (-3.7), FVC (-3.9). The percentage of acute symptoms reported by animal food workers included: cough (53.5%), dyspnea (47.9%), throat irritation (46.5%), throat dryness (54.9%), eye irritation (53.5%), nose dryness (53.5%), nose bleeding (9.9%), and headache (32.4%).

OBJECTIVES

Dust exposure in the food processing industry has not been extensively studied. The overall objective of this study was to describe dust exposure during processing of freeze-dried and air-dried fruits and vegetables. The specific objectives of this study were to quantify personal exposures to dust and describe those exposures as a function of operation and product.

METHODS

Test Location

A field study was executed to quantify personal dust exposures at a food processing facility. A review of the literature shows very little exposure information in the food processing industry. The facility was identified because it

was affiliated with a farming operation that was a participant in a large agricultural safety study. The operations at this facility are standard for dried food processing. Although we have limited ability to judge the occupational hygiene of other similar food processing facilities, this is a modern facility with a mechanical ventilation system for general environmental control.

The processing area consisted of a series of four rooms, connected by a closed-loop ventilation system, housed within a larger warehouse-type facility. Each room had an air supply located along the same wall near floor level, and an overhead exhaust hood positioned on the ceiling near the center of the room. One-hundred percent of the air exhausted from the four rooms was re-circulated after filtration. Figure 1 shows a schematic of the processing rooms.

Workers were exposed to various fruit and vegetable dusts during the grinding, sieving, mixing and packaging of freeze-dried or air-dried products. These operations varied for the multitude of products processed, per customer specifications. Material to be processed usually arrived to a processing room in a large plastic bag, ranging from approximately 9 to 18 kg in weight.

For grinding, the product was fed from the plastic bag into a hopper, and the material would pass through the grinder and the output was collected below.

In sieving operations, the material to be processed was fed into a hopper and fell with gravity onto the surface of a sieve. Alternatively, the product was sometimes dumped directly into

the upper level of the sieve. The sieving equipment could be configured to permit fractionation of material into several particle size ranges. Often the workers would use their hands to help force the material through the primary sieve screen.

Mixing (or blending) was accomplished by two different methods. One method was to load material to be processed into a hopper, where it was then processed into a homogenous mixture as it traveled the length of a corkscrew auger. These materials were collected at the end as the product fell with gravity into a plastic bin. A second method entailed the use of a V-shaped mixing vessel, which rotated upon a horizontal axis, similar to equipment commonly employed in the pharmaceutical industry for such operations.

With each of these operations, the material that had been processed was ultimately collected in a bin lined with a plastic bag. The bag would be removed from the bin and secured closed with a plastic tie. Figure 2 shows a worker removing a bag of processed material from a bin after sieving. Prior to switching to a new product, the rooms were cleaned by sweeping the floor and using compressed air to remove dust from the processing equipment, followed by washing the rooms with wet methods.

Current Controls

Depending on the dustiness and the irritant properties of a product, worker respiratory protection ranged from simple paper dust masks and N-95 respirators, to full face air purifying

FIGURE 1. Schematic of processing rooms.

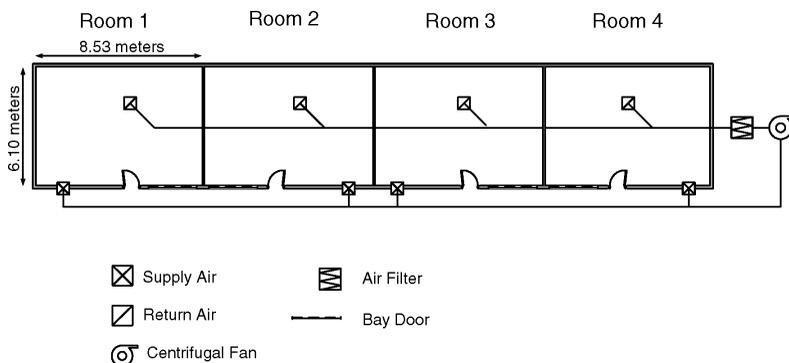


FIGURE 2. Worker packaging product.



respirators. For example, during our study, dust masks were used for generally non-irritating products such as basil or spinach, N-95 respirators were used while processing respiratory irritants such as aloe vera, and full face air purifying respirators were used while processing jalapenos. General observations by the authors were that where respirators were utilized, they appeared to be worn correctly. However, a comprehensive review of the facility respiratory protection program was beyond the scope of this study. Tyvek jumpsuits or lab coats, and gloves were used to provide mutual protection of the food product and the worker.

Workers used plastic sheeting to isolate major dust generation points, and pathways where product would deposit with gravity. The processing rooms were of recent construction for the facility, built in the late 1990s. The design entailed supply air entering each processing room near floor level from a 0.61 m × 0.61 m supply vent, and air being removed via a 0.61 m × 0.61 m overhead exhaust hood at the center of the room. Ventilation rates were measured at the supply and exhaust ventilation locations using an Alnor Balometer (Alnor Corp., Shoreview, MN).

Air Sampling

Breathing zone dust concentrations were measured for all workers involved in food processing operations. There were five processing operators who worked in this area; all five operators were sampled on Day 1, and three opera-

tors were sampled on Day 2. In order to assess the effects of operation and product on personal exposure, 32 two-hour task based samples were collected. To quantify total dust exposure, low-volume air sampling pumps utilizing 37 mm polyvinyl chloride (PVC) filters with 5 μm pore size at a flow rate of approximately 2.0 L/min were used, in accordance with NIOSH Method 0500. Within the two-hour task sampling periods, actual flow rates were checked at the beginning, middle, and end points of each sampling period using a calibrated rotameter. The rotameter was calibrated using the primary standard of a simple bubblemeter prior to the field study.

The mass of dust collected on each sampling filter was determined gravimetrically with a Sartorius model MC5 electronic balance. Filters were desiccated for 48 hours prior to determination of pre-sampling and post-sampling weight. Each filter was weighed a minimum of three times before and after sampling to verify constant weight; additional measurements were made as needed until measurement variance was limited to ± 5%.

ANALYSIS

Personal exposure measurements were analyzed using SAS (Cary, NC) to determine statistically significant differences due to operation using a one-way analysis of variance (ANOVA). For this analysis, the data were log-transformed to better satisfy the normality assumption of the model. Following the overall test from the ANOVA, comparisons of all pairs of operations (e.g., sieving vs. grinding, sieving vs. blending, and blending vs. grinding) were made using Tukey's multiple comparison procedure. This procedure properly controls the overall significance level for this set of specific comparisons. For each comparison, we present the Tukey-adjusted confidence interval for the pairwise comparison of means. If the confidence interval does not contain the value of 0, it may be concluded that the compared means are not equal, at an overall significance level of $\alpha = 0.05$.²⁵

RESULTS

Twenty-nine task based personal samples were collected over the two-day period (three samples were lost due to pump failure). The sampling time for each sample was approximately two hours. The concentrations ranged from 0.33 to 103 mg/m³, with a geometric mean (GM) of 10.6 mg/m³. Results for each sampling interval are shown in Table 1 along with the processes and products used during that interval. The time-weighted average (TWA) exposures for each worker each day are also given in Table 1. For the few cases with sample times slightly less than eight hours, a conservative approach was taken by estimating the concentration during the unsampled time to be equal to the average concentration measured during the sampled time.

Descriptive statistics were run on these data, encompassing all operations being performed on all products, as seen in Table 2. The Shapiro and Wilk Test (W-test) determined the data followed a lognormal distribution ($\alpha = 0.05$). The arithmetic mean (AM) is noted in Table 2. Since the data are non-normally distributed, the geometric mean and the geometric standard deviation (GSD) are displayed. The minimum and maximum concentrations are also noted.

Next, the data were stratified and descriptive statistics are presented for each operation being performed (e.g., sieving, grinding, blending), and by both operation and product. When sorted by both operation and product, there were few data points for analysis, and only those combinations with at least four data points were selected for comparing means by process or product. These results are shown in Table 2.

The overall ANOVA indicated a significant difference between the three operations in terms of the mean of log-transformed personal sampling concentrations ($F = 9.82$, $df = 2$, $p < 0.05$). The mean log (Concentration) for each operation and Tukey's analysis results are presented in Table 3. Since the confidence interval does not contain the value of 0 for the comparison of sieving operations to both grinding and blending operations, it is determined that the mean exposure during sieving is indeed greater than the mean exposure in grinding and blend-

ing. The confidence interval for the comparison of blending and grinding operations does contain the value of 0, thus we may conclude that these means are not significantly different.²⁶

Area concentration data are presented in Table 4, along with breathing zone concentrations from personal sampling. Results are reported by operation and product being processed. Area concentrations were determined by averaging source-sampling results, which will be presented in another publication. Personal samples were, generally, much greater than area concentrations.

DISCUSSION

No assessment of ventilatory capacity or acute symptoms was performed in the current study. Exposure measurements (Table 5) are comparable to those in the literature. If workers are exposed to concentration levels reported in this study, without the use of respiratory protective equipment, one may reasonably anticipate similar health outcomes to those reported in the literature, but the specific nature of the dust may play an important role in the health effects observed.

Although there are no directly appropriate occupational exposure limits that may be used for comparison, we selected the Threshold Limit Value (TLV) for particulates not otherwise classified (PNOC) of 10 mg/m³ for inhalable particles. Neglecting the respiratory protection used, five out of eight of the worker time-weighted averages exceeded the TLV. It should be noted that the TLV is based on the inhalable fraction and in this study total suspended particulate was measured; additionally, the TLV is applicable for dusts that are insoluble or poorly soluble, and have low toxicity, which may have limited protective ability in this case due to the irritant nature of certain dusts (e.g., jalapeno peppers, aloe vera).²⁷

The ventilation measurements were generally consistent among rooms over time. This ventilation design was not effective in properly clearing the 180 m³ processing rooms of contaminant. Additionally, the air cleaner filters clogged easily resulting in the need for frequent maintenance.

TABLE 1. Personal Dust Concentrations (mg/m³) by Operation and Material Processed

Worker	Day	Room	Period	Operation	Material Processed	Respiratory Protection Used	Concentration (mg/m ³)	Sampling Time (hours)	8-Hour TWA
1	1	2	1	Grinding	Vanilla	Nuisance Dust Mask/N-95 ^A	1.41	2.00	
1	1	2	2	Grinding	Vanilla	Nuisance Dust Mask/N-95	5.80	2.02	3.08
1	1	2	3	Grinding	Vanilla	Nuisance Dust Mask/N-95	2.63	1.82	
1	1	2	4	Grinding	Vanilla	Nuisance Dust Mask/N-95	2.46	2.12	
1	2	2	1	Sieving	Coconut	Nuisance Dust Mask/N-95	2.36	1.77	
1	2	2	2	Sieving	Spinach	Nuisance Dust Mask/N-95	29.8	1.78	32.5 ^C
1	2	2	3	Sieving	Spinach	Nuisance Dust Mask/N-95	..B	..B	
1	2	2	4	Sieving	Strawberry	Nuisance Dust Mask/N-95	62.8	1.92	
2	1	3	1	Sieving	Cilantro	Nuisance Dust Mask/N-95	92.6	1.83	
2	1	3	2	Sieving	Basil	Nuisance Dust Mask/N-95	49.4	2.07	42.9
2	1	3	3	Sieving	Basil	Nuisance Dust Mask/N-95	10.5	1.82	
2	1	3	4	Sieving	Basil	Nuisance Dust Mask/N-95	21.3	2.10	
2	2	3	1	Blending	Jalapeno	Full Face Respirator	2.13	1.72	
2	2	3	2	Blending	Jalapeno	Full Face Respirator	7.63	2.15	3.73
2	2	3	3	Blending	Jalapeno	Full Face Respirator	2.25	1.83	
2	2	3	4	Blending	Jalapeno	Full Face Respirator	2.32	2.05	
3	1	3	1	Sieving	Cilantro	Nuisance Dust Mask/N-95	97.1	1.80	
3	1	3	2	Sieving	Basil	Nuisance Dust Mask/N-95	1.64	2.20	59.8
3	1	3	3	Sieving	Basil	Nuisance Dust Mask/N-95	42.9	1.68	
3	1	3	4	Sieving	Basil	Nuisance Dust Mask/N-95	103	2.08	
3	2	3	1	Blending	Jalapeno	Full Face Respirator	0.33	1.53	
3	2	3	2	Blending	Jalapeno	Full Face Respirator	..B	..B	4.20 ^C
3	2	3	3	Blending	Jalapeno	Full Face Respirator	4.45	1.83	
3	2	3	4	Blending	Jalapeno	Full Face Respirator	6.89	2.03	
4	1	4	1	Grinding/ Blending	Aloe	N-95	63.2	1.80	
4	1	4	2	Blending	Aloe	N-95	89.2	1.95	42.4
4	1	4	3	Cleaning/ Set-up	Aloe/ Raspberry	N-95	2.47	1.72	
4	1	4	4	Grinding/ Sieving	Raspberry	Nuisance Dust Mask/N-95	13.4	2.07	
5	1	4	1	Grinding/ Blending	Aloe	N-95	47.4	1.93	
5	1	4	2	Blending	Aloe	N-95	13.6	2.10	25.6 ^C
5	1	4	3	Cleaning/ Set-up	Aloe/ Raspberry	N-95	..B	..B	
5	1	4	4	Grinding/ Sieving	Raspberry	Nuisance Dust Mask/N-95	17.4	2.02	

^AWorkers used Nuisance Dust Mask and N-95 Respirator interchangeably.

^BPump failure.

^CAssumes concentration during the unsampled time is equal to the average concentration measured during the sampled time.

These data show that exposure varied with the operation being performed and the product being processed. This is consistent with intuitive thoughts on factors affecting exposure based on observation. Some operations seemed

to generate more dust, and some products being processed seemed to generate more dust than others.

Grinding/mixing aloe vera had the highest geometric mean exposure, followed by sieving

TABLE 2. Descriptive Analysis of Personal Sampling (mg/m³)

	N	AM	GM (GSD)	Concentration Range
All Operations, All Products	29	27.6	10.6 (4.83)	0.33-103
Sieving, Basil	6	38.1	20.8 (4.33)	1.64-103
Sieving, All Products	13	41.8	23.7 (3.81)	1.64-103
Grinding/Mixing Aloe vera	4	53.3	43.7 (2.27)	13.6-89.2
Grinding, Vanilla	4	3.08	2.70 (1.79)	1.41-5.80
Blending, Jalapenos	7	3.94	2.83 (2.90)	0.33-7.63

AM is arithmetic mean.
GM is geometric mean.
GSD is geometric standard deviation.

TABLE 3. The 95% Confidence Interval for the Difference Between Each Pair of Means of Personal Sampling Concentrations by Operation

Operation	N	Mean of log (Conc)	95% CI
Sieving	13	1.37	0.20-1.68
Grinding	4	0.43	
Sieving	13	1.37	0.32-1.53
Blending	7	0.45	
Blending	7	0.45	-0.79-0.83
Grinding	4	0.43	

all products and sieving basil. The operations resulting in the lowest geometric mean concentrations were grinding vanilla and blending jalapenos. Although blending generated the least amount of airborne dust, it is not without consequence to the worker. Our observations indicated that even relatively low amounts of airborne jalapeno dust is irritating to the skin, eyes, nose, and throat; workers selected higher levels of personal protective equipment when processing jalapenos.

Sieving was found to result in significantly higher dust concentrations than grinding or blending. These data must be qualified as to the possible confounding effect where a particular operation was only observed processing one type of product. Blending samples were taken while processing jalapenos and grinding samples were taken while processing vanilla, thus concentrations in Table 3 may not simply be a function of operation, but of product as well. Seven personal samples do not easily fit into any category of processing, as several processing variables were influencing exposure at the same time, thus making it difficult to reasonably integrate these data points into the overall analysis. During these sampling periods, workers performed sieving, grinding, blending, setting-up equipment, and cleaning equipment, with two different products being processed. To incorporate these data into the overall analy-

TABLE 4. Area Concentrations and Personal Exposure Measurements (mg/m³) in Rooms 2 and 3

Day	Room	Period	Operation	Product	Average Area Concentration	Breathing Zone Concentration(s) ^A
1	2	1	Grinding	Vanilla	-- ^B	1.41
		2	Grinding	Vanilla	3.03	5.80
		3	Grinding	Vanilla	2.51	2.63
		4	Grinding	Vanilla	4.77	2.46
1	3	1	Sieving	Cilantro	7.79	92.6, 97.1
		2	Sieving	Basil	2.29	49.4, 1.64
		3	Sieving	Basil	3.03	10.5, 42.9
		4	Sieving	Basil	5.99	21.3, 103
2	2	1	Sieving	Coconut	1.27	2.36
		2	Sieving	Spinach	1.08	29.8
		3	Sieving	Spinach	0.63	-- ^B
		4	Sieving	Strawberry	9.86	62.8
2	3	1	Blending	Jalapenos	1.50	0.33, 2.13
		2	Blending	Jalapenos	0.98	-- ^B , 7.63
		3	Blending	Jalapenos	1.43	4.45, 2.25
		4	Blending	Jalapenos	1.79	6.89, 2.32

^AEach value represents the breathing zone concentration of one worker, as some operations involved more than one worker per room.

^BMissing data.

TABLE 5. Food Processing Exposures Reported in the Literature and Present Study

Study	Product Processed	Sampling Strategy	N	Total Dust (mg/m ³)		N	Respirable Dust (mg/m ³)	
				Mean	Range		Mean	Range
Zuskin et al., 1988	Spices	Area Sampling (8-hr TWA)	Not reported	2.9	0.5-10.1			
Zuskin et al., 2000	Coffee	Area Sampling (8-hr TWA)	≥ 10 ^A	10.2	1.4-62.3	≥ 10 ^A	0.33	0.1-1.9
	Tea		≥ 10 ^A	8.1	2.9-13.6	≥ 10 ^A	1.13	0.2-2.9
	Spices		≥ 10 ^A	2.9	0.5-10.1	≥ 10 ^A	1.0	0.1-2.1
	Confectionery		≥ 10 ^A	31.2	4.1-95.5	≥ 10 ^A	2.0	0.3-5.4
	Dried fruits		≥ 10 ^A	16.8	8.3-24.9	≥ 10 ^A	3.2	1.0-6.4
	Cocoa		≥ 10 ^A	9.1	2.0-16.1	≥ 10 ^A	2.1	0.9-3.5
	Flour		≥ 10 ^A	12.3	2.4-17.1	≥ 10 ^A	1.9	0.5-2.7
Zuskin et al., 1989	Animal food	Area Sampling (8-hr TWA)	Not reported		0.77-10.6			0.34-2.94
	Product transfer	(task-based sampling)	Not reported	35.59			2.07	
Zock et al., 1995	Potatoes	Area Sampling (≥ 6-hr TWA)	81	2.15 ^B	< 0.4-44.2 ^B	78	0.18	< 0.06-1.58
		Personal Sampling (≥ 6-hr TWA) (task-based sampling)	211	3.3 ^B	< 0.4-153 ^B			
Lacey et al., 2005	Food processing	Area Sampling	61	3.21	0.30-14.7			
		Personal Sampling (8-hr TWA)	8 ^C	26.8 ^C	3.08-59.8 ^C			
		Personal Sampling (task-based sampling)	29	27.6	0.33-103			

^ATotal and respirable dust were collected by the same apparatus, and it was only reported that at least 10 samples were collected for each industry.

^BInhalable dust.

^CAs described in this paper, 8-hr TWA concentrations were calculated from the partial period task-based samples.

sis would cloud the relationship between operation and product, so the analysis was limited to work that was more consistently performed over a given sampling period.

Measured personal exposures for total suspended particulate were often much greater than measured area concentrations. These data are in good agreement with area concentrations for food processing facilities reported in the literature. Table 5 shows food processing exposure data reported in the literature, along with the results of the current study. Measuring area concentrations alone in this environment is not a sufficient means of estimating personal exposures, as personal exposures were approximately 10 times higher than area sampling results. The discrepancy between the measured concentrations from area samplers versus personal samplers is likely due to work practices and positioning of the workers' breathing zone for some operations. For example, during sieving operations, we observed workers leaning over the sieve surface as they worked the product through the screen, their head and face

clearly in the pathway of a cloud of dust from the sieve surface. During grinding operations, a worker would position himself so that he was above the grinder hopper, with his breathing zone very close to the dust generation source. The results of this study indicate that area samplers do not adequately capture such exposures very near the source.

Table 1 notes the respiratory protective equipment used by workers for operations with the various products. Workers used nuisance dust masks and N-95 respirators interchangeably for nearly all products. The exceptions were the processing of aloe vera and jalapenos. Aloe vera dust, as noted by the study authors, provoked a strong cough response, and this response was adequately controlled by the N-95 respirator. Jalapeno processing was very irritating to the eyes and nose, making use of a full face respirator preferable. Full face respirators carry an Assigned Protection Factor of 50, and the Threshold Limit Value for particulates not otherwise classified is 10 mg/m³ (eight-hour TWA). The product of these two values reflects

the Maximum Use Concentration, in this case 500 mg/m³. Since TWA values for personal sampling while processing jalapenos never exceeded 6 mg/m³, the protection afforded by the full face respirator is compliant with NIOSH recommendations.²⁸ A quantitative evaluation of respirator effectiveness was beyond the scope of this study. The authors' observations reflect that workers selected levels of respiratory protection based on their experience with the processing of specific foods.

No attempt was made for respirable sampling. While the smaller size fraction of the dust may indeed have significant health consequences, total dust is significant in this setting due to the irritating nature of the contaminants. Zuskin's study of spice factory workers estimated that over 96% of the total dust present was greater than 9.5 μm. This is consistent with Zuskin's study of dried food- and animal food-processing workers, where particles in the respirable fraction represent about one-third of the particles present. Despite the generally large particle size in these studies, health effects were present, as noted earlier.

The study was planned for sampling over two days. There was not enough repetition in both operation and product to delineate exposure contribution to one or the other. Though there were few samples representative of a particular operation performed with a particular product, an attempt was made to analyze the difference between these groups. Several operation/product classes were observed only once, obviously eliminating them from any type of operation/product comparison. Some operation/product classes were observed four or more times, so an attempt was made to compare these classes. Statistical significance was found in the comparison of these classes, even with only four observations, so the authors reported these results.

CONCLUSIONS

Partial period personal dust exposures for specified tasks ranged from 0.33-103 mg/m³. As stated earlier, there are no directly appropriate occupational exposure limits that may be used for comparison. Recognizing the limitations of the TLV in this particular exposure sce-

nario, five out of eight of the worker time-weighted average concentrations exceeded 10 mg/m³.

Sieving resulted in significantly higher exposure than grinding and blending. There were too few observations for other processes to determine significant differences in exposure.

Measured personal exposures for total suspended particulate were often much greater than measured area concentrations. Measuring area concentrations alone in this environment is not a sufficient method of estimating personal exposures due to work practices for some operations.

RECOMMENDATIONS

There were a limited number of concentration estimates for each operation/product, and this study involves only one facility, so it may be inappropriate to generalize the results to similar facilities. However, certain basic recommendations for dust control may be suggested. Future efforts of control should be aimed at local exhaust ventilation at the points of dust generation. In the interim, workers must continue to use plastic sheeting to shroud significant dust generation points as effectively as possible. Additionally, workers must carefully set-up processing equipment directly under the overhead hood in order to take full advantage of the current ventilation configuration.

Research into possible health effects, both irritating and allergenic, from exposure to food products is needed, with the goal of establishing appropriate exposure guidelines and standards.

Future studies should be organized to ensure a more appropriate number of operation/product based samples to better understand the relationship to exposure.

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RECEIVED: 07/19/2005

REVISED: 10/28/2005

ACCEPTED: 01/05/2006