

**EVALUATING OCCUPATIONAL EXPOSURES
AND WORK PRACTICES**

AT

**GOLD COAST INGREDIENTS, INC.
COMMERCE, CA**

A Technical Assistance Report to the
California/Occupational Safety and Health Administration

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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Introduction

In response to a technical assistance request from California Division of Occupational Safety and Health (Cal/OSHA) in 2006, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted site visits of Gold Coast, Inc. at their Commerce, California plant on November 14-16, 2006 and July 11-12, 2007. Gold Coast is participating in the Flavoring Industry Safety and Health Evaluation Program (FISHEP), a voluntary special emphasis program. This program was initiated by the California Department of Health Services (CDHS) and the California Division of Occupational Safety and Health (Cal/OSHA) in 2006 to identify workers with flavoring-related lung disease such as bronchiolitis obliterans (BO) and institute preventive measures in the California flavoring industry. Under FISHEP, companies must report the results of worksite industrial hygiene assessments to CDHS, and implement control measures recommended by Cal/OSHA. This site report was conducted as the result of a formal technical assistance request on occupational exposures to potentially hazardous chemicals in the manufacturing of food flavors.

Due to the high volumes of diacetyl used, this site was selected for inclusion in this investigation at the specific request of Cal/OSHA. The objectives of the industrial hygiene surveys conducted included identifying common work tasks, plant processes, and procedures as well as characterizing potential occupational exposures within the flavoring industry. A secondary goal was to provide preliminary engineering control guidance, which has been addressed in other correspondence[1, 2].

Process Description

The Gold Coast Ingredients, Inc. is a wholesale flavors and color manufacturer. The company produces over 1,500 flavors in liquid, powder, spray dried, natural, natural and artificial, or artificial forms[3]. In October 2006, Gold Coast Ingredients, Inc employed production workers in areas such as the liquid production room, spray drying room, pre-production corridor and powder production room.

Flavors are produced by compounding ingredients identified on recipes on computer batch tickets. These tickets identify the order and quantity of ingredients which need to be added to make a flavor formulation. High priority chemicals, i.e. substances that may pose a respiratory hazard as designated by the Flavoring Extract and Manufacturing Association[4], are identified and appropriate respiratory protection is also highlighted on the batch ticket. Some chemicals, such as diacetyl, are cold-stored to reduce volatility during use.

Exposures vary dramatically depending upon the flavor formulations completed on a particular day. An employee can make numerous flavor formulations daily depending upon the size and complexity of a batch order. It was not unusual to observe at least 7 different batches being compounded concurrently by different employees in the production areas. The majority of flavors manufactured are on an as ordered basis, with little advance notice.

Liquid Flavor Production

The liquid production area typically consists of a total of 17 stationary or mobile open tanks for mixing liquid flavoring ingredients (Figure 1). There were 4 tanks greater than 4 feet in

diameter and 13 tanks smaller than this size. There were several small and medium mobile tanks which were moved throughout the facility according to need of the batch or formulation. Employees typically pour and mix small quantities of flavoring ingredients on top of a bench top. Employees complete large pours, near the large open tanks often pouring directly into the tank. The liquid room is served by a combination of general exhaust and supply ventilation registers located on the ceiling of the room. There are six air registers located in the room overall. Measurements of the flow from each register showed that two were exhausting air at a combined flow rate of 980 cubic feet per minute (cfm), one was supplying air at a rate of 1300 cfm, and three were not moving air at all. In addition to general ventilation, there was a fume canopy exhaust hood over two mixing tanks which exhaust air when the fan was activated. These tanks are heated and used to produce flavored fruit fillings.

Following the initial survey in November 2006, recommendations on the design and implementation of engineering controls were provided to the company in a letter, dated February 7, 2007. A new local exhaust ventilation system was developed and installed in the liquid production room by Gold Coast in conjunction with a contractor. These controls were installed during the May-June 2007 timeframe and consist of two main types of local exhaust ventilation hoods. The first type is a ventilated bench-top, back draft slotted hood used to control worker exposure to chemicals during small batch mixing, weighing and pouring activities which comprise a majority of the workday. Overall, five bench-top ventilated workstations were installed in the liquid compounding room. The second hood type is a small booth hood which allows for the rolling in of large kettles. The primary function of this hood is to collect chemical vapors when the worker is pouring flavoring ingredients into the large mixers and to contain

evaporative losses when a flavor is being mixed. However, this hood was also observed being used during the packaging of powder flavorings. A total of three of these hoods were installed in the liquid compounding room.

Powder Flavor Production

Powders or pastes were typically mixed within ribbon industrial blenders in the powder production room. In these mixers, a starch or carbohydrate was combined with a liquid or paste flavoring agent. The mixing process was a source of potential exposures with visible airborne dust depending upon the work practices employed during pouring, mixing and packaging. The powder production room and the two spray-drying areas were substantially smaller than the liquid production room. The powder compounding area consisted of 2 blenders, both outfitted with local exhaust ventilation. Both blenders were located on platforms with fixed ladders used for access. The smaller blender was 5 feet 6 inches (length) x 2 feet 8 inches (wide) and was outfitted with a canopy-type exhaust hood. The larger blender was 8 feet (length) x 3 feet 6 inches (wide) and outfitted with a slotted exhaust hood located about 8 feet above the platform and behind the work platform. There was no supply air directly provided to the powder compounding room. Airflow into the room comes solely from infiltration from the warehouse area through the 10 feet x 10 feet door opening and a 15 inch x 15 inch vent opening located about 11 feet above the floor. The vent is open to the warehouse area.

Spray Drying Production

Adjacent to the powder blending room, the spray dryer production room contained three spray dryers (one large and one medium stationary spray dryer, and one mobile spray dryer). Inside a spray dryer, a slurry compound is infused with a flavor, which is converted to encapsulated

particles. Many volatile compounds are encapsulated in an amorphous carbohydrate, producing more stable products with more manageable properties. Release of the flavor from the encapsulated particle is generally fast and complete upon contact with moisture.[5]

Weighing and measuring of flavoring ingredients can occur at various locations throughout the production room, usually near the mixing tank or blender that will be used to produce the final product. It was noted that, for the most part, workers were assigned to either liquid, powder, or spray drying flavoring processes.

Materials and Methods

Information on processes and procedures was obtained through discussions with management and by observation of the processes. Prior to the site visit, the management provided production quantities for chemicals identified as 'high priority' by FEMA. This information was used to refine the sampling scheme used by investigators. Use of personal protective equipment, and work practices were also observed during site visits.

The primary objective of the November survey was to comprehensively characterize worker exposures in the production areas. The objective of the July survey was to again document occupational exposures, but with alternate sampling methods for diacetyl. Characterization of the workplace environment was accomplished through the use of personal, area, and task based air sampling methods (see figures 1 and 2 for facility layout and sample locations). In November, personal and area air samples were collected for various processes at a number of locations throughout the facility including: liquids, powders, pre-production corridor, quality assurance, office administration and research and development locations. Air samples were collected for diacetyl, acetoin, total and respirable particulates, acids (phosphoric, butyric,

acetic and propionic) and five specific aldehydes (2-furaldehyde, acetaldehyde, benzaldehyde, isovaleraldehyde, and propionaldehyde). In July, area air measurements were collected in liquids, powders, pre-production corridor, distribution warehouse and spray drying locations for diacetyl, acetoin and five specific aldehydes (2-furaldehyde, acetaldehyde, benzaldehyde, isovaleraldehyde, and propionaldehyde). Relative humidity and temperature measurements were collected using HOBO Pro Model H08-032-08 temperature and humidity dataloggers (Onset Computer Corp., Bourne, MA) in all area locations. Table 1 lists the sample type, flow rate, and standard methods utilized during the November and July site visits. Figure 1 and Figure 2 display sample locations for the November and July site visits, respectively. All sampling pumps were calibrated in accordance with the sampling methods utilized. Pump calibration was conducted using a Bios Drycal DC-LITE , Model DCL-M primary flow standard (BIOS, Butler, NJ). Additional air monitoring equipment used during the survey was within their calibration periods, and checked for accuracy for the contaminant of interest before being used to collect field measurements.

Personal Air Sampling

November Site Visit

During the November site visit, eight-hour time weighted average (TWA) personal air samples were collected over three consecutive days on almost all of the employees (9 of 13) assigned to work in the liquid and powder production areas. Personal samples were collected for ketones, acids, and aldehydes using calibrated battery-powered personal sampling pumps (SKC Inc., Model 210-1002, Eighty Four, PA) with appropriate sampling media for the contaminant of interest (Table 1, Figure 3). Diacetyl and acetoin samples were collected using carbon molecular

sieve media at a flowrate of approximately 0.1 liters per minute and were analyzed according to NIOSH method 2557. Acid samples were collected with silica gel media (200mg/400mg) at a flowrate of approximately 0.2 liters per minutes and were analyzed according to draft NIOSH method 5048 (acetic, butyric and propionic) or NIOSH method 7903 (phosphoric acid).

Aldehyde samples were collected using dinitrophenylhydrazine (DNPH) treated silica gel media at a flowrate of approximately 0.1 Liters per minute and were analyzed according to EPA TO-11 method. Employees working in the powder production room were also sampled for an Eight-hour TWA for respirable dust using the model GK 2.69, personal cyclone sampler (BGI , Waltham, MA.) mated with an Airchek 2000 personal sampling pump at a flowrate of approximately 4.2 Liters per minute (SKC Inc., Eighty Four, PA). Respirable dust samples were analyzed according to NIOSH method 0600.

July Site Visit

Personal 8-hour TWA sampling was not conducted during the July site visits.

During both the July and November site visits, short duration task-based air sampling was also conducted for ketones, aldehydes or acids using appropriate sampling media and calibrated pumps to obtain measurements of exposure during selected short-term procedures. Task-based samples were collected during particular tasks (i.e pouring or mixing) or during batch formulations which contained higher quantities of ketones, acids or aldehydes. Samples were collected for the duration of a pouring task (diacetyl, ketones or acids), or the entire duration of a mixing batch formulation depending on the overall length of the process. Video exposure monitoring was conducted for select tasks or work practices that were anticipated to produce elevated airborne concentrations (i.e., increased potential for inhalation exposures) during both

November and July site visits. Video monitoring consisted of filming the task or work process of interest, while simultaneously measuring the workers inhalation exposure to volatile organic compounds (VOCs) in real time using a MiniRAE 2000 or ToxiRAE photoionization detector (PID) (Rae Systems, Inc., Sunnyvale, CA).

Area Air Sampling

November Site Visit

In November, area samples were also collected in various locations in the plant, including the administration office, pre-production corridor, quality-control area, and research and development laboratory (Figure 1) to map contaminant concentrations. Eight-hour time weighted average (TWA) area air samples were collected over three consecutive days for ketones (diacetyl and acetoin), aldehydes (acetaldehyde, benzaldehyde, isovaldehyde, 2-furaldehyde, propionaldehyde) and acids (acetic, butyric, proprionic and phosphoric). Area samples for diacetyl were collected according to the NIOSH method 2557 and a modified U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Method PV2118. This modified OSHA method used larger collection tubes (400/200 milligram silica gel tubes) which have greater collection capacity and minimize breakthrough of contaminant to the backup tube.

All area sample collection devices were housed inside a metal basket, which was located near employee work stations (Figure 4). Respirable dust and total dust samples were also collected in the powder production areas. Respirable dust samples were collected using a BGI cyclone at a flowrate of 4.2 liters per minute (lpm). Real-time VOC concentrations were measured in selected area baskets using MiniRAE 2000 and ToxiRAE photoionization detectors (PID) (Rae Systems, Inc., Sunnyvale, CA). PIDs were programmed to log volatile organic compound

(VOC) concentrations every minute. The PIDs were calibrated for isobutylene and could detect isobutylene equivalent VOC concentrations from 1 ppm to 2000 ppm.

Thermal desorption samples were collected at all area locations for approximately two hours each day. The stainless steel thermal desorption tubes contained three beds of sorbent material: the first section contains Carbopack Y (90 mg), the second section contains Carbopack B (115 mg) and the last section contains Carboxen 1003 (150 mg). The thermal tube sorbents were run for approximately 2 hours at a flowrate of 0.1 liters per minute and were analyzed according to NIOSH method 2549. These samples provided both a qualitative and a semi-quantitative analysis of volatile organic compounds in the work environment.

Area real-time dust concentrations were monitored in the powder production room on one day using the Model PDR-1000An/1200 Personal DataRams® (PDR) (Thermo Electron Corporation, Franklin, MA). These monitors were calibrated at the factory using SAE Fine (ISO fine) powder with a mass median aerodynamic particle diameter of 2-3 μm and a bulk density of 2.6-2.65 g/cm^3 . Each monitor was set to log dust concentrations every minute throughout the sampling period.

July Site Visit

In July, area samples were collected in various sampling locations in the plant, including the powder production area, liquid production area, pre-production corridor, spray dry room and distribution warehouse (Figure 2). Two-hour TWA area air samples were collected over two consecutive days for ketones (diacetyl and acetoin) and aldehydes (acetaldehyde, benzaldehyde,

isovaldehyde, 2-furaldehyde, propionaldehyde). All ketone (diacetyl/acetoin) samples were collected over approximately two hours at a flow rate of 0.05 LPM using a modified OSHA Method PV2118. (Since select OSHA results from the November site visits exhibited breakthrough of the front tube due to extended sampling volumes, the volumes were reduced in July.) Aldehyde samples were also run for two hours at a flowrate of 0.2 liter per minute and were analyzed according to EPA TO-11. Additional details on the industrial hygiene sampling methods used during this survey are provided in Table 1.

After the November site visit was complete, a laboratory investigation indicated that the NIOSH method for diacetyl was affected by relative humidity, resulting in an underestimation of true concentrations. A NIOSH project is currently underway and chamber studies of generated atmospheres are planned to investigate the extent of this phenomenon and determine at what relative humidity levels it occurs.

Statistical Analyses

Laboratory reports provided sample results in micrograms (μg) of analyte per sample. Analytical results were converted to an airborne concentration by dividing by the air volume associated with the sample (mg/m^3), then converting to parts per million (ppm) by volume standard temperature and pressure using the gram molecular weight of the analyte at standard temperature and pressure. All calculations to determine airborne concentrations, and provide descriptive statistics were conducted using SAS (SAS 9.1.3, SAS Institute, Cary, NC). Sampling results that were below the limit of detection for the sampling methods used were assigned a

value of one-half of the airborne concentration limit of detection (LOD) for statistical analyses [6].

Applicable Occupational Exposure Limits (OELs)

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. 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. However, not all workers will be protected from adverse health effects even if 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 a 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 the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, thus contributing to the overall exposure.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values where there are health effects from higher exposures over the short-term. Unless otherwise noted, the

STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations. The U.S. Department of Labor OSHA PELs [29 CFR 1910 (general industry); 29 CFR 1926 (construction industry); and 29 CFR 1917 (maritime industry)] are legal limits that are enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH recommended exposure limits (RELs) are recommendations that are made based on a critical review of the scientific and technical information available on the given hazard and the adequacy of methods to identify and control the hazards. NIOSH RELs can be found in the *NIOSH Pocket Guide to Chemical Hazards*[7]. NIOSH also recommends preventive measures (e.g., engineering controls, safe work practices, personal protective equipment, and environmental and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the U.S. include the threshold limit values (TLVs)[®] recommended by the American Conference of Governmental Industrial Hygienists (ACGIH)[®], a professional organization[8] and the workplace environmental exposure levels (WEELs) recommended by the American Industrial Hygiene Association, another professional organization. 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.” WEELs have been established for some chemicals “when no other legal or authoritative limits exist”[9].

Employers should understand that not all hazardous chemicals have specific OSHA PELs and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect their employees from hazards even in the absence of a specific OSHA PEL. 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, NIOSH investigators encourage employers to make use of other OELs when 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). Table 2 contains a listing of all substances sampled during the July and November site visits, and provides applicable OELs, where available.

Results

Descriptive statistics for the 8-hr time weighted average samples, by work area, and task based samples from the November site visits are presented in Table 3, Table 4 and Table 5, respectively. Overall two hour samples, by work area from the July site visits are presented in Tables 6 and 7. Task based samples from the July site visit are presented in Table 8.

Outdoor air temperatures ranged from 56°F to 87°F during the November site visit (no indoor air temperatures were collected). Indoor air temperatures in the facility ranged from 71 °F to 90 °F during the July site visit. Relative humidity in the powder production, liquid production, pre-production corridor, distribution warehouse and spray drying area during the July survey ranged from 28% to 78%, 33% to 63%, 35% to 55%, 28% to 53%, 23% to 65%, respectively during the two days of sampling.

Ketones (Diacetyl and Acetoin)

A total of 39 personal and area diacetyl/acetoin 8-hr time weighted samples were collected using NIOSH method 2557/2558 and fourteen area 8-hr time weighted average samples were collected using modified OSHA method PV2118 during the November site visit (Tables 3 and Table 4).

The distributions of diacetyl concentrations were skewed to the right; therefore, the natural logarithm of the sample concentration was used in all statistical analyses. Diacetyl area samples and personal samples collected on the same day in the same production area were not significantly different than one another (p -value = 0.384). Accordingly both personal and area samples are presented together in Table 3 and Table 4. A total of 30 2-hr TWA samples and 10 task-based samples were collected for diacetyl during the July site visit, all using the modified OSHA method (Tables 6-8).

As stated earlier, a recent laboratory investigation revealed that the NIOSH method #2557 for diacetyl is influenced by relative humidity concentrations. Although diacetyl samples analyzed using the NIOSH method have been presented, it should be noted that these measurements are

likely underestimates of true concentrations. Therefore, we have presented these results solely for comparison to previous investigations.

During both the November and July site visits, area diacetyl samples were collected using a modified OSHA method for diacetyl (200 mg/400 mg silica gel media). Select OSHA modified method results from the November site visits exhibited breakthrough of the front tube due to extended sampling volumes. Sample volumes were significantly reduced for the July site visits. Based on the initial laboratory study, it is believed that samples analyzed with the modified OSHA analytical method provide more accurate results than samples analyzed with the NIOSH method.

In an analysis limited to samples analyzed according to the modified OSHA method, average area diacetyl concentrations were highest in the liquid production room (Arithmetic Mean(AM): 0.46 ppm, n= 3) followed by the powder production room (AM: 0.34 ppm, n=3) and the pre-production corridor (AM:0.21ppm, n=2) during the November site visit.

During the July site visit (Tables 6 and 7), two-hour time weighted average diacetyl concentrations were again higher in the liquid production room (AM: 0.529ppm) compared to the powder production room (AM: 0.483 ppm). The highest diacetyl two-hour time weighted average (6.33 ppm) measured in the facility was in the spray drying room when spray drying was in operation in the early morning hours of July 11, 2007. The diacetyl concentration in the preproduction corridor was also highest during the early morning hours when spray drying was

in operation. Measurable diacetyl concentrations in the distribution warehouse also occurred during the late morning and early afternoon hours of July 12, 2007.

Task Based Samples

All task-based sample results are shown in Tables 5 and 8. Diacetyl exposures varied considerably during the site visits depending upon production area, batch formula, worker task and work practices. During the November site visit, a worker was observed pouring diacetyl from a 55 gallon drum into multiple 5 gallon containers in the pre-production corridor. During the operation, the worker wore a full-face respirator and a task-based concentration of 11 ppm was observed. Eight-hour TWA area concentrations in the pre-production corridor were also notably higher on this day.

During the July site visit, several task based samples were collected on a variety of flavor formulations (Table 8). Sifting and packaging powder formulations resulted in the highest diacetyl concentrations observed. The highest task-based diacetyl sample (17.4 ppm) was observed over an eight minute time period while a worker scooped butter flavored powder from a large metal container and packaged it into smaller containers. Diacetyl comprised less than 2% of the total butter flavored powder formulation. The worker was wearing a respirator during this process. This task was performed inside one of the newly installed booth-type kettle ventilation hoods in the liquid compounding room. A 10 minute task-based concentration of 10 ppm diacetyl was measured while an employee re-packaged butter flavored powder from larger storage bin into smaller containers. The employee wore a respirator while he completed this procedure inside a ventilated booth-type hood. A task-based sample concentration of 9.32 ppm

was also measured over approximately 1 hour when an employee (wearing respiratory protection) scooped butter flavored powder into a manual sifter. The worker reached deeply into the metal grinder vat to successfully remove all butter flavored powder placing his breathing zone into the contaminated area. Also, when an employee (wearing respiratory protection) packaged dairy flavored powder into smaller containers, a task-based sample concentration of 4.75 ppm was observed over a thirty-three minute sample period. Diacetyl comprised less than 1% of the total dairy flavored powder formulation.

Acetoin

In November, acetoin concentrations were highest in the liquid production room (AM = 0.15 ppm, n=17). In July, the average acetoin concentrations were highest in the spray dryer operation room, with all measurements lower than 1 ppm. Acetoin was always observed in lower concentrations than diacetyl during the task-based samples. The highest task-based acetoin sample concentration in the liquid compounding room was measured during the mixing of a butter flavor during the November site visit (1.05 ppm). The highest task-based acetoin sample concentration in the powder compounding room was measured during the packaging of a butter flavor during the July site visit (2.78 ppm).

Thermal Desorption Samples

One hundred and ninety-one contaminants were identified on the thermal desorption tubes collected at this facility. To interpret the response from the thermal tube sample analysis, these responses were categorized (using height of peak and area under peak) in each sample as 1) non-detected, 2) trace quantity present, 3) minor component of mixture, 4) significant quantity

present, and 5) major component of mixture. The top 100 contaminants identified during each site visit are presented in Table 9, in order of decreasing magnitude.

The compounds observed in the liquid, powder and other areas did not appear appreciably different during each site visit and were found in relatively high abundance. Overall, the thermal desorption results from the July visit suggest better environmental controls in the workplace, because concentrations were lower even though the magnitude of contaminants was similar.

Acids

During the November site visit, 8-hr TWA acetic, butyric and propionic acid samples were collected on employees working in production areas and within area baskets samples throughout the facility. All samples were below occupational exposure limits for these compounds (Table 2). Eight-hour TWA personal samples collected in the powder production area were the highest acid samples observed in the facility (Table 4). Acid concentrations were observed while a worker poured and mixed ingredients for a butter flavor batch during task-based sampling (Table 5, acetic acid: 1.93 ppm, butyric acid: 1.20 ppm, propionic acid: 1.43 ppm).

Phosphoric Acid

A total of 14 8-hr TWA phosphoric acid samples were collected in all area baskets during the November site visits. All samples were below the analytical limit of detection and all occupational exposure limits for phosphoric acid(Table 2).

Dust Concentrations

Respirable and total dust concentrations were measured on employees working in the powder production room, but were at concentrations below established occupational exposure limits (Table 2). Real-time dust concentrations were continuously logged for one-minute periods during powdered flavor production over one day during the November site visit. The dust concentrations were highly variable as exhibited on the right axis illustrated in Figure 5. One-minute average dust concentrations peaked as high as 1.6 mg/m³. The dust concentrations are shown along with the VOC concentrations in Figure 5. During some time-periods, increasing dust concentrations corresponded with rising VOC concentrations. This suggests that some dust formulations also contained high quantities of VOC content. There were also examples where VOC concentrations rose, but dust concentrations did not increase. This scenario could be reflective of a liquid pour preceding the initiation of blending.

Real-time VOC samples

Real-time PIDs measured room area VOC concentrations during the November site visit (see Figures 5-8). These detectors respond to a broad range of volatile compounds and do not provide concentrations specific to any particular compound. However, they do provide insight into the variation of VOCs throughout the workday. Figures 5-8 illustrate the instantaneous concentrations of VOCs by production area presented as ppm isobutylene equivalent.

Concentrations were highly variable in all work areas and likely reflect the diversity of batches and their ingredients. The most variable and highest peak concentrations throughout the three sampled days were measured in the liquid production room. The pre-production corridor also showed increasing VOC concentrations throughout the workday. Although real-time concentrations in all production areas were reviewed, no apparent trends were observed. It did

not appear that sudden peaks in the liquid or powder rooms resulted in corresponding increases in VOC levels in the pre-production corridor (reflecting migration) during these sampling periods.

Respiratory Protection Program

A respiratory protection program was operational in the facility. The program's quality evolved throughout the several visits at the facility. During the November site visits, production employees generally wore respirators at all times in the liquid and powder production area. In November, respirator use included both half-face cartridge respirators and full-face cartridge respirators with organic and P100 cartridges and employees had been qualitatively fit tested. During conversations with employees, they seemed uncertain how often to change respirator cartridges. Respirators were stored in the production areas. NIOSH provided specific guidance to both management and employees on respirator use, and storage. Cal/OSHA representatives were also in communication with the company regarding respiratory protection following the November site visit.

During the July site visit, the respiratory protection program was notably improved. Respirators had a specific storage location outside the powder production area. Management indicated that cartridges were changed after approximately eight hours and had stored used cartridges to confirm this schedule. New cartridges were visibly available and employee use seemed more consistent. Management reported that production workers had been quantitatively fit-tested and trained. Observations suggested respirators were worn more frequently and appropriately by

production workers. There were still some individuals (quality control officials, management officials, etc) who entered the production areas without respiratory protection periodically.

Discussion

The July task-based diacetyl samples clearly demonstrate that packaging product, whether liquid or powder, was an activity associated with the highest exposures. Tasks such as scooping powders and manually sifting them into packages as well as the filling of liquid containers were identified as high exposure procedures. These activities should always be conducted with respiratory protection and engineering controls.

The November task-based samples revealed the highest exposure when an employee redistributed pure diacetyl from a 55 gallon drum into 5 gallon containers in the pre-production corridor. When performing this task, employees should continue to wear appropriate respiratory protection and storing diacetyl in cold storage prior to use. (Cold storage can reduce volatility.) Redistributing diacetyl should be completed in the liquid production area within a ventilated booth to reduce worker exposure and migration of diacetyl to other areas of the facility.

During both the November and July site visits, diacetyl concentrations were higher in the liquid production room compared to the powder production room. Although engineering controls were installed in the liquid production room prior to the July visit, diacetyl concentrations in the liquid production room were higher during this survey than during the November visit. This may be due to the fact that batch ingredients vary dramatically, and that the formulations completed in July simply contained more diacetyl than those completed in November. Additionally, samples

collected in November were collected over an eight-hour average versus a two hour averages in July. Short duration samples will more accurately reflect peak exposures compared to samples integrated over a longer time period.

However, there may have been another reason for the higher levels of diacetyl measured in the liquid compounding room. During the collection of short term diacetyl samples, a worker was packaging butter flavored powder inside one of the ventilated booths located in the liquid production room. A personal sample collected on the worker and area samples throughout the liquid production room showed high concentrations of diacetyl during this procedure. After reviewing the data and pictures taken with the facility, an alternate hypothesis was developed as described below.

NIOSH investigators found the engineering controls installed in the liquid production room exhibited good capture when testing the emission of contaminants from a mixing tank within the ventilated booths. However, it is possible that the exhaust fan was not operating during the powder packaging. The exhaust fans on these booths are activated when an object (such as a tank) comes within an inch or so of a proximity switch mounted on the back of the booth. This feature decreases electricity usage by shutting down the fans while the booths are not in use. If the powder packaging apparatus did not effectively engage this switch, the fan would not have come on and the contaminant would not have been captured (see Figure 9). Therefore, it is possible that the dust and vapors emitted during this process were not adequately captured and contributed to the personal and area diacetyl concentrations measured during this operation. Unfortunately, the fan operation cannot be verified by sound due to the high background noise

levels from the adjacent fan/hood systems. A visual indicator such as a fan operational light should be connected to the fan circuit and mounted on the booth to indicate to the employee that the fan is operational. Secondly, boxes with packaged material were moved outside the booth after packaging. This would allow compounds to be emitted in the liquid production room before being closed entirely.

The implementation of ventilated booths in the liquid production room provides a good engineering control which can be used for a variety of tasks including large tank ventilation. Other operations such as powder packaging and pouring/redistribution of diacetyl and other high priority chemicals can be more safely completed in these booths once the workers have been properly trained on use and new operation safeguards such as the one mentioned above are implemented. Important topics for training include verifying fan operation status, making sure that the worker knows to always position the contaminant source between him and the exhaust hood, and closing packaged boxes completely before removing them from the ventilated booths.

The thermal desorption results provide evidence that the benchtop ventilation stations were working as designed. Although similar compounds were observed and diacetyl was higher in the rank order, the relative abundance was lower for most contaminants overall.

Recommendations

1. Engineering Controls:

1) Re-design the proximity switch to insure ventilation systems are on when employees operate the engineering controls in liquid production room. Add a fan operational status light to each hood to provide an indication to the worker that the booth is functional.

2) Install appropriate engineering controls in the powder production and spray dryer rooms. These controls should address the potential sources of exposure documented in the letter from NIOSH, dated February 7, 2007.

3) Train employees on how to use the engineering control hoods properly; provide guidance on proper usage and good work practices such as avoiding filling up the bench-top hoods with non-essential items.

4) Engineering controls should be evaluated periodically to insure proper operation in accordance with engineering control guidance[2]. System performance checks should be added to a preventative maintenance routine.

2. Work Practices:

1) Avoid pouring, measuring, or open transfer of flavoring chemicals or ingredients in the pre-production corridor. These operations should be completed in a ventilated booth using appropriate work practices.

- 2) Continue to improve work practices for any flavoring containing diacetyl or other priority chemicals to fully utilize the engineering controls employed in the liquid production room.
- 3) Avoid removing containers packaged with flavoring containing diacetyl or other priority chemicals product from the ventilated booth until they are closed entirely.
- 4) Keep containers of flavoring chemicals and/or ingredients sealed when not in use.
- 5) Utilize cold water washes and cold storage of chemicals when feasible.
- 6) Clean spills promptly to minimize emissions of chemical vapors.
- 7) Add diacetyl and other high priority chemicals into a batch last, when possible, to minimize volatilization and exposure potential/duration.
- 8) Wear personal protection equipment including respirators and skin protection when cleaning up spills or washing empty containers of flavoring chemicals or ingredients.

3. Respiratory Protection:

- 1) Continue to require mandatory respirator use for all production workers, distribution warehouse workers, and other workers who enter the production area.

2) Re-locate the respirator storage and cartridge re-load area from outside the powder production room/pre-production corridor to an alternate area with lower concentrations of flavoring chemicals.

3) Restrict access to the pre-production corridor, liquid production room, powder production room, spray-drying areas, and distribution warehouse to only employees that need to be there, have been properly quantitatively fit-tested, and are wearing appropriate respiratory protection.

4) In accordance with Cal/OSHA direction, "full-facepiece respirators fit-tested with an approved quantitative method are needed as minimal protection for employees exposed to flavoring ingredients in this industry. All employees entering flavor formulation areas or unprotected areas (e.g., packaging areas) must wear respirators" (FISHEP correspondence from K. Howard dated Oct. 13, 2006). Specifically, a NIOSH-certified full-face respirator with organic vapor/acid gas cartridges and particulate filters is the minimum level of respiratory protection recommended in conjunction with a fully operational respiratory protection program. Information about respirators is available at the NIOSH website

(<http://www.cdc.gov/niosh/npptl/topics/respirators/> and <http://www.cdc.gov/niosh/docs/2005-100/default.html>). Details on the OSHA Respiratory Protection Standard are available on the OSHA website (<http://www.osha.gov/>).

4. Eye Protection:

1) Enforce use of eye protection in the laboratory and quality controls areas. Full face respirators provide eye protection in the production areas.

5. Skin Protection:

- 1) Wear long sleeve shirts, pants, and chemical-resistant gloves in the production areas.

6. Medical Surveillance:

- 1) Follow medical surveillance guidance and recommendations as specified in communication related to health hazard request 2007-033 [10, 11]

7. Hazard Communication:

- 1) Ensure workers understand the hazards associated with flavoring chemicals and how to protect themselves. OSHA's Hazard Communication Standard, also known as the "Right to Know Law" (29 CFR 1910.1200) requires that employees are informed and trained of potential work hazards and associated safe practices, procedures, and protective measures.

The California Code of Regulations, Title 8, Section 5194, Hazard Communication, is available at <http://www.dir.ca.gov/title8/5194b.html>.

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Table 1. Sampling and Analysis Table

Type	Analysis Method	Media	Analytes	Objective	Flowrate	Sample Duration
November Site Visit						
Aldehydes	EPA TO-11	Dinitrophenylhydrazine (DNPH) treated silica (150/300 mg)	2-Furaldehyde Acetaldehyde, Benzaldehyde, Isovaleraldehyde Propionaldehyde	8-hr TWA	100cc/min	300 minutes
	EPA TO-11	Dinitrophenylhydrazine (DNPH) treated silica	2-Furaldehyde Acetaldehyde, Benzaldehyde, Isovaleraldehyde Propionaldehyde	Task Based Sample	200cc/min	15 minutes -1 hour
Acids	Draft NMAM 5048	Silica Gel (200mg/400mg)	Acetic Acid Butyric Acid Propionic Acid	8-hr TWA	200cc/min	480 minutes
	NMAM 7903	Silica Gel (200mg/400mg)	Phosphoric Acid	8-hr TWA	200cc/min	480 minutes
	Draft NMAM 5048	Silica Gel (200mg/400mg)	Acetic Acid Butyric Acid Propionic Acid	Task Based Sample	200cc/min	15 minutes -1 hour
Ketones	OSHA PV2118 (modified method)	Silica Gel (200mg/400mg)	Diacetyl	8-hr TWA	100cc/min	480 minutes
	NIOSH 2557/2558	CMS (75mg/150mg)	Diacetyl/Acetoin	8-hr TWA	100cc/min	480 minutes
	NMAM 2557/2558	CMS (75mg/150mg)	Diacetyl/Acetoin	Task Based Sample	200cc/min	15 minutes -1 hour

Type	Analysis Method	Media	Analytes	Objective	Flowrate	Sample Duration
November Site Visit (continued from previous page)						
VOCs	NMAM 2549	Thermal Desorption Tubes	Varied based on Thermal tubes	2-hr TWA	100cc/min	60 minutes
Respirable dust	NMAM 0600	37 mm PVC filter, BGI cyclone	Respirable dust	8-hr TWA	4.2L/min	240 minutes
Total Dust	NMAM 0500	37 mm PVC filter	Total dust	8-hr TWA	1.5L/min	240 minutes
July Site Visit						
Aldehydes	EPA TO-11	Dinitrophenylhydrazine (DNPH) treated silica	2-Furaldehyde Acetaldehyde, Benzaldehyde, Isovaleraldehyde Propionaldehyde	2-hr TWA	200cc/min	120 minutes
	EPA TO-11	Dinitrophenylhydrazine (DNPH) treated silica	2-Furaldehyde Acetaldehyde, Benzaldehyde, Isovaleraldehyde Propionaldehyde	Task Based Sample	200cc/min	15 minutes -1 hour
Ketones	OSHA PV2118 (modified method)	Silica Gel (200mg/400mg)	Diacetyl/Acetoin	2-hr TWA	50cc/min	120 minutes
	OSHA PV2118 (modified method)	Silica Gel (200mg/400mg)	Diacetyl/Acetoin	Task Based Sample	50cc/min	15 minutes -1 hour

NOTES:

NMAM: NIOSH Manual of Analytical Methods

Table 2. Relevant Occupational Exposure Limits

Chemical Name	Occupational Exposure Limits								
	NIOSH REL			OSHA PEL			ACGIH TLV		
	TWA	STEL	Ceiling	TWA	STEL	Ceiling	TWA	STEL	Ceiling
2-Furaldehyde	NE	NE	NE	5 ppm ^(A)	NE	NE	2 ppm ^(A,B)	NE	NE
Acetaldehyde	NE ^(C)	NE ^(C)	NE ^(C)	200 ppm	NE	NE	NE	NE	25 ppm ^(B)
Acetic acid	10ppm	15ppm	NE	10ppm	NE	NE	10ppm	15ppm	NE
Acetoin	NE	NE	NE	NE	NE	NE	NE	NE	NE
Benzaldehyde	NE	NE	NE	NE	NE	NE	NE	NE	NE
Butyric acid	NE	NE	NE	NE	NE	NE	NE	NE	NE
Diacetyl	NE	NE	NE	NE	NE	NE	NE	NE	NE
Isovaleraldehyde	NE	NE	NE	NE	NE	NE	NE	NE	NE
Phosphoric acid	1 mg/m ³	3 mg/m ³	NE	1 mg/m ³	NE	NE	1 mg/m ³	3 mg/m ³	NE
Propionaldehyde ^D	NE	NE	NE	NE	NE	NE	20 ppm	NE	NE
Propionic acid	10 ppm	15 ppm	NE	NE	NE	NE	10 ppm	NE	NE
Respirable particulate	NE	NE	NE	5 mg/m ³	NE	NE	3 mg/m ³	NE	NE
Total particulate	NE	NE	NE	15 mg/m ³	NE	NE	10 mg/m ³ ^(E)	NE	NE
Total volatile organic compounds	NE	NE	NE	NE	NE	NE	NE	NE	NE

NOTES:

A - Skin notation

B - ACGIH confirmed animal carcinogen with unknown relevance to humans [8]

C - NIOSH potential occupational carcinogen - (See Appendix A and C in the NIOSH Pocket Guide to Chemical Hazards [7])

D - Testing has not been completed to determine the carcinogenicity of acrolein, butyraldehyde (CAS#: 123-72-8), crotonaldehyde, glutaraldehyde, glyoxal (CAS#: 107-22-2), paraformaldehyde (CAS#: 30525-89-4), propionaldehyde (CAS#: 624-67-9), propionaldehyde (CAS#: 123-38-6), and n-valeraldehyde, nine related low-molecular-weight-aldehydes. However, the limited studies to date indicate that these substances have chemical reactivity and mutagenicity similar to acetaldehyde and malonaldehyde. Therefore, NIOSH recommends that careful consideration should be given to reducing exposures to these nine related aldehydes. [12]

E - Inhalable fraction [8]

NE - Not established

Table 3 November Site Visit Eight-hour Time Weighted Average Descriptive Statistics

Analyte	units	n	AM	SD	GM	GSD	Min	Max
2-Furaldehyde	ppm	39	0.01	0.01	0.01	3.00	0.0002	0.06
Acetaldehyde	ppm	39	0.09	0.11	0.06	2.49	0.001	0.68
Acetic Acid	mg/m ³	38	0.44	0.98	0.13	4.47	0.018	4.80
Acetoin	ppm	39	0.12	0.10	0.08	2.84	0.005	0.47
Benzaldehyde	ppm	39	0.05	0.03	0.04	2.43	0.001	0.11
Butyric Acid	ppm	38	0.07	0.07	0.03	3.59	0.007	0.30
Diacetyl (MOSHA) ¹	ppm	14	0.23	0.29	0.10	4.21	0.019	1.00
Diacetyl (NIOSH) ²	ppm	39	0.19	0.35	0.04	6.64	0.001	1.71
Isovaleraldehyde	ppm	39	0.03	0.05	0.01	4.32	0.001	0.30
Respirable Particulate	mg/m ³	24	0.17	0.18	0.11	2.55	0.032	0.73
Propionaldehyde	ppm	39	0.03	0.02	0.02	2.32	0.002	0.08
Propionic Acid	ppm	38	0.08	0.09	0.03	5.95	0.003	0.35
Total Particulate	mg/m ³	15	0.47	0.49	0.25	3.42	0.034	1.47

NOTES:

n: Number of samples

AM: Arithmetic Mean

SD: Standard Deviation

GM: Geometric Mean

GSD: Geometric Standard Deviation

Max: Maximum

Min: Minimum

¹ Collected/analyzed using modified OSHA method PV2118 for diacetyl

² Collected/analyzed using NIOSH method 2557 for diacetyl, which likely underestimates true exposure.

Table 4. November Site Visit Descriptive Statistics
 Eight-hour Time Weighted Averages, Area and Personal Samples by Work Area

Analyte	units	n	AM	SD	GM	GSD	Min	Max
Powder Production								
2-Furaldehyde	ppm	12	0.01	0.01	0.004	4.04	0.0002	0.04
Acetaldehyde	ppm	12	0.14	0.19	0.08	2.64	0.026	0.68
Acetic Acid	ppm	11	0.75	1.45	0.20	5.08	0.018	4.80
Acetoin	ppm	12	0.09	0.58	0.08	1.79	0.035	0.19
Benzaldehyde	ppm	12	0.03	0.01	0.03	1.50	0.012	0.07
Butyric Acid	ppm	11	0.10	0.09	0.05	3.88	0.007	0.30
Diacetyl (MOSHA) ¹	ppm	3	0.34	0.28	0.17	6.38	0.020	0.52
Diacetyl (NIOSH) ²	ppm	12	0.35	0.51	0.09	8.29	0.005	1.71
Isovaleraldehyde	ppm	12	0.01	0.01	0.01	2.40	0.003	0.04
Respirable Particulate	mg/m ³	12	0.26	0.22	0.19	2.40	0.038	0.73
Propionaldehyde	ppm	12	0.03	0.02	0.02	2.63	0.003	0.06
Propionic Acid	ppm	11	0.12	0.12	0.05	6.37	0.003	0.35
Total Particulate	mg/m ³	3	1.28	0.21	1.26	1.18	1.058	1.47
Liquid Production Area								
2-Furaldehyde	ppm	17	0.01	0.01	0.01	1.89	0.002	0.03
Acetaldehyde	ppm	17	0.07	0.03	0.06	2.71	0.001	0.14
Acetic Acid	ppm	17	0.44	0.86	0.15	4.45	0.018	3.60
Acetoin	ppm	17	0.15	0.13	0.09	3.54	0.005	0.47
Benzaldehyde	ppm	17	0.07	0.02	0.07	1.46	0.035	0.11
Butyric Acid	ppm	17	0.08	0.06	0.05	2.84	0.008	0.21
Diacetyl (MOSHA) ¹	ppm	3	0.46	0.05	0.20	7.41	0.021	1.00
Diacetyl (NIOSH) ²	ppm	17	0.14	0.27	0.03	6.64	0.001	1.05
Isovaleraldehyde	ppm	17	0.05	0.07	0.02	3.74	0.003	0.30
Respirable Particulate	mg/m ³	3	0.14	0.84	0.11	2.32	0.043	0.18

Table 4. November Site Visit Descriptive Statistics
 Eight-hour Time Weighted Averages, Area and Personal Samples by Work Area- *Continued*

Analyte	units	n	AM	SD	GM	GSD	Min	Max
Liquid Production Area (continued from previous page)								
Propionaldehyde	ppm	17	0.02	0.01	0.02	2.16	0.002	0.77
Propionic Acid	ppm	17	0.09	0.08	0.05	4.08	0.003	0.26
Total Particulate	mg/m ³	3	0.61	0.35	0.52	2.11	0.224	0.91
Quality Assurance/ Quality Control								
2-Furaldehyde	ppm	3	0.01	0.01	0.01	2.35	0.003	0.02
Acetaldehyde	ppm	3	0.06	0.04	0.05	2.08	0.024	0.10
Acetic Acid	ppm	3	0.09	0.08	0.07	2.94	0.020	0.17
Acetoin	ppm	3	0.07	0.05	0.05	2.98	0.015	0.12
Benzaldehyde	ppm	3	0.06	0.03	0.05	1.68	0.031	0.09
Butyric Acid	ppm	3	0.008	0.0003	0.008	1.04	0.008	0.008
Diacetyl (MOSHA) ¹	ppm	3	0.07	0.06	0.05	2.29	0.028	0.13
Diacetyl (NIOSH) ²	ppm	3	0.02	0.01	0.02	1.81	0.012	0.04
Isovaleraldehyde	ppm	3	0.003	0.002	0.002	2.05	0.001	0.005
Respirable Particulate	mg/m ³	3	0.05	0.10	0.05	1.11	0.043	0.05
Propionaldehyde	ppm	3	0.05	0.01	0.04	1.45	0.028	0.05
Propionic Acid	ppm	3	0.003	0.0001	0.003	1.04	0.003	0.003
Total Particulate	mg/m ³	3	0.08	0.06	0.07	2.08	0.034	0.14
Pre-Production Corridor								
2-Furaldehyde	ppm	3	0.02	0.03	0.01	3.87	0.005	0.05
Acetaldehyde	ppm	3	0.07	0.03	0.07	1.49	0.047	0.10
Acetic Acid	ppm	3	0.08	0.06	0.06	2.67	0.02	0.14
Acetoin	ppm	3	0.07	0.06	0.04	5.22	0.006	0.11
Benzaldehyde	ppm	3	0.03	0.01	0.03	1.26	0.023	0.04
Butyric Acid	ppm	3	0.008	0.0004	0.008	1.05	0.007	0.008

Table 4. November Site Visit Descriptive Statistics
 Eight-hour Time Weighted Averages, Area and Personal Samples by Work Area- *Continued*

Analyte	units	n	AM	SD	GM	GSD	Min	Max
Pre-Production Corridor								
Diacetyl (MOSHA) ¹	ppm	2	0.21	0.20	0.16	3.20	0.068	0.35
Diacetyl (NIOSH) ²	ppm	3	0.07	0.09	0.04	3.74	0.013	0.17
Isovaleraldehyde	ppm	3	0.002	0.001	0.001	2.25	0.001	0.003
Respirable Particulate	mg/m ³	3	0.11	0.08	0.09	2.46	0.034	0.20
Propionaldehyde	ppm	3	0.02	0.02	0.02	2.44	0.007	0.04
Propionic Acid	ppm	3	0.003	0.0002	0.003	1.05	0.003	0.003
Total Particulate	mg/m ³	3	0.26	0.15	0.22	2.13	0.095	0.39
Office Administration								
2-Furaldehyde	ppm	1	0.02					
Acetaldehyde	ppm	1	0.04					
Acetic Acid	ppm	1	0.02					
Acetoin	ppm	1	0.04					
Benzaldehyde	ppm	1	0.01					
Butyric Acid	ppm	1	0.007					
Diacetyl (MOSHA) ¹	ppm	1	0.02					
Diacetyl (NIOSH) ²	ppm	1	0.003					
Isovaleraldehyde	ppm	1	0.01					
Respirable Particulate	mg/m ³	1	0.05					
Propionaldehyde	ppm	1	0.05					
Propionic Acid	ppm	1	0.003					

NOTES:

n: Number of samples; AM: Arithmetic Mean; SD: Standard Deviation; GM: Geometric Mean; GSD: Geometric Standard Deviation; Max: Maximum; Min: Minimum

¹ Collected/analyzed using modified OSHA method PV2118 for diacetyl

² Collected/analyzed using NIOSH method 2557 for diacetyl, which likely underestimates true exposure.

Other: Per analyte, the total number of samples (n) in Table 4 may not equal the total number of samples (n) presented in Table 3. Some employees worked in multiple production areas within a day and could not be listed within one particular production area.

Table 5. November Site Visit Task Based Personal Sampling

Production Area	Task completed	Duration (mins)	Analyte	(ppm)	Flavor
Liquid	Pouring and Mixing Ingredients	53	2-Furaldehyde	0.01	Fruit Flavor
Liquid	Pouring and Mixing Ingredients	53	Acetaldehyde	0.19	Fruit Flavor
Liquid	Pouring and Mixing Ingredients	45	Acetoin	0.16	Butter Flavor
Liquid	Pouring and Mixing Ingredients	61	Acetoin	1.05	Butter Flavor
Liquid	Pouring and Mixing Ingredients	15	Acetoin	0.09	Butter Flavor
Liquid	Pouring and Mixing Ingredients	59	Acetoin	0.18	Carmel Flavor
Liquid	Pouring and Mixing Ingredients	55	Acetoin	0.50	Fruit Flavor
Powder	Small Pouring and Mixing Ingredients	15	Acetoin	0.18	Carmel Flavor
Powder	Pouring and Mixing Ingredients	26	Acetoin	0.05	Powder Mix
Pre-production Corridor	Pouring Diacetyl from 55 gallon drum to 5 gal drum	10	Acetoin	0.14	Diacetyl Transfer
Liquid	Pouring and Mixing Ingredients	45	Diacetyl(NIOSH) ¹	0.04	Butter Flavor
Liquid	Pouring and Mixing Ingredients	61	Diacetyl(NIOSH) ¹	0.08	Butter Flavor
Liquid	Pouring and Mixing Ingredients	15	Diacetyl(NIOSH) ¹	0.09	Butter Flavor
Liquid	Pouring and Mixing Ingredients	59	Diacetyl(NIOSH) ¹	0.02	Carmel Flavor
Liquid	Pouring and Mixing Ingredients	55	Diacetyl(NIOSH) ¹	0.03	Fruit Flavor

Production Area	Task completed	Duration (mins)	Analyte	(ppm)	Flavor
Powder	Small Pouring and Mixing Ingredients	15	Diacetyl(NIOSH) ¹	1.58	Carmel Flavor
Powder	Pouring and Mixing Ingredients	26	Diacetyl(NIOSH) ¹	0.05	Powder Mix
Pre-production Corridor	Pouring Diacetyl from 55 gallon drum to 5 gal drum	10	Diacetyl(NIOSH) ¹	11.04	Diacetyl Transfer
Liquid	Pouring and Mixing Ingredients	53	Isovaleraldehyde	0.04	Fruit Flavor
Liquid	Pouring and Mixing Ingredients	53	Propionaldehyde	0.05	Fruit Flavor
Liquid	Pouring and Mixing Ingredients	61	Acetic Acid	1.93	Butter Flavor
Liquid	Pouring and Mixing Ingredients	61	Butyric Acid	1.20	Butter Flavor
Liquid	Pouring and Mixing Ingredients	61	Propionic Acid	1.43	Butter Flavor

NOTES:

¹ Collected/analyzed using NIOSH method 2557 for diacetyl, which likely underestimates true exposure.
ppm: parts per million

Table 6. July Site Visit Two-hour Time Weighted Average Descriptive Statistics, Area Samples

Analyte (ppm)	n	AM	SD	GM	GSD	min	max
2-Furaldehyde	30	0.009	0.009	0.005	3.59	0.001	0.04
Acetaldehyde	30	0.22	0.513	0.045	5.19	0.006	2.57
Acetoin ¹	30	0.115	0.083	0.096	1.77	0.048	0.37
Benzaldehyde	30	0.076	0.238	0.013	5.46	0.001	1.29
Diacetyl ¹	30	0.445	1.168	0.085	6.53	0.008	6.33
Isovaleraldehyde	30	0.076	0.149	0.011	7.49	0.001	0.43
Propionaldehyde	30	0.032	0.039	0.011	6.2	0.001	0.17

NOTES:

n: Number of samples

AM: Arithmetic Mean

SD: Standard Deviation

GM: Geometric Mean

GSD: Geometric Standard Deviation

Max: Maximum

Min: Minimum

¹ Collected/analyzed using modified OSHA method PV2118 for diacetyl

Table 7 July Site Visit Descriptive Statistics,
Two-hour Time Weighted Averages, Areas Samples by Work Area

Analyte (ppm)	n	AM	SD	GM	GSD	Min	Max
Distribution Warehouse							
Acetoin ¹	6	0.067	0.01	0.066	1.18	0.048	0.08
Diacetyl ¹	6	0.041	0.053	0.023	3.12	0.008	0.14
2-Furaldehyde	6	0.007	0.010	0.002	5.75	0.001	0.02
Acetaldehyde	6	0.014	0.007	0.013	1.56	0.008	0.03
Benzaldehyde	6	0.004	0.003	0.003	2.53	0.001	0.01
Isovaleraldehyde	6	0.002	0.002	0.001	2.48	0.001	0.01
Propionaldehyde	6	0.016	0.017	0.007	5.66	0.001	0.04
Liquid Production Area							
Acetoin ¹	6	0.07	0.009	0.07	1.137	0.058	0.09
Diacetyl ¹	6	0.529	0.297	0.467	1.712	0.26	1.04
2-Furaldehyde	6	0.007	0.004	0.006	1.67	0.004	0.01
Acetaldehyde	6	0.273	0.245	0.17	3.32	0.031	0.69
Benzaldehyde	6	0.295	0.498	0.09	5.49	0.016	1.29
Isovaleraldehyde	6	0.011	0.005	0.01	1.71	0.004	0.02
Propionaldehyde	6	0.031	0.027	0.02	5.65	0.001	0.06
Powder Production Area							
Acetoin ¹	6	0.163	0.082	0.144	1.78	0.07	0.26
Diacetyl ¹	6	0.483	0.572	0.288	2.97	0.10	1.58
2-Furaldehyde	6	0.008	0.007	0.004	3.76	0.001	0.02
Acetaldehyde	6	0.343	0.45	0.112	5.95	0.015	1.02
Benzaldehyde	6	0.034	0.055	0.017	2.98	0.007	0.15
Isovaleraldehyde	6	0.013	0.055	0.012	1.52	0.006	0.02
Propionaldehyde	6	0.080	0.056	0.061	2.48	0.012	0.17

Table 7 July Site Visit Descriptive Statistics,
Two-hour Time Weighted Averages, Areas Samples by Work Area – continued

Analyte (ppm)	n	AM	SD	GM	GSD	Min	Max
Pre-Production Corridor							
Acetoin ¹	6	0.077	0.027	0.074	1.35	0.053	0.13
Diacetyl ¹	6	0.098	0.151	0.031	5.13	0.009	0.38
2-Furaldehyde	6	0.012	0.015	0.005	4.99	0.001	0.04
Acetaldehyde	6	0.029	0.018	0.024	2.16	0.006	0.05
Benzaldehyde	6	0.012	0.005	0.012	1.51	0.007	0.02
Isovaleraldehyde	6	0.006	0.004	0.004	3.36	0.001	0.01
Propionaldehyde	6	0.011	0.016	0.003	6.60	0.001	0.04
Spray Dryer Production							
Acetoin ¹	6	0.20	0.118	0.165	1.99	0.063	0.37
Diacetyl ¹	6	1.07	2.578	0.048	11.5	0.011	6.33
2-Furaldehyde	6	0.01	0.01	0.007	2.40	0.003	0.03
Acetaldehyde	6	0.44	1.042	0.032	8.74	0.008	2.57
Benzaldehyde	6	0.03	0.07	0.005	7.21	0.001	0.18
Isovaleraldehyde	6	0.35	0.131	0.309	1.88	0.086	0.43
Propionaldehyde	6	0.02	0.023	0.010	5.03	0.001	0.05

NOTES:

n: Number of samples

AM: Arithmetic Mean

SD: Standard Deviation

GM: Geometric Mean

GSD: Geometric Standard Deviation

Max: Maximum

Min: Minimum

¹ Collected/analyzed using modified OSHA method PV2118 for diacetyl

Table 8. July Site Visit Personal Task-Based Sampling Results

Area	Task Description	Duration (mins)	Analyte	Result (ppm)	Batch Flavor
Liquid	Benchtop Liquid Pouring	12	2-Furaldehyde	0.004	Nut Emulsion
Powder	Packaging powder product into boxes	33	2-Furaldehyde	0.04	Dairy flavored Powder
Liquid	Mixing into stand alone vessel	33	2-Furaldehyde	0.001	Tropical Fruit Flavor
Liquid	Liquid Pouring	12	Acetaldehyde	0.01	Nut Emulsion
Powder	Packaging powder product into boxes	33	Acetaldehyde	4.02	Dairy flavored Powder
Liquid	Mixing	33	Acetaldehyde	0.08	Tropical Fruit Flavor
Liquid	Benchtop Pouring	12	Acetoin	0.17	Nut Emulsion
Liquid	Scooping butter from metal bin into boxes; Worker leaned into bin remove all powder	8	Acetoin	0.59	Butter flavor.
Liquid	Benchtop mixing	35	Acetoin	0.24	Wine Flavor
Liquid	Worker prepares for task (setting up boxes, moving equip., etc). Worker scoops powder (one scoop at a time) over head into a mechanical sifter.	61	Acetoin	0.88	Butter flavored powder
Liquid	Cleaning grinder/sifter (used for butter powder) with hose	21	Acetoin	0.10	Butter flavored powder
Liquid	Pouring butter emulsion into 1-gallon bottles; cleans pan of butter blend to catch butter drippings.	33	Acetoin	0.06	Butter Emulsion
Powder	Packaging powder product into boxes	33	Acetoin	2.78	Dairy flavored powder
Liquid	Worker used exhaust hood to scoop out butter flavor powder into smaller packages.	10	Acetoin	0.72	Butter flavored powder

Table 8. July Site Visit Personal Task-Based Sampling Results- continued

Area	Task Description	Duration (mins)	Analyte	Result (ppm)	Batch Flavor
Powder	Benchtop liquid pour, Dumping substrate into mixer, Mixing, Packaging, pulling QC sample	17	Acetoin	0.12	Confectionary flavor
Small Spray Dryer	Operating small spray dryer	99	Acetoin	0.14	Dried fruit flavor
Liquid	Benchtop Liquid Pouring	12	Benzaldehyde	0.13	Nut emulsion
Powder	Packaging powder product into boxes	33	Benzaldehyde	0.06	Dairy flavored powder
Liquid	Mixing into stand alone vessel	33	Benzaldehyde	0.05	Tropical fruit flavor
Liquid	Benchtop Pouring	12	Diacetyl	0.27	Nut emulsion
Liquid	Scooping butter from metal bin into boxes; Worker leaned into bin remove all powder	8	Diacetyl	17.38	Butter flavor
Liquid	Benchtop mixing	35	Diacetyl	0.65	Wine flavor
Liquid	Worker prepares for task (setting up boxes, moving equip., etc). Worker scoops powder (one scoop at a time) over head into a mechanical sifter.	61	Diacetyl	9.32	Butter flavored powder
Liquid	Cleaning grinder/sifter (used for butter powder) with hose	21	Diacetyl	0.53	Butter flavored powder
Liquid	Pouring butter emulsion into 1-gallon bottles; cleans pan of butter blend to catch butter drippings.	33	Diacetyl	1.03	Butter emulsion
Powder	Packaging powder product into boxes	33	Diacetyl	4.75	Dairy flavored powder
Liquid	Worker used exhaust hood to scoop out butter flavor powder into smaller packages.	10	Diacetyl	10.05	Butter flavored powder.
Powder	Benchtop liquid pouring, Dumping substrate into mixer, Mixing, Packaging, pulling QC sample	17	Diacetyl	4.84	Confectionary flavor
Small Spray Dryer	Operating small spray dryer	99	Diacetyl	0.11	Dried fruit
Liquid	Benchtop Liquid Pouring	12	Isovaleraldehyde	0.01	Nut emulsion

Table 8. July Site Visit Personal Task-Based Sampling Results- continued

Area	Task Description	Duration (mins)	Analyte	Result (ppm)	Batch Flavor
Powder	Packaging powder product into boxes	33	Isovaleraldehyde	0.01	Dairy flavored powder
Liquid	Benchtop Liquid Pouring	12	Propionaldehyde	0.004	Nut emulsion
Powder	Packaging powder product into boxes	33	Propionaldehyde	0.002	Dairy flavored Powder
Liquid	Mixing into stand alone vessel	33	Propionaldehyde	0.02	Tropical fruit

NOTES:

ppm: parts per million

Table 9. The 100 Most Abundant Compounds Observed in Thermal Desorption Sample Results in Rank Order

November Visit	July Visit
Limonene	Limonene
Ethyl butyrate	Ethyl butyrate
Benzaldehyde	Benzaldehyde
C10H16 terpene, alpha-pinene	Ethyl acetate
Ethyl acetate	Isoamyl acetate (3-methyl-butyl acetate)
Isoamyl acetate (3-methyl-butyl acetate)	Propylene glycol
Butyl butyryl lactate	Diacetyl
Decamethylcyclopentasiloxane	Isovaleraldehyde (3-methylbutanal)
Ethyl propionate	Vanillin
p-Cymene	Ethyl isovalerate (ethyl 3-methyl butyrate)
C10H16 terpene, beta-pinene	C3H4O2 isomer, methyl glyoxal
C10H16 terpene, myrcene	Ethyl propionate
Propylene glycol	Methyl amyl ketone
Methyl amyl ketone	Isovaleraldehyde propylene glycol acetal
Ethyl isovalerate (ethyl 3-methyl butyrate)	Trimethyl pyrazine
Ethyl caproate (hexanoate)	Amyl alcohol
Cinnamaldehyde	Ethyl 2-methyl butyrate
Gamma-Terpinene	C10H16 terpenes (such as thujene, sabinene, fenchene, phellandrene, etc.)
Diacetyl	p-Cymene
Toluene	Gamma-Terpinene
Diethylphthalate	C10H16 terpene, alpha-pinene
2-Methylbutyl acetate	Ethanol
Ethanol	Linalool
Isovaleraldehyde (3-methylbutanal)	Butyl butyryl lactate
Ethyl 2-methyl butyrate	p-Dichlorobenzene
C10H16 terpenes (such as thujene, sabinene, fenchene, phellandrene, etc.)	Ethyl phenyl acetate

Table 9. The 100 Most Abundant Compounds Observed in Thermal Desorption Sample Results in Rank Order - continued

November Visit	July Visit
Hexyl acetate	5-Methylfurfural
Isopropyl myristate	SO2
Pentane	Pentane
Acetic acid	Acetic acid
Methyl salicylate	Benzene/butanol
Trans-anethole	Toluene
Isobutyl acetate	Hexanal
C3H4O2 isomer, methyl glyoxal	Ethyl caproate (hexanoate)
Isoamyl butyrate	C10H16 terpene, beta-pinene
Isopentane	C10H16 terpene, myrcene
Butyric acid	Decane
Dodecane	Menthol
C6 aliphatic hydrocarbons	Allyl caproate
cis 3-Hexen-1-ol	Valeraldehyde propylene glycol acetal
Ethyl benzene/xylene	Ethyl vanillin
Butyl acetate	Isopentane
Decane	Furfural
Isoamyl caprylate (octanoate)	Hexyl acetate
Vanillin	Methyl salicylate/naphthalene/
Benzene/butanol	Isoamyl caprylate (octanoate)
Trichloroethylene	gamma-Nonalactone
Isooctane	C7 aliphatic hydrocarbons
Hexanal	Isoamyl phenyl acetate
Benzyl acetate	Methyl vanillin
SO2	Methylcyclopentane
Methylcyclopentane	Propionic acid
Octane	Isooctane
Furfural	Isobutyl acetate

Table 9. The 100 Most Abundant Compounds Observed in Thermal Desorption Sample Results in Rank Order - continued

November Visit	July Visit
Benzyl alcohol	Octane
C10H14O isomer, carvone	Ethyl valerate
gamma-Nonalactone	Isoamyl butyrate
Methyl cinnamate	Benzyl acetate
Amyl alcohol	Ethyl caprylate (octanoate)
2-Hexenal	Cinnamaldehyde
Ethyl vanillin	Trans-anethole
Styrene	Menthyl acetate
C15H24 isomer, beta-caryophyllene	delta-Decalactone
Ethyl valerate	Butyric acid
Acetoin	Butyl acetate
Propionic acid	Isovaleric acid
Dimethyl styrene isomer	2-Methylbutyl acetate
Ethyl caprate (decanoate)	6-methyl-5-hepten-2-one
Isoamyl alcohol (3-methyl-1-butanol)	Menthone
2-Methylbutanol	Isomenthone
Ethyl lactate	Dodecane
C10H16 terpene, camphene	Isopropyl myristate
C15H24 isomer, alpha-copaene	Methyl ethyl ketone
Ethyl benzoate	Cyclohexane
C10H16O isomers (such as neral, geranial, citral)	Heptane
Hexanoic acid	Isoamyl isovalerate (apple oil)
Isovaleric acid	Methyl caprylate (octanoate)
Linalool	2-Butoxyethanol
delta-Decalactone	nonanal
gamma-Undecalactone	Formaldehyde
Menthol	C6 aliphatic hydrocarbons
Melitol	Acetol

Table 9. The 100 Most Abundant Compounds Observed in Thermal Desorption Sample Results in Rank Order - continued

November Visit	July Visit
Formaldehyde	Cyclohexanone
Ethyl caprylate (octanoate)	Hexanoic acid
Ethyl pelargonate (nonanoate)	Benzyl alcohol
delta-dodecalactone	Tolualdehyde
Ethyl ether	Dimethyl styrene isomer
Hexanol	Maltol
alpha-Terpineol	C ₁₀ H ₁₆ O isomers (such as neral, geranial, citral)
Glyoxal	Menthene
Acetol	Neral/geranial acetates
6-methyl-5-hepten-2-one	Dimethyl anthranilate
Menthone	gamma-Decalactone
Carane	
2-Methylfuran	
Hexane	

NOTES:

This list is not comprehensive and only lists the top 100 compounds.

Figure 1. Facility Layout and November Site Visit Sampling Locations

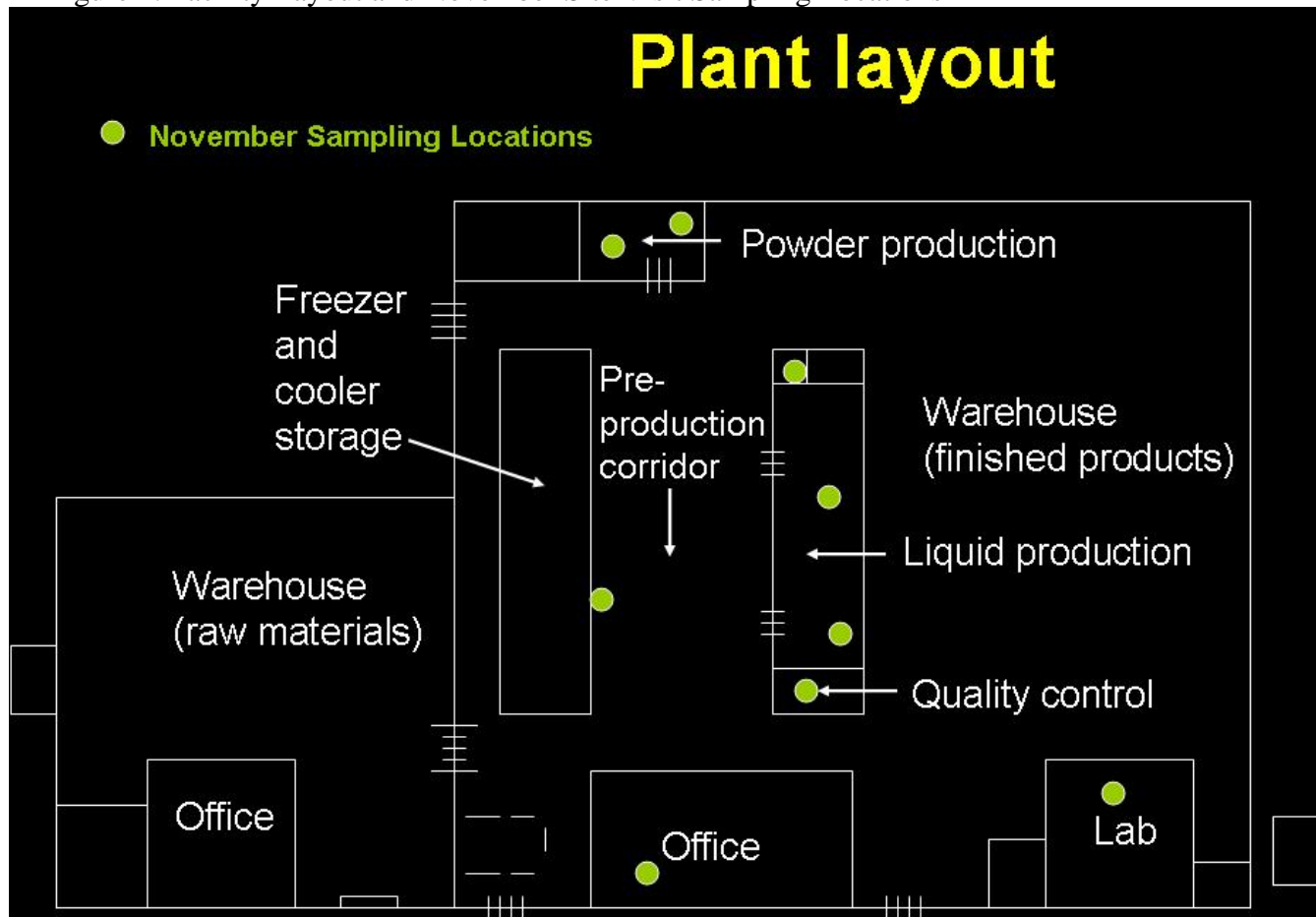


Figure 2. July Site Visit Sampling Locations

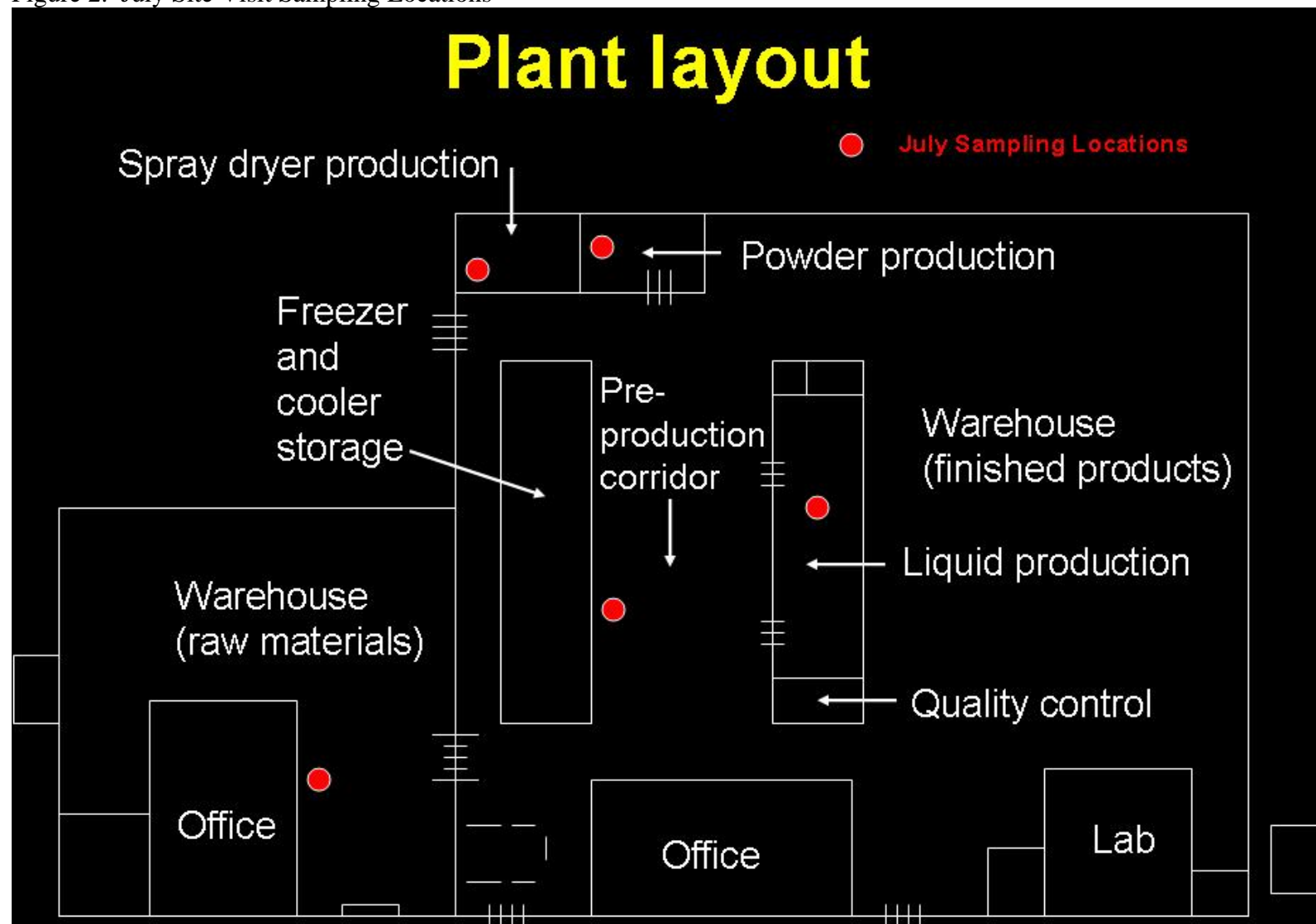


Figure 3. Personal Sampling



Figure 4. Area Sampling



Figure 5. Total Dust and VOC Concentrations in Powder Production Area

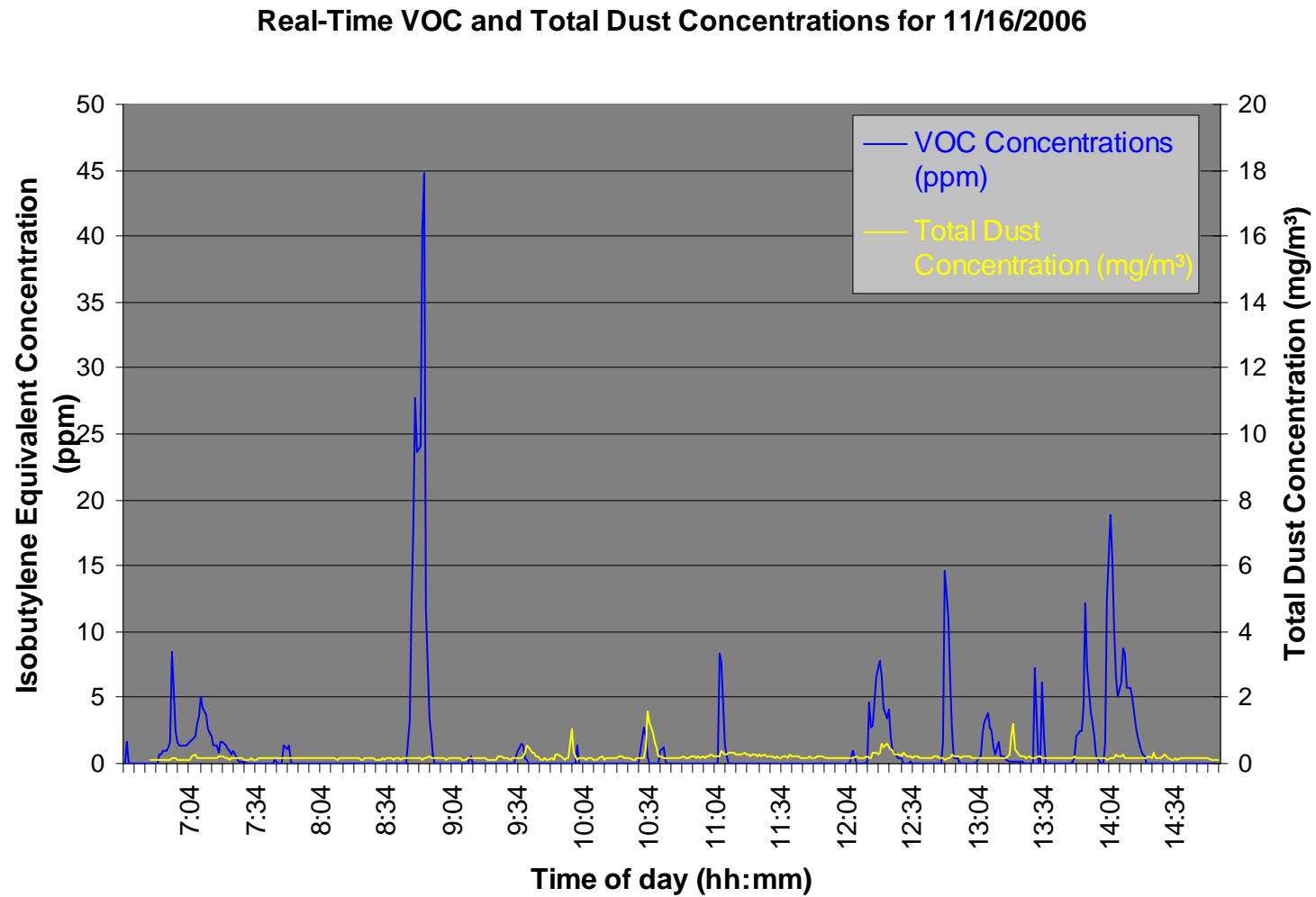


Figure 6.

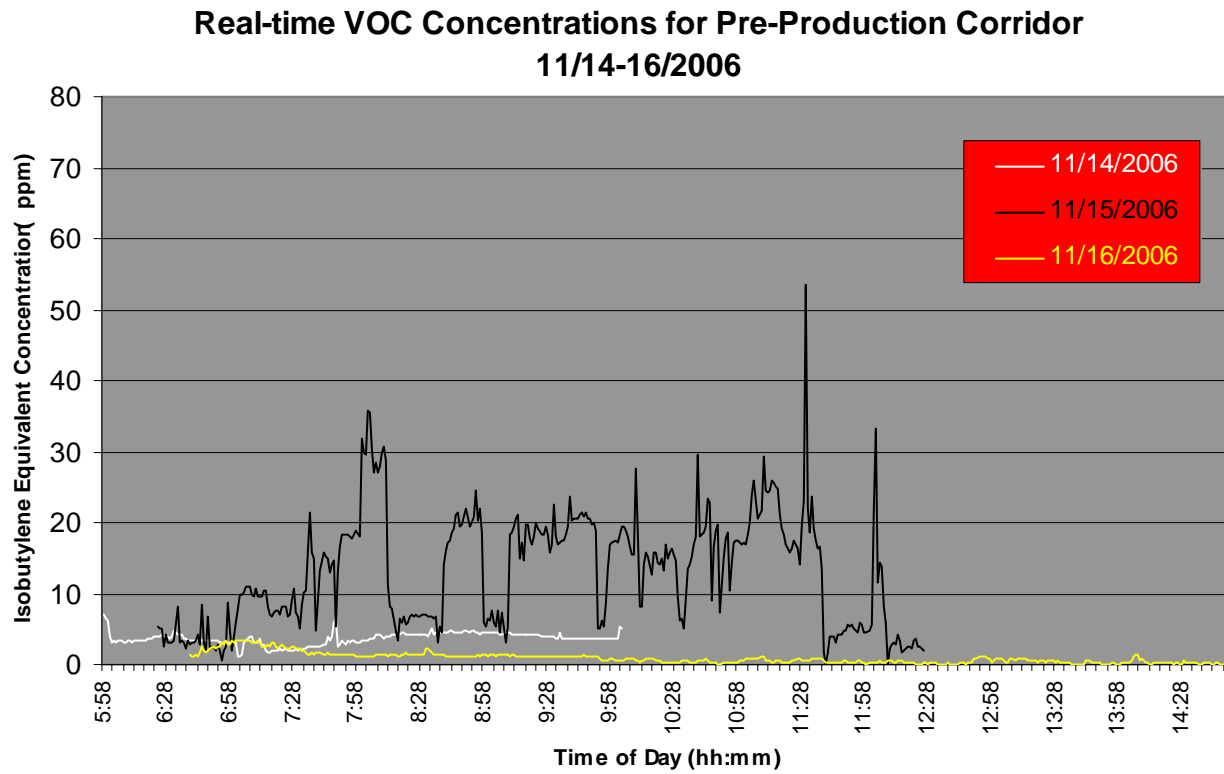


Figure 7. VOC Concentrations in the Liquid Production Area

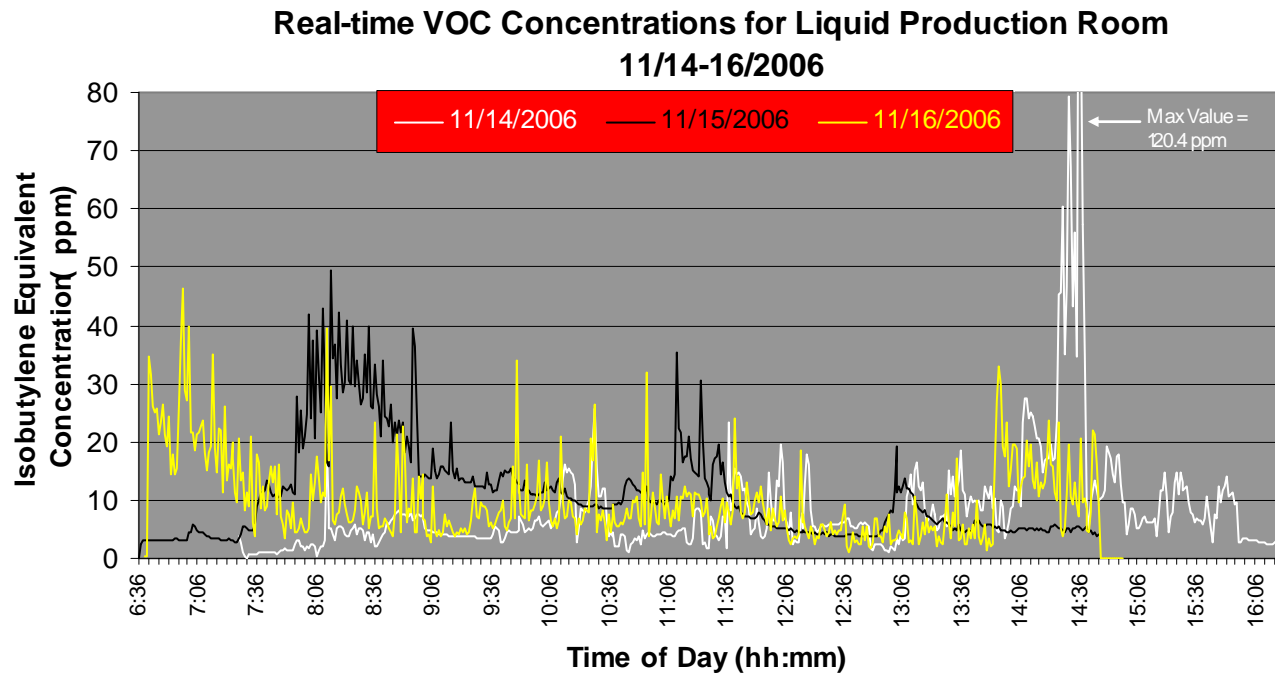


Figure 8. VOC Concentrations in the Powder Production Area

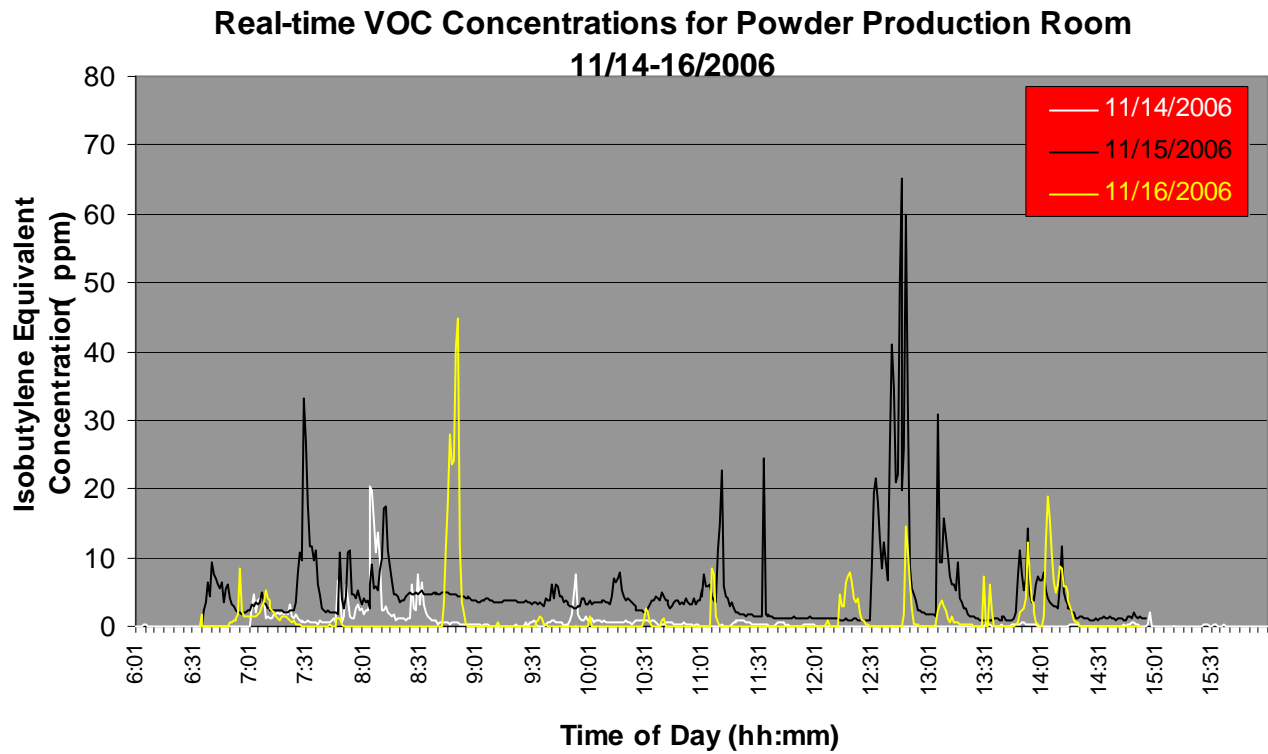


Figure 9. Packaging of butter flavored powder in the ventilated mixing tank booth

