In-Depth Survey Report

Process Evaluation at Kraft Atlantic, Inc.

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Abstract

Researchers from the Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH) conducted an engineering control evaluation at Kraft Atlantic, a producer that manufactures food flavorings and gelatin, to evaluate their manufacturing processes regarding potential exposure to diacetyl and other food-related flavorings; document the effectiveness of existing exposure control techniques; and identify areas where engineering controls may need to be developed or improved. A separate NIOSH team of industrial hygienists conducted an exposure assessment at this facility. Personal sampling and ventilation assessment were conducted to evaluate potential risks during various tasks monitored during the engineering control survey.

Diacetyl exposure is of concern at the Boston, Massachusetts, Kraft Foods facility, with all eight (four personal and four area) positive samples for diacetyl being well above the proposed NIOSH recommended exposure limit of 0.02 mg/m^3 for eight hours, and the NIOSH proposed REL of 0.09 mg/m^3 for short term exposure limit. Several other chemicals that may be of concern were detected at levels below 1 mg/m^3. All the chemicals sampled for, with the exception of 2,3 pentanedione, 2,3 hexanedione, and 2,3 heptanedione, are considered Flavoring and Extract Manufacturers Association (FEMA) high priority chemicals for consideration as substances that may pose respiratory hazards in flavor manufacturing workplaces. However, for those chemicals that have Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL) (Table 4), all samples were below the PELs. The chemicals 2,3 pentanedione, 2,3 hexanedione, and 2,3 heptanedione, are structurally similar chemicals to diacetyl and are increasingly being used as replacements for diacetyl in flavor formulations. There is some concern that these chemicals may exhibit similar or related toxicological properties as diacetyl. Research is currently being conducted to ascertain this. None of the area and personal samples contained detectable amounts of these chemicals. Acetaldehyde was detected at Kraft Atlantic, but well below occupational exposure limits. Acetaldehyde is considered by NIOSH to be a potential carcinogen. Therefore, exposures to this compound should be minimized to the greatest extent possible.

Evaluations were based on a variety of tests including air velocity measurements, real-time monitoring, and smoke release observations. Most of the local exhaust ventilation (LEV) systems at Kraft consisted of flexible ducts connected to plastic hoods. The experiments showed that generally there is good capture by all the LEV hoods. All hoods performed well under all test conditions.

General and task-specific recommendations are included to control and reduce both diacetyl and dust exposures.

General Recommendations

1. Use engineering controls such as LEV and work practices aimed at reducing dust and chemical vapor generation are primary preventive steps for reduction of exposure.

2. Clean spills immediately. Shovel large dry spills carefully into a waste bag. Workers might need to wear respiratory protection when cleaning spills.

3. Do not clean a dry spill with a brush or compressed air. Vacuum or wet cleaning processes are recommended.

4. Enclose the mixer as much as possible by using lids and, if possible, provide seals on the lids and other access points.

5. Where possible, locate the working area away from doors, windows, and walkways to prevent drafts from interfering with the ventilation and the spreading of dusts.

Task-specific Recommendations

1. The use of ventilation at the barrel opening has been recommended for capture of vapors during transfer of chemicals. For drum filling, the Industrial Ventilation control guidance recommends the use of an annular exhaust hood around the interface between the drum and feed pipe (at the bung hole). The recommended airflow is a minimum of 100 feet per minute (fpm) across the drum cap/bung hole. For flammable liquids, suitable fans and equipment as well as appropriate grounding schemes should be used to prevent the buildup and discharge of static electricity.

2. Since weighing and pouring are often performed on a bench-top workstation, the addition of a ventilated booth for the bench weighing area is recommended to control dust and vapor exposure.

3. Bag dumping and disposal during the tumbler filling operation can potentially create a significant amount of dust. Bag opening, dumping, and disposal of empty bags should be done in a ventilated enclosure. A ventilated bag dump station, consisting of a hopper outfitted with an exhaust ventilation system to pull dusts away from workers as they open, dump, and discard bags of powdered material, is frequently used in bag dumping operations and should be considered for this facility.

Introduction

Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of engineering control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document, evaluate, and develop effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background for this Study

On September 1st – 2nd, 2009, researchers from NIOSH visited the Kraft Atlantic Gelatin Plant, a Kraft Foods facility in Woburn, Massachusetts, to conduct an exposure and engineering control assessment of the facility for flavoring related compounds. This report presents the results of the exposure and engineering control assessment conducted during that visit. NIOSH is engaged in occupational safety and health research on diacetyl and other food flavoring chemicals. As part of this research agenda, NIOSH is conducting an exposure assessment and engineering control study in several food production facilities where flavorings are used.

Occupational exposures in the flavoring and food production industry have been associated with respiratory disease, such as bronchiolitis obliterans. Bronchiolitis obliterans is a rare and life-threatening form of obstructive lung disease characterized by significant permanent decreases in pulmonary function. It can progress to the need for a double lung transplant, or to death [California Occupational Safety and Health Administration 2009]. While the microwave popcorn industry has received the most attention both in the media and in the scientific community, the first occurrences of bronchiolitis obliterans in food production were observed in 1985 at a facility which made various flavorings for the baked goods industry [NIOSH 1985]. Severe bronchiolitis obliterans was observed in two men (both never-smokers and in their 20's) who held similar mixing jobs and blended corn starch and flour with various flavorings. During a NIOSH Health Hazard Evaluation (HHE), other workers who had held the same mixing job were evaluated for respiratory symptoms, and two additional cases were found (for a total of four out of the six mixers). A review of common ingredients listed diacetyl among other flavoring chemicals. A recent retrospective epidemiologic study found cases of bronchiolitis obliterans in workers who were employed in a chemical plant with exposures to diacetyl, acetoin, acetic acid, and acetaldehyde [van Rooy 2007].

Diacetyl is one of the main components in butter flavoring that gives it a buttery taste and has been identified as a prominent volatile organic compound (VOC) in air samples from microwave popcorn plants [Parmet and Von Essen 2002; Kanwal and Martin 2003; Akpinar-Elci et al. 2004; Kanwal et al. 2004; Kanwal et al. 2006]. It has several synonyms including 2,3-butanedione; biacetyl; 2,3-butadione; 2,3-diketobutane; dimethyl glycol; dimethyl diketone; dimethylglyoxal; and dioxobutane [National Toxicology Program 1994]. Diacetyl is used as a synthetic flavoring agent and aroma carrier in margarine, caramel, vinegar, dairy products, and is also naturally found in some foods. Flavor formulations are then sold to downstream users for the production of flavored food products. Flavored food production involves the manufacturing of food and beverage products containing added flavorings to enhance or modify the taste of the product. Examples of flavored food products include cake mixes, flour, beer, wine, margarines and soft spreads, cheese, candy, bakery products, crackers, cookies, ice cream, and frozen foods. The addition of concentrated flavorings, including diacetyl, is a cost effective way to impart the desired properties to manufactured food items.

Initial research concerning occupational exposure to flavorings focused on workers who directly produce flavorings or use them in the microwave popcorn industry. However, the employment figures for the food production industry suggest that a substantial number of workers have potential exposure to diacetyl and similar flavoring agents. Small scale weighing and handling of ingredients are common tasks in flavoring production, bakeries, dairy production, and snack food manufacturing. Weighing both dry and wet food ingredients can lead to worker exposure primarily through the scooping, pouring, and dumping of these materials. Ingredient mixing is also a source of potential exposure, depending upon the work practices employed when dumping dry ingredients (which may produce visible airborne dust), pouring wet ingredients into the mixer, and opening and closing the mixer lid.

NIOSH is continuing diacetyl-related research through engineering control assessments, toxicological studies, respiratory protective equipment program evaluations, medical surveillance, and exposure assessments. NIOSH is evaluating occupational exposure to diacetyl in industries such as dairy/cheese processing, chocolate manufacturing, baked goods, frozen food, and other identified manufacturing sectors with potential for diacetyl exposure. However, the potential for both exposure and disease in the flavored food production industry still remains largely unstudied. There are few data documenting occupational exposures in flavoring and food manufacturing. With the lack of occupational exposure limits for a majority of the flavoring chemicals used in food production, the development of exposure control guidance is critical to help reduce the risk of flavoring-related obstructive lung disease. The Flavoring and Extract Manufacturing Association (FEMA) reports that of the more than 1,000 chemicals considered to be potential respiratory irritants or hazards, only 46 have established Permissible Exposure Limits (PELs) [FEMA 2004]. As a safe level for diacetyl is currently unknown, protecting workers from flavorings-related lung disease requires limiting exposure through use of the hierarchy of controls. One representation of this hierarchy can be summarized as follows:

- Elimination
- Substitution
- Engineering controls
- Administrative controls
- Personal protective equipment (PPE) [NIOSH 2003; Kreiss 2007].

The idea behind this hierarchy is that the control methods at the top of the list are potentially more effective, protective, and economical (in the long run) than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced. Additionally, new diacetyl substitutes, such as 2,3-pentanedione, are being used in production with little or no toxicological information. Until more is known, diacetyl substitutes should not be assumed safe.

Plant Description

Kraft Foods is the largest food company in the U.S., and the second largest in the world. Kraft Atlantic Gelatin Plant in Woburn, MA, is a private company categorized under Gelatin Dessert Preparations. The facility employs approximately 100-250 people and manufactures food flavorings and gelatin.

Description of Processes and Controls

The Kraft Atlantic Gelatin Plant manufactures flavors and gelatin. During the sampling, three liquid flavors were made: artificial ranch, Swiss cheese and natural butter. Diacetyl was an ingredient in all three flavors. During the manufacturing process, all workers were wearing full face respirators with organic vapor and particle combination filters when handling diacetyl. Full shift area and personal air samples were collected in selected production areas for the following compounds: ketones (diacetyl, acetoin, 2,3 pentanedione, 2,3 hexanedione, 2,3 heptanedione), acids (butyric, acetic and propionic), and aldehydes (2-furaldehyde, acetaldehyde, benzaldehyde, isovaleraldehyde, and propionaldehyde).

Bulk mixing in Ribbon Blenders

Bulk mixing was evaluated because the process used various powder mixes and often utilized bench-top weighing. Two ribbon blenders were evaluated. The two blenders were located in Towers 36 and 54. A ribbon mixer or ribbon blender is a type of impeller-driven industrial mixer (as is a paddle mixer). The ribbon mixer features a U-shaped horizontal trough, with an impeller shaft running the length of the trough and a long ribbon blade mounted on the shaft. As the shaft rotates, the ribbon blade aerates the mixture, forming a fluidized bed. Ribbon mixers provide gentle handling with minimal particle degradation.

Ribbon mixers are widely used in the food industry and are usually constructed so that the powder near the outside of the container is moved in one direction and in the middle it is moved in the opposite direction. Loading and cleaning of a ribbon blender are usually done from the top of the trough. Ribbon blenders are often used when blending materials of similar shape, size, and bulk density, like powders or granular ingredients.

In these mixers, a powdered starch or other carbohydrate is combined with a liquid or paste flavoring agent. Blending ingredients is a source of potential exposures, depending upon the work practices employed when dumping bags of powders (which may produce visible airborne dust), pouring ingredients into the blender, discharging of the blender, and packaging the blended material. When the blending is completed, the powder product is discharged into a bulk tote and finally packaged into smaller containers.

Each stationary blender is mounted on a stand and is outfitted with local exhaust ventilation (LEV) on top of the blender where bags of ingredients and flavors are dumped into the blender (see Figure 1).

Emulsion Room

Various processes take place in the emulsion room. The emulsion room consisted of multiple liquid vats; only mixing of liquids occurred in this area. Some of the mixing vessels were fixed, large scale vats and some were medium to small size vats on wheels. Movable flexible ducts attached to hoods were outfitted to the openings of the large mixing vats and the room was equipped with several other movable flexible ducts attached to hoods to accommodate LEV for those smaller mixing vessels (see Figure 2).

Mixing of actual flavorings did not occur in this room during the engineering control evaluation. Only ventilation measurements and qualitative smoke release observations were conducted in these hoods.

Laboratory Mixing Area

The laboratory mixing area serves as a small mixing room where the majority of the flavorings used throughout the processes are manufactured. It also serves as a quality control/assurance area to verify the quality of the products being manufactured during regular operations. This room was outfitted with three different means of LEV: 1) a canopy hood located above a small weight scale, 2) a laboratory fume hood, and 3) a movable flexible duct attached to a hood adjacent to the fume hood.

The canopy hood and the movable flexible duct with hood (see Figure 3) were both evaluated during this site visit. Mixing of actual flavorings did not occur in this room during the engineering control evaluation. Only ventilation measurements and qualitative smoke release observations were conducted in these two hoods.

Packaging Lines

The evaluated product packaging stations were located below the ribbon blenders in the powder production room. Each packaging line is outfitted with an LEV system on the top where the finished product is discharged (see Figure 4). This is typically a two person operation. One worker filled the bags with the powder product while another worker applied labels, taped the boxes, and moved boxes to a pallet. A typical batch consisted of 20 boxes per pallet at approximately 52 pounds (lbs) per box.

An inflatable bladder system was also evaluated during this site visit. An inflatable seal was used to create a dust tight seal on the discharge outlet of an industrial blender (see Figure 5). The outlet spout of a large-scale blender was fitted with an inflatable seal that prevents dust from escaping during the bag filling process. The seal inflates automatically during the product transfer from the blender to the packaging bag (providing the seal) and deflates once the transfer is completed to allow removal of the packaging bag. These systems are available on many commercially available bulk bag filling systems.

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended OELs when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at or below the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time weighted average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended Short Term Exposure Limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) PELs [CFR 2003] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH REL's are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the TLVs® recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH 2010]. ACGIH TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace environmental exposure levels

(WEELs) are recommended OELs developed by the American Industrial Hygiene Association (AIHA), another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation) (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Exposure Criteria

Dust

For respirable dust, the OSHA PEL is 5 milligrams per cubic meter (mg/m^3). There is no NIOSH recommended exposure limit (REL) for respirable dust. The ACGIH® TLV for respirable dust is 3 mg/m^3.

Diacetyl

Exposure to diacetyl can occur by inhalation or skin contact [Acetoin and Diacetyl 2008]. Although listed as a high priority chemical by FEMA, there is no OSHA PEL or NIOSH REL for diacetyl or 2,3-pentanedione [Martyny et al. 2008]. Currently, work is being conducted by NIOSH to propose a draft NIOSH TWA and STEL REL of 5 ppb and 25 ppb, respectively [NIOSH forthcoming].

Methodology

Exposure Assessment

Exposure assessment sampling was conducted during the manufacture of three liquid flavors: artificial ranch, Swiss cheese and natural butter. Diacetyl was an ingredient in all three flavors. During the manufacturing process, all workers were wearing full face respirators with organic vapor and particle combination cartridges when handling diacetyl. Full shift area and personal air samples were collected in selected production areas for the following compounds: ketones (diacetyl, acetoin, 2,3 pentanedione, 2,3 hexanedione, 2,3 heptanedione), acids (butyric, acetic and propionic), and aldehydes (2-furaldehyde, acetaldehyde, benzaldehyde, isovaleraldehyde, and propionaldehyde). The sampling methods used and the limits of detection (LOD) are provided in Table 1. The dates and locations where the air sampling occurred are presented in Tables 2 and 3. Sample results were reported in micrograms (µg) of analyte per sample and air concentrations are presented as µg/m^3. Results can be converted to PPM concentrations by using Equation 1.

Equation 1:

$$C_{ppm} = \frac{C_{\mathrm{mg/m^3}} \times 24.45}{MW}$$

Where,

$C_{mg/m}{}^3$ = concentration, mg/m^3

MW = molecular weight of compound, [Lide 2008]

Local Exhaust Ventilation (LEV) Characterization

A variety of methods were used to evaluate the LEV system. Initial characterization included measuring exhaust flow rates, face velocity and slot velocity for each hood. The capture velocity of the hood is defined as the velocity created by the hood at the point of contaminant generation (Goodfellow and Tahti, 2001). For enclosing hoods, the capture velocity is the air velocity measured at the face of the hood. To provide uniform velocity across the face of a hood, exhaust slots are typically used. In addition to the face and slot velocity measurements, a smoke tracer is used to confirm the direction of the airflow and effect of secondary airflows on hood performance. Secondary airflows can be attributed to natural plant draft currents, auxiliary fans to aid with cooling, or simply the effect of moving objects in the proximity of the hoods.

Hood Velocity Measurements

Equipment

A TSI Velocicalc Plus Model 8388 thermal anemometer (TSI Incorporated, St. Paul, MN) was used to measure air speeds at the face of each hood.

Procedure

Face velocity tests were performed by dividing the opening of the hood into equal area grids of approximately 0.09 m^2 (1 ft^2) and averaging the velocity measurements at the center point of each grid over a period of 5 seconds. Each measurement was made with the anemometer probe held perpendicular to the air flow direction at each center point. Air velocities were also measured across each slot hood to evaluate the air flow distribution across these LEV hoods. Slot velocities were logged approximately every 0.25 meters (10 inches) across the length of the slot.

Hood Qualitative Smoke Tracer Test

Equipment
A Wizard Stick (Zero Toys, Inc., Concord, MA) smoke generator was used to visualize air movement inside and around the periphery of the hood.

Procedure
Smoke was released around the periphery of each LEV hood and in the interior of the hood to qualitatively evaluate the capture efficiency and determine areas of concern. If the smoke was captured quickly and directly by the hood, it was a good indication of acceptable control design and performance. At the source of operation, if the smoke was slow to be captured when released at the source, or took a circuitous route to the air intake for the exhaust, the hood design was considered marginal at that point. Smoke release observations were made in the interior of the enclosing hoods to look for reverse flow and at the edges of the hood to identify escape. Also, the adverse effect of cross drafts on the hood was evaluated by releasing smoke near the periphery of the hood face.

Real Time Exposure Monitoring Tests

Dust
Equipment
A HazDust IV hand-held aerosol photometer (Environmental Devices Corporation, Plaistow, NH) measured dust concentration. It operates on the principle of near-forward light scattering. It provides real-time measures of airborne dust particle concentration and displays the result in mg/m^3. The HazDust IV has an internal air sampling pump that is controlled by a microprocessor. The instrument has a detached sensor that can be positioned near the worker's breathing zone. OSHA-defined inhalable, thoracic, and respirable interchangeable sampling heads can also be added to the sensor. In past studies, the thoracic sampling head was used to collect dust measurements during the engineering control surveys. Therefore, for this study, the HazDust IV unit was outfitted with a thoracic sampling inlet. An in-line 37 millimeter (mm) filter cassette was simultaneously collected and analyzed with gravimetric methods. The HazDust IV can detect particle sizes from 0.1 to 100 micrometers (µm) and dust concentrations from 0.01 to 200 mg/m^3, respectively. The HazDust IV is calibrated with the NIOSH Method 0600 using Arizona Road Dust; it does not differentiate between types of dust (e.g., cinnamon and flour) and may respond differently to dusts with optical properties different from Arizona Road Dust. As this may cause

some uncertainties in the actual dust concentrations, reported concentrations should be taken as a relative measure.

Procedure

The HazDust IV instrument was spanned and programmed according to manufacturer's instructions each sampling day. Verbal consent was obtained from each employee prior to participating in the sampling program. The HazDust IV was placed on the worker during the various operations (mixing, coating, and syrup manufacturing) to measure dust concentrations. The sampling head of the HazDust IV was positioned near the worker's breathing zone. The HazDust IV recorded data in ten-second intervals. Data from the instrument were downloaded to a computer and analyzed using Microsoft Excel.

Volatile Organic Compounds (VOC)

Equipment

A MiniRAE 2000 (RAE Systems Inc., San Jose, CA) photo-ionization detector (PID) was used to measure VOC concentrations in parallel with the HazDust IV. The PID is calibrated using isobutylene; it does not differentiate between types of VOC's and may respond differently to vapors with optical properties different from isobutylene. As this may cause some uncertainties in the actual VOC concentrations, reported concentrations should be taken as a relative measure.

Procedure

The PID was placed on the worker near his/her breathing zone to evaluate engineering control effectiveness while performing activities around the two blenders (Towers 36 and 54), in the emulsion room, in the laboratory mix area, and Towers 36 and 54 packaging lines.

Results

Exposure Assessment

A total of eight area samples and six personal samples were collected. The results for the area air samples are presented in Table 2, and the results of the personal air samples are presented in Table 3. Diacetyl was detected in four of the area samples, and in four of the personal air samples. The highest area and personal samples were 6.9 mg/m^3 and 2.1 mg/m^3, respectively. Results from the real time evaluation and LEV characterization are described below.

HazDust IV Results

Mean dust concentrations are in general below the OSHA PEL of 5 mg/m^3 for respirable dust for the ribbon blenders. However, there are some peak concentrations, for both blenders, above 25 mg/m^3 (temporary). These peaks might be, in part, because most of the cutting of boxes and bags prior to loading the blenders was done outside of the control area of the LEV.

Another source of dust release occurred when empty plastic bags were pushed into used cardboard boxes for disposal. Some dust was observed to leak from below the mixing area when the empty boxes were dumped onto a pallet for disposal. Additionally, some dust escaped the control area of the LEV when bags were dropped onto the surface of the blender and pressed to remove product from the bags.

Dust release was minimal when filling boxes; however, when scooping from one box to another to match the desired quantities, dust release was dramatically higher. Mean dust concentrations on the two packaging lines (Towers 36 and 54) were recorded at 1.76 and 1.86 mg/m^3, respectively, and did not exceed the OSHA PEL of 5 mg/m^3. Figure 1 shows a graph depicting the real time activities recorded with the HazDust IV.

PID Results

Results from the VOC's in the ribbon blenders indicate exposures ranging between non-detect (ND) and 6.1 ppm. Results from the VOC's indicate exposures ranging between 0 ppm and 1.7 ppm on the packaging area. However, due to the nature of the instruments used during this evaluation, it is impossible to determine if these concentrations are attributable to diacetyl or to any other organic vapor. Figure 2 shows a graph indicating the real time activities recorded with the PID.

LEV Measurements

Air velocity measurements conducted in Tower 36 blender indicate good exhaust velocities when measured at the face of the takeout opening and then decayed dramatically at the bag dump hood face. Air velocities at the face of the takeout average 415 feet per minute (fpm) and then decreased to 41 fpm at the face of the blender. Table 6 shows the results of the hood characterization for Tower 36.

Air velocity measurements conducted in Tower 54 blender indicate a poor air distribution on the slot section of the hood. The average slot velocity was 389 fpm but these measurements ranged from 20 fpm to 975 fpm within the slot opening. The average hood face velocity was calculated at 117 fpm at the face of the blender. Table 7 shows the results of the hood characterization for Tower 54.

Four movable hoods with flexible ducts were evaluated in the emulsion room. Results of the measurements and calculations for these four hoods are presented in Table 8. All hoods showed good capture velocities. Smoke observations indicate good capture within less than 5-inches on each side of the hood and less than 1-foot below the hood. Anything out of this capture area presented marginal to poor capture with these systems.

Two hoods were evaluated in the laboratory mixing area. The average face velocity for the flexible hood was recorded to be 451 fpm. The average face velocity for the canopy hood located above the weight scale was 225 fpm. Similar to the movable hoods located in the emulsion area, the flexible hood in the laboratory also indicated good capture within less than 5-inches on each side of the hood and less than 1-foot below the hood. Anything out of this capture area presented marginal to poor capture on these systems.

The discharge hoods in the packaging area generally had higher exhaust velocities at the hood face due to smaller opening areas compared with the upper bag dump hoods. They also showed better capture characteristics during smoke tracer tests. The hoods had adequate capture up to about 12-inches from the hood face.

Air velocity measurements conducted in these two packaging lines indicated good exhaust velocities. Air velocities at the face of the takeout averaged 1650 fpm and then decreased to 200 fpm around the hood enclosure.

Discussion

Diacetyl exposure does exist and is of concern at the Boston, Massachusetts Kraft Foods facility, with all eight (four personal and four area) positive samples for diacetyl being well above the proposed NIOSH REL of 0.02 mg/m^3 for eight hours, and the NIOSH proposed REL of 0.09 mg/m^3 for short-term exposure. Several other chemicals that may be of concern were detected at levels below 1 mg/m^3. All the chemicals sampled for, with the exception of 2,3 pentanedione, 2,3 hexanedione, and 2,3 heptanedione, are considered FEMA high priority chemicals for consideration as substances that may pose respiratory hazards in flavor manufacturing workplaces. However, for those chemicals that have an OSHA PEL (Table 10), all samples were below the PELs. The chemicals 2,3 pentanedione, 2,3 hexanedione, and 2,3 heptanedione, are structurally similar chemicals to diacetyl and are increasingly being used as replacements for diacetyl in flavor formulations. There is some concern that these chemicals may exhibit similar or related toxicological properties as diacetyl. Research is currently being conducted to ascertain this. None of the area and personal samples contained detectable amounts of these chemicals. Acetaldehyde was detected at Kraft Atlantic but well below occupational exposure limits. Acetaldehyde is considered by NIOSH to be a potential carcinogen. Therefore, exposures to this compound should be minimized to the greatest extent possible.

The blender bag dump hoods generally had high capture velocities at the face of the hoods overall. However, most of the blender bag dump openings are too large for a standard exhaust to work effectively. The blender openings range from 95-inches (Tower 36) to 81-inches (Tower 54) in length. Typically, the air velocity decayed about one order of magnitude at about 1-foot away (from about 400 fpm to 40 fpm, for example) to less than the resolution of the air velocity meter at 2-feet (about 10 fpm or less). These blenders should be re-designed to enclose the process as much as possible and promote an even flow throughout the face of the enclosure. The slot opening in the blender located in Tower 54 should be redesigned to provide an even flow across the length of the slot. Currently, this blender is provided with a right takeout LEV with no baffles on the slot opening which explains the high face velocities on the right section of the hood and very poor to marginal capture on the left side of the opening.

Using a ventilated enclosure around the ribbon blender opening should provide better capture during bag dumping activities. The ACGIH Industrial Ventilation Manual provides design guidance which may be applicable to this operation including design plates, VS-15-20, Toxic Material Bag Opening, and VS-50-10, Bin and Hopper Ventilation. In general, the primary design parameter from these plates is enclosing the top of the blender as much as possible and designing for a face velocity of 150-250 fpm. In addition to these design plates, there are several commercial vendors who provide ventilated bag dumping stations which may be effective.

Hoods on the Emulsion room presented good capture. However, these types of hoods require worker interaction to ensure proper positioning of these systems. Proper positioning of these hoods will strongly affect how well contaminants are captured. When working with highly hazardous material, the ACGIH Ventilation Design Manual recommends using an enclosing hood rather than a moveable capture hood such as the one described above (ACGIH 2010). A partially enclosing booth might provide better worker protection when compared to a flexible hood.

The packaging discharge hoods showed adequate capture based on the results of all tests performed. The real-time measurements showed low dust concentrations and moderate presence of VOC's. The key design parameters for these hoods are adequate air velocity and proximity to the discharge source.

In addition to monthly monitoring of the hood static pressure, the types of measurements which should be taken to ensure adequate system performance include smoke tube testing and hood slot/face velocity and possibly duct velocity measurements using a pitot tube or a hot wire anemometer. These tasks need to become part of a routine preventative maintenance schedule to check system performance.

Recommendations

Kraft Foods is encouraged to use good hygiene practices. Levels of diacetyl appear to be high during flavoring production, and it is recommended that workers continue to wear respiratory protection while working with diacetyl. Additionally, medical surveillance of workers potentially exposed to diacetyl should be practiced. Exposures to other flavoring compounds appear to be low; however, every attempt to minimize exposure should be made. Continued personal and area air monitoring are recommended.

Several recommendations are provided to reduce potential exposure to flavoring chemicals (including diacetyl) and further control flavoring exposures.

General Recommendations

1. Use of engineering controls such as LEV and work practices aimed at reducing dust and chemical vapor generation are primary preventive steps to reduce exposures.

2. Install hood static pressure gauges on each hood to provide important information on hood performance. Include the recording of hood static pressure and performance of hood airflow checks into the preventative maintenance schedule.

3. Provide worker training on proper techniques for using hoods such as clearing the bench of unnecessary chemicals/materials and as much as possible to reduce the restriction of airflow into the slot exhaust. Also, discuss proper use of booth type hoods such as proper orientation of worker and contaminants (i.e., worker should not be between contaminant and exhaust hood).

4. Consider using the booth for packaging of liquid flavorings and pouring of high priority chemicals until other controls are in place for these tasks. Ensure that the workers use proper techniques and that the control system allows for activation of the exhaust fan when performing these tasks.

5. Clean spills immediately. Workers should wear respiratory protection when cleaning spills.

6. Do not clean a dry spill with a brush or with compressed air. Vacuum or wet cleaning processes are recommended.

7. Enclose the mixer as much as possible and, if possible, provide seals on the lids and other access points.

8. Where possible, locate the working area away from doors, windows, and walkways to prevent drafts from interfering with the ventilation and the spreading of dusts.

9. Respirators should not be used as the primary means of controlling worker exposures to inhalation hazards for routine operations. Whenever possible, techniques discussed below are preferred. For cases when respiratory protection is required, instruct workers to use an N-95 filtering-facepiece or half-face respirators with particulate filters when performing tasks that generate dust, such as the bulk mixing, cinnamon smear, and bench-top weighing operations. When

respiratory protection is used, employers need to establish a written respiratory protection program that meets the requirements of the OSHA respiratory protection program [29 CFR 1910.134]. The program must be administered by a suitably trained program administrator and updated to reflect changes in workplace conditions that affect respirator use [29 CFR 1910.134]. The comprehensive respiratory protection program must include the following elements:

- Procedures for selecting respirators for use in the workplace;
- Medical evaluations of employees required to use respirators;
- Fit testing procedures for tight-fitting respirators;
- Procedures for proper use of respirators in routine and reasonably foreseeable emergency situations;
- Procedures and schedules for cleaning, disinfecting, storing, inspecting, repairing, discarding, and otherwise maintaining respirators;
- Procedures to ensure adequate air quality, quantity, and flow of breathing air for atmosphere-supplying respirators;
- Training of employees in the respiratory hazards to which they are potentially exposed during routine and emergency situations;
- Training of employees in the proper use of respirators, including putting on and removing them, any limitations on their use, and their maintenance; and
- Procedures for regularly evaluating the effectiveness of the program.

Task-specific Recommendations

1. Since weighing and pouring are often performed on a bench-top workstation, the addition of slotted backdraft ventilation for both the bench and the weighing area is recommended to control dust and chemical exposure. The British Health and Safety Executive (HSE) has developed a series of control approaches based on common processes in a variety of industries. One approach is similar to the one evaluated by NIOSH in flavoring facilities [NIOSH 2008a; NIOSH 2008b] and recommends a control velocity of 100–200 fpm [0.5–1 meter per second (m/s)] at the face of the work station when working with flour improvers (see Figure 6) [Health and Safety Executive 2003].

2. Bag dumping and disposal while loading the blenders creates a significant amount of dust. Ensure workers tip powdered sugar bags gently, never dump them. Workers should tip powdered sugar bags with the open end facing away. If feasible, use closed transfer processes to reduce worker exposure.

3. Technology used to control dusts during bag dumping has been in place for many years. Bag opening, dumping, and disposal should be

done in a ventilated enclosure [Heitbrink and McKinnery 1986]. The standard control, a ventilated bag dumping station, consists of a hopper outfitted with an exhaust ventilation system to pull dusts away from workers as they open and dump bags of powder materials (i.e., powdered sugar bags). The designs for these devices are available from several sources of good industrial ventilation guidance. HSE has developed a control approach for a ventilated station for emptying bags of solid materials. The control includes the specification of a face velocity of 200 fpm (1.0 m/s) and includes a waste bag collection chute (see Figure 7) [Health and Safety Executive 2003].

The American Conference of Governmental Industrial Hygienists (ACGIH®) Industrial Ventilation Manual also has two designs that are applicable to the control of powder materials during bag dumping. Design plate VS-15-20, Toxic Material Bag Opening, is similar in design to the HSE station described above but recommends a slightly higher control velocity of 250 fpm at the face of the station opening. In addition, design plate VS-50-10, Bin and Hopper Ventilation, requires a hood face velocity of 150 fpm. In general, higher velocities may be needed to adequately capture dusts in a plant environment. Air velocities around 200 fpm into the hood should provide reasonable contaminant removal for these operations [ACGIH 2010].

For further information on flavorings and workplace health and safety, please visit the NIOSH flavorings web page: **http://www.cdc.gov/niosh/topics/flavorings**. To access the Draft NIOSH Criteria for a Recommended Standard: Occupational Exposure to Diacetyl and 2,3-Pentanedione, go to the following link: **http://www.cdc.gov/niosh/docket/archive/pdfs/NIOSH-245/DraftDiacetylCriteriaDocument081211.pdf.**

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Appendix

Figure 1. Real Time HazDust IV Results

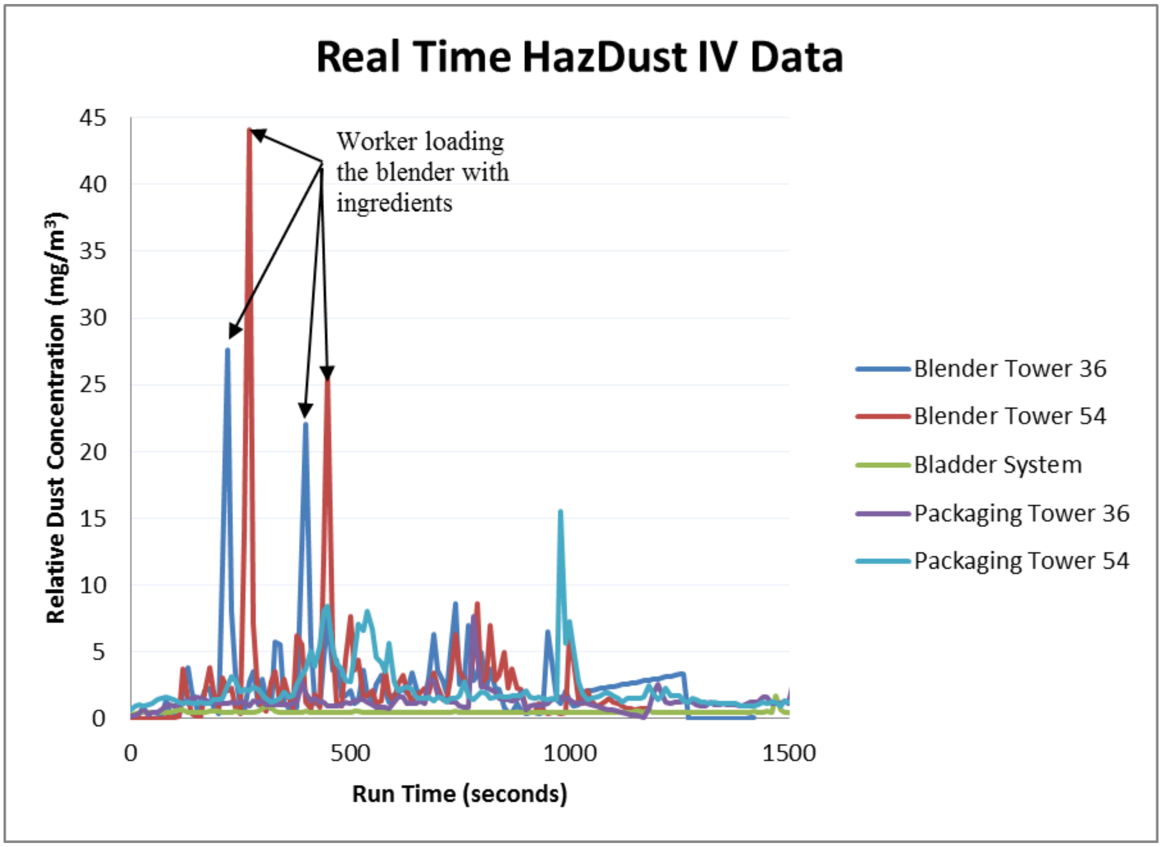

Figure 2. Real Time PID Results

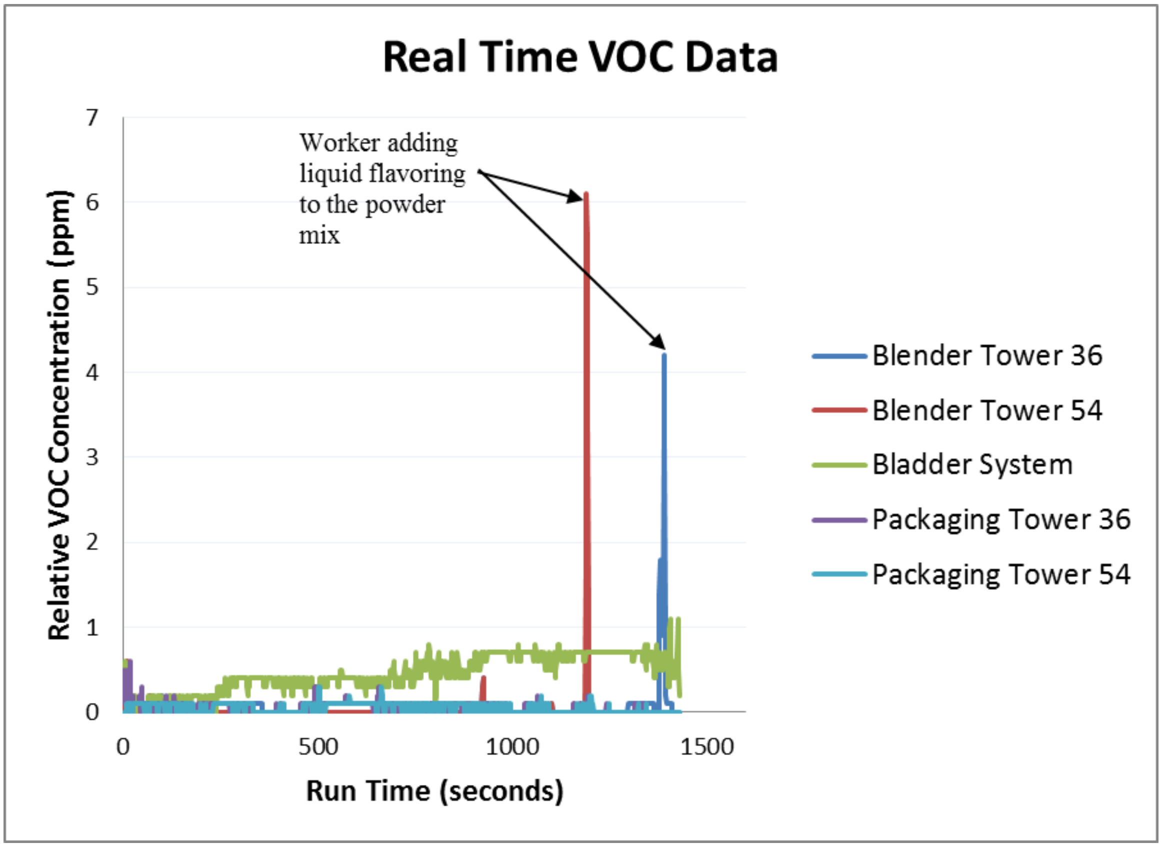

Figure 3. Ribbon Blender outfitted with local exhaust ventilation

Figure 4. Flexible Hoods (Elephant trunks) located in the Emulsion Room

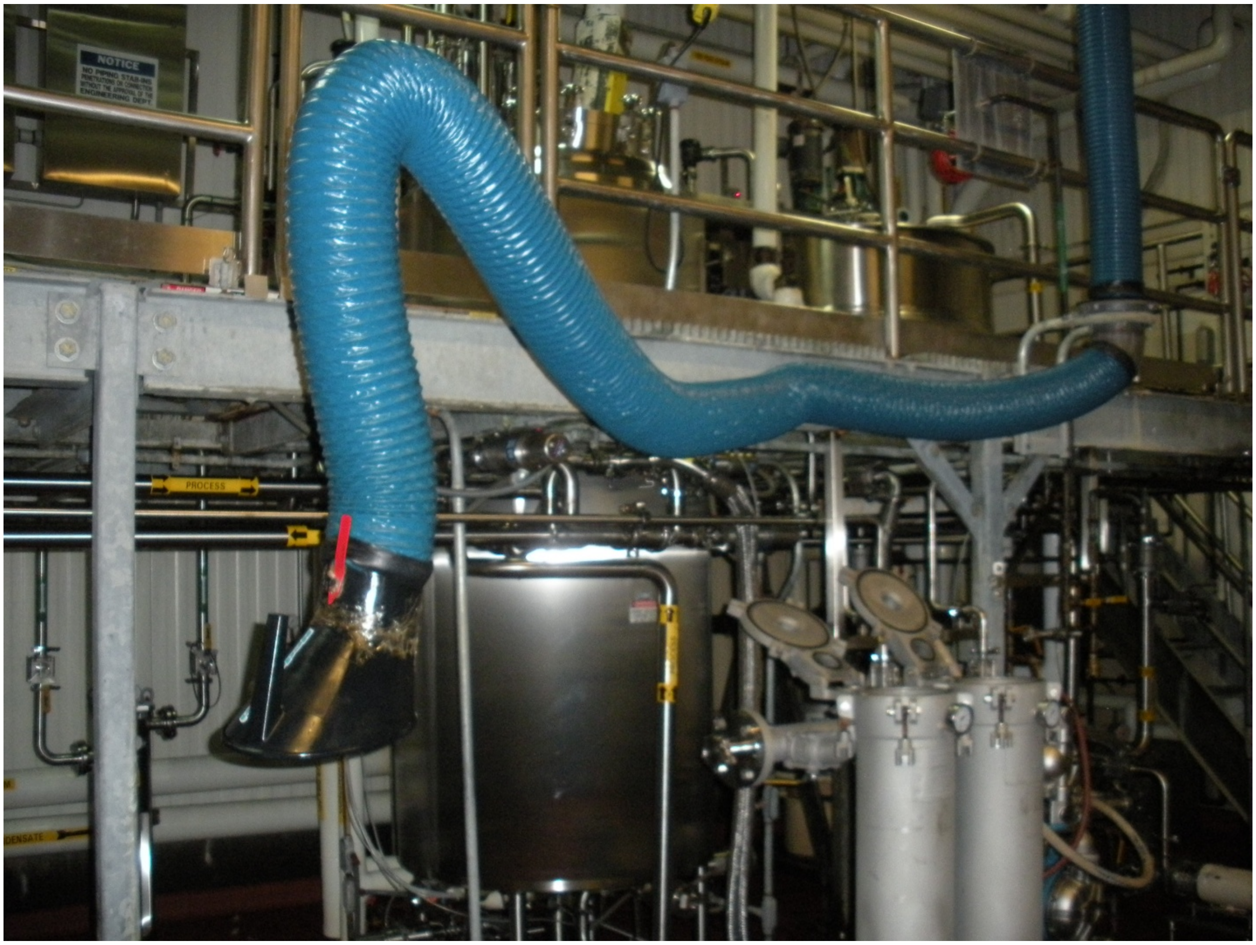

Figure 5. Hood located in the Laboratory mixing area

Figure 6. Engineering control outfitted on the packaging lines

Figure 7. Inflatable seal for the packaging lines

Figure 8. Bench-top ventilation for weighing/handling powders (HSE FL02) (0.5-1 m/s is equivalent to 100-200 fpm). Contains public sector information published by the Health and Safety Executive and licensed under the Open Government License v1.0.

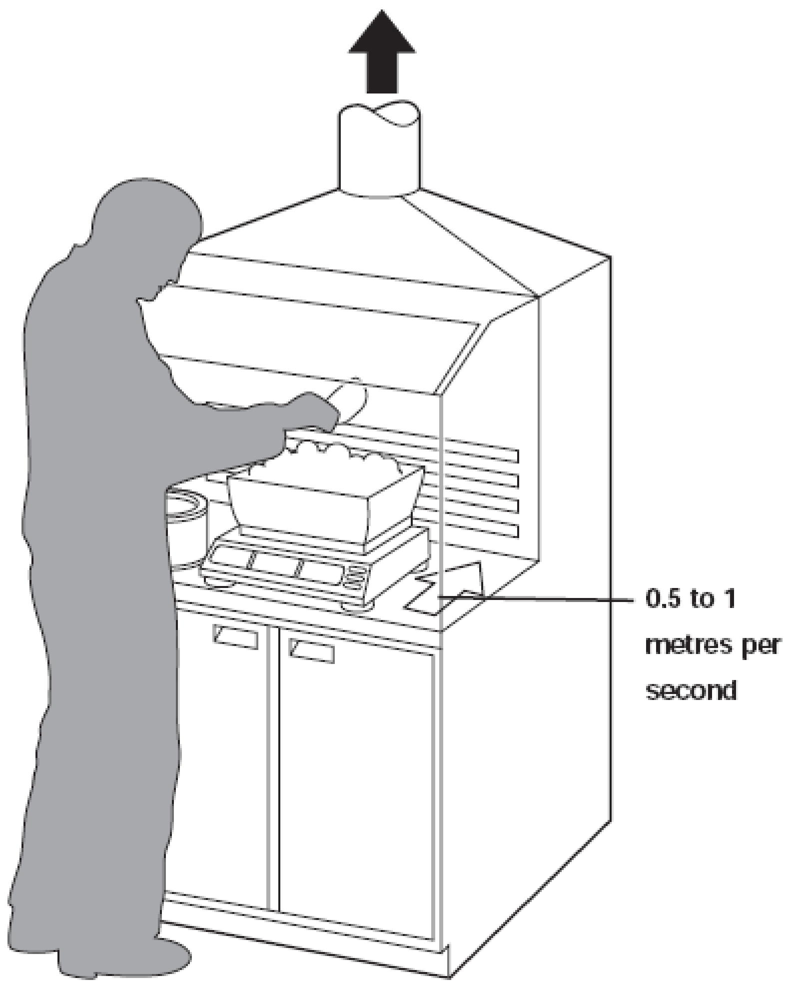

Figure 9. Ventilated Bag Dumping/Emptying Station, 1.0 mps is equivalent to 200 fpm. Contains public sector information published by the Health and Safety Executive and licensed under the Open Government License v1.0.

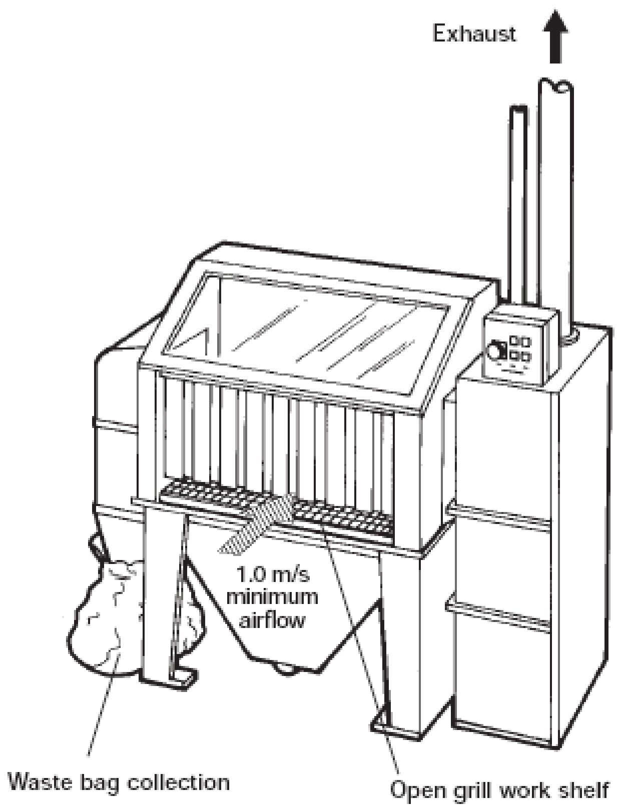

Table 1: Sampling methods for flavoring compounds in food production.

Compound	Analysis Method	Flow Rate	Media	Analytes	LOD[1]
Aldehydes	EPA TO-11a	0.2 L/min	Dinitrophenylhydrazine (DNPH) treated silica	2-Furaldehyde Acetaldehyde Benzaldehyde Isovaleraldehyde Propionaldehyde	0.03 0.01 0.03 0.03 0.03
Acids	Draft NIOSH NMAM 5048	0.2 L/min	Silica Gel (200mg/400mg)	Acetic Acid Butyric Acid Propionic Acid	10 10 10
Ketones	OSHA 1013	0.05 L/min	Silica Gel (200mg/400mg)	Diacetyl Acetoin 2,3 pentanedione 2,3 hexanedione 2,3 heptanedione	1 1 1 1 1

[1] Limit of detection (LOD) units are µg/sample except bulk sample which is mg/kg
NMAM = NIOSH Manual of Analytical Methods; n/a = not applicable

Table 2. Area air sample results (μg/m^3)[1]

Date	Sample Location	Location ID	Flavors Handled	Diacetyl	Acetoin	2,3-Pentanedione	2,3-Hexanedione	2,3-Heptanedione	Acetaldehyde	2-Furaldehyde	Benzaldehyde	Isovaleraldehyde	Propionaldehyde	Acetic Acid	Butyric Acid	Propionic Acid
09/01/09	Emulsion room upper level	04A01A	art ranch flavor (4% diacetyl in neobee oil)	0.0	0.0	0.0	0.0	0.0	8.8	0.0	12.8	3.4	1.5	0.0	0.0	0.0
	Emulsion room lower level,	04A02A	Art Ranch flavor (4% diacetyl in Neobee oil)	0.0	0.0	0.0	0.0	0.0	6.0	0.0	12.5	2.6	1.2	0.0	0.0	0.0
	Warehouse	04A03A	none	0.0	0.0	0.0	0.0	0.0	50.6	0.0	376.4	2.3	0.9	0.0	0.0	0.0
09/02/09	Emulsion room upper level	04A01B	Swiss Cheese Flavor (4% diacetyl in neobee, propionic acid, butyric acid, acetic acid)	164.6	0.0	0.0	0.0	0.0	8.2	0.0	14.9	3.1	1.0	0.0	0.0	0.0
	Emulsion room lower level,	04A02B	Swiss Cheese Flavor (4% diacetyl in neobee, propionic acid, butyric acid, acetic acid)	0.0	0.0	0.0	0.0	0.0	5.6	0.0	14.8	2.1	1.2	0.0	0.0	0.0
	Warehouse	04A03B	none	379.8	0.0	0.0	0.0	0.0	12.2	1.2	246.4	6.7	0.8	0.0	0.0	0.0
	Explosion room lower level;	04A04A	nat butter type flavor (neat diacetyl)	888.9	0.0	0.0	0.0	0.0	18.5	0.0	67.6	10.4	0.8	0.0	0.0	0.0
	Explosion room upper level	04A05A	nat butter type flavor (neat diacetyl)	6872.8	0.0	0.0	0.0	0.0	5.7	0.0	27.4	7.5	0.2	0.0	0.0	0.0

[1] A zero value means the sample was below the limit of detection.

Table 3. Personal air sample results (µg/m^3)[1]

Date	Location	Location ID	Flavors Handled	Diacetyl	Acetoin	2,3-Pentanedione	2,3-Hexanedione	2,3-Heptanedione	Acetaldehyde	2-Furaldehyde	Benzaldehyde	Isovaleraldehyde	Propionaldehyde	Acetic Acid	Butyric Acid	Propionic Acid
09/01/09	emulsion room	04P01A	art ranch flavor (4% diacetyl in neobee oil)	0.0	0.0	0.0	0.0	0.0	12.2	0.0	78.5	2.5	1.3	0.0	0.0	0.0
	emulsion room	04P02A	art ranch flavor, (4% diacetyl in neobee oil)	0.0	0.0	0.0	0.0	0.0	19.4	0.0	86.9	3.0	1.0	0.0	0.0	0.0
09/02/09	emulsion room	04P01B	Swiss Cheese Flavor (4% diacetyl in neobee, propionic acid, butyric acid, acetic acid)	418.1	0.0	0.0	0.0	0.0	16.6	1.1	153.3	5.4	1.3	0.0	0.0	0.0
	emulsion room	04P02B	Swiss Cheese Flavor (4% diacetyl in neobee, propionic acid, butyric acid, acetic acid)	197.2	0.0	0.0	0.0	0.0	14.3	0.5	164.9	4.7	1.0	0.0	0.0	0.0
	explosion room	04P03A	nat butter type flavor (neat diacetyl)	2073.5	0.0	0.0	0.0	0.0	701.9	0.0	136.2	12.2	1.1	0.0	0.0	0.0
	explosion room	04P04A	nat butter type flavor (neat diacetyl)	1532.2	0.0	0.0	0.0	0.0	59.5	0.7	108.4	12.9	1.8	0.0	0.0	0.0

[1] A zero value means the sample was below the limit of detection.

Table 4. Air velocity measurements for blender located in Tower 36. Measurements are reflected in fpm.

Takeout #1

330	410	320
420	600	430
390	450	400

Average= 416 fpm

Takeout #2

350	420	360
460	590	470
310	440	370

Average= 418 fpm

Blender Face Velocity

45	60	54	47	20	16	36	20
54	80	61	42	28	28	50	15
59	43	22	34	45	50	60	48
		0	0	68	55	20	49

Average= 40.3 fpm

Table 5. Air velocity measurements for blender located in Tower 54. Measurements are reflected in fpm.

Slot Opening

31	59	70	372	530	725	975
35	56	64	360	520	735	960
20	57	65	350	530	720	930

Average= 388.76 fpm

Blender Face Velocity

28	41	47	70	189	110	101
14	12	67	83	160	116	970
23	72	75	87	171	117	95
52	80	75	72			

Average= 117.08 fpm

Table 6. Summary of Air velocity measurements for flexible hoods in the Emulsion room.

Hood #	Shape	Diameter of Takeout Duct (in)	Average Face Velocity (fpm)	Length (in)	Width (in)	Area (ft^2)	Flow Rate (cfm)
1	Ellipse	6	906.54	12	10	0.65	589.25
2	Round	6	1663.08	6	6	0.2	332.62
3	Ellipse	6	847.69	12	10	0.65	551.00
4	Ellipse	6	1716.92	8	6	0.26	446.40

Table 7. Summary of Air velocity measurements for hoods in the Laboratory mixing area.

Hood	Shape	Diameter of Takeout Duct (in)	Average Face Velocity (fpm)	Length (in)	Width (in)	Area (ft^2)	Flow Rate (cfm)
Flexible	Ellipse	6	451.15	12	10	0.65	293.25
Canopy	Rectangle	6	225.00	28.5	10.5	1.59	357.75

Table 8. Occupational exposure limits

Chemical	OSHA Permissible Exposure Limit (PEL)	NIOSH Recommended Exposure Limit (REL)	ACGIH Threshold Limit Value (TLV)
Acetoin	None	None	None
Diacetyl*	None	5 ppb (0.02 mg/m^3) TWA, 25 ppb (0.09 mg/m^3) STEL	None
2,3-Heptanedione	None	None	None
2,3-Hexanedione	None	None	None
2,3-Pentanedione*	None	9.3 ppb (0.04 mg/m^3) TWA, 31 ppb (0.13 mg/m^3) STEL	None
Acetic Acid	25 mg/m^3 TWA	25 mg/m^3 TWA, 37 mg/m^3 STEL	25 mg/m^3 TWA, 37 mg/m^3 STEL
Butyric Acid	None	None	None
Propionic Acid	30 mg/m^3 TWA	30 mg/m^3 TWA, 45 mg/m^3 STEL	30 mg/m^3 TWA
Acetaldehyde	360 mg/m^3 TWA	Potential occupational carcinogen, minimize exposure	45 mg/m^3 ceiling
Benzaldehyde	None	None	None
Isovaleraldehyde	None	None	None
Propionaldehyde	None	Potential occupational carcinogen, minimize exposure	47.5 mg/m^3 TWA
2-Furaldehyde	20 mg/m^3 TWA (skin)	None	7.9 mg/m^3 TWA (skin)
Particulate, Respirable	5 mg/m^3 TWA	None	3 mg/m^3 TWA

* The proposed NIOSH RELs for diacetyl and 2,3-pentanedione are currently in draft and are not final.
TWA (time weighted average): Average exposure concentration for an 8 hour workday and 40 hour workweek.
STEL (short term excursion limit) A 15 minute TWA exposure concentration that cannot be exceeded at any time.
Ceiling (ceiling limit): The exposure concentration that should not be exceeded at anytime

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