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Occupational Exposure to Flavoring Substances: Health Effects and Hazard Control

Safety and Health Information Bulletin
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This Safety and Health Information Bulletin is not a standard or regulation, and it creates no new legal obligations. The Bulletin contains both recommendations to protect workers and descriptions of relevant mandatory safety and health standards. The recommendations are advisory in nature, informational in content, and are intended to assist employers in providing a safe and healthful workplace. Pursuant to the Occupational Safety and Health Act (OSH Act) (29 U.S.C. 651 et seq.), employers must comply with safety and health standards promulgated by OSHA or by a state with an OSHA-approved state plan. In addition, pursuant to Section 5(a)(1), the General Duty Clause of the Act, employers must provide their employees with a

workplace free from recognized hazards likely to cause death or serious physical harm.

Introduction

This Safety and Health Information Bulletin (SHIB) is addressed to employers and workers involved in the manufacture of "flavorings," (as defined by the Food and Drug Administration (FDA) in 21 CFR 101.22)[1] in flavoring, food and beverage manufacturing. The SHIB provides information about the potential health effects associated with exposure to flavoring substances or its substitutes. It is important that all manufacturers and users of flavorings understand that even though a flavoring is considered safe to eat, it does not mean that the flavoring is also safe to breathe or handle in occupational settings.

Many substances are used in the manufacture of flavorings. Diacetyl is a substance widely used in food and beverage flavorings. Diacetyl is used in a wide variety of food flavorings, although flavor manufacturers have begun to reduce or eliminate the amount of diacetyl in some kinds of flavorings because of health concerns. The principal types of flavorings that use diacetyl are dairy flavors (e.g., butter, cheese, sour cream, egg, and yogurt flavors) and the so-called "brown flavors" (e.g., caramel, butterscotch, brown sugar, maple or coffee flavors). Some fruit flavors (e.g., strawberry and banana) may also contain diacetyl (Table 1). There are also a variety of special uses of diacetyl such as in vanilla, tea, and other flavorings that are difficult to categorize broadly. Industries where some firms are known to use these flavorings include, but are not limited to, candies, snack foods, prepared canned or frozen foods (especially with sauces), some dairy products, bakeries, animal foods, soft drinks, and flavored cooking oils. Some foods (e.g., dairy products, wine and

beer) contain naturally occurring diacetyl.

The occurrence of severe lung disease among workers in workplaces where diacetyl is manufactured and used has led some manufacturers to reduce or eliminate the amount of diacetyl in some kinds of flavorings, foods, and beverages. They have begun to use substitutes such as acetyl propionyl (2,3 pentanedione) and acetoin. These substitutes, some of which are structurally similar to diacetyl, have not been well-studied and there is growing concern that they also pose health risks for workers. There is additional concern that combinations of chemicals may increase the harm.

OSHA does not have permissible exposure limits (PELs) for most flavoring substances, including diacetyl and acetoin. The SHIB provides recommendations for controlling exposure to diacetyl, diacetyl substitutes and other flavorings to protect employees from serious respiratory disease.

Purpose

The purpose of this SHIB is to:

- Help employers understand the steps they must take to provide their workers a safe and healthful work environment free of recognized hazards.
- Provide employers and workers involved in flavorings, food and beverage manufacturing with information about the potential health effects associated with exposure to flavoring substances including diacetyl and diacetyl substitutes.

- Recommend workplace exposure control and medical surveillance measures employers can implement to control and monitor each worker's exposure to flavoring substances.

- Inform employers and workers of applicable mandatory OSHA standards.

Background

In 2000, the Missouri Department of Health and Senior Services and the National Institute for Occupational Safety and Health (NIOSH) conducted an investigation of a microwave popcorn processing plant in Jasper, Missouri. Nine former workers had been diagnosed with a rare, severe lung disease called bronchiolitis obliterans characterized by the finding of fixed airways obstruction on spirometry (a common type of pulmonary function test (PFT)). Five of the former workers had worked in the mixing room where butter flavorings and oil are mixed. The other four had worked on the packaging lines where popcorn and the oil/flavorings mixture are added to microwaveable bags and packaged for shipment. The NIOSH investigation of the plant found that current workers in the plant also had signs and symptoms and lung function abnormalities (fixed airway obstruction) similar to the former workers (1, 2, and 3). Diacetyl, a butter-flavoring chemical, was the predominant chemical isolated from air samples in the facility (1). The investigation of the Jasper plant concluded that there was a risk of occupational lung disease in workers who had inhalation exposure to butter flavoring (2). Five of the nine former workers diagnosed with bronchiolitis obliterans were considered candidates for lung transplants (3). One of the ill workers died in 2006.

By early 2006, NIOSH had investigated five additional microwave

popcorn manufacturing facilities and had documented lung disease in workers similar to that reported at the Jasper plant (4, 5). NIOSH researchers identified workers who had fixed airways obstruction in five of these plants, including workers with clinical findings consistent with bronchiolitis obliterans. The study of these six facilities concluded that workers exposed to butter flavorings were at risk of developing occupational lung disease. The study also concluded that high short-term exposure to butter flavoring may be hazardous, even with low average exposures in the workplace (5).

A recently published study of four microwave popcorn production plants examined the association between diacetyl exposure and decrements (gradual decreases) in pulmonary function among 725 current full-time workers between February 2005 and January 2006 (47). Since April 2003, workers who entered the mixing area were required to wear a powered air-purifying respirator (PAPR). The study found that mixers employed prior to the PAPR requirement were at increased risk of airway obstruction and loss of pulmonary function. These workers had the highest exposure to butter flavoring vapors containing diacetyl. Significant decrements in pulmonary function were not observed among PAPR mixers or non-mixers with lower exposures to the butter flavoring. The authors concluded that "increased exposure to a reactive substance such as diacetyl alone or in combination with other butter flavorings likely increases the risk of obstructive lung diseases including bronchiolitis obliterans in susceptible individuals. Control of exposure to butter flavoring, including diacetyl and other airway reactive flavoring agents, for primary prevention is warranted both in regard to an eight hour workday exposure and short-term peak exposure (47)."

Similar cases of occupational lung disease have been identified in workers in flavoring manufacturing facilities in California. In 2004, a worker in a flavoring manufacturing plant was diagnosed with bronchiolitis obliterans. The published case report stated that diacetyl was considered the cause of the worker's disease although exposure to other flavoring substances may also have contributed (6). In April 2006, another flavoring-manufacturing worker from a second facility in California was diagnosed with bronchiolitis obliterans, and five other workers were found to have lung disease characterized by severe fixed airways obstruction. Six of the seven workers identified in California were flavoring compounders who mixed and handled flavoring substances including diacetyl. The other worker packaged powdered flavorings, some of which included diacetyl (6, 7, and 8). As of April 2007, an additional 22 flavoring manufacturing workers in California were undergoing medical evaluations due to abnormalities found on spirometry. Information from 28 flavoring manufacturing plants in California was evaluated to gain a better understanding of work-related risk factors for development of occupational lung disease (6). NIOSH has also received reports of cases of bronchiolitis obliterans in flavoring-manufacturing facilities in Indiana, Ohio, and New Jersey, and in Maryland after a dimethylphenol spill (6, 11, and 12).

In 2008, a published case report described pulmonary symptoms and non-reversible lung function changes in a worker of a British company that manufactured food flavorings for potato chips. The worker intermittently worked with diacetyl and reported symptoms of chest tightness and shortness of breath four months after an episode in which he was exposed for several hours to a reportedly acute, high concentration of diacetyl. According to the report, the worker's symptoms and decreased lung function did not improve even after removal from the workplace (9).

In addition to flavoring manufacturing and microwave popcorn manufacturing plants, cases of lung disease have also been reported among workers who worked in a chemical plant in the Netherlands that produced diacetyl for the flavoring industry. Besides diacetyl, potential exposures to this group of workers also included acetoin (a chemical structurally similar to diacetyl), acetic acid, acetaldehyde, chlorine, and ammonia. The study identified at least four cases of bronchiolitis obliterans among 206 workers who were exposed during the period of diacetyl production from 1960 - 2003. The authors concluded that the study suggests a causal role of diacetyl in the development of airway injury. However, they could not rule out a possible contribution of acetoin or acetaldehyde as causative or contributing agents (10).

The occurrence of severe fixed airways obstruction, including the rare lung disease bronchiolitis obliterans, demonstrates the potential risk to workers from uncontrolled airborne exposures to certain flavoring substances (4, 5). Flavorings are complex mixtures of chemicals and the inhalational toxicities of many of these substances have not been evaluated (5). Other volatile flavoring substances, in addition to diacetyl, were found in air samples during NIOSH investigations of microwave popcorn plants and flavoring manufacturing facilities. Researchers are currently investigating the role of flavoring substances, including diacetyl and its substitutes, in the development of fixed airways obstruction and bronchiolitis obliterans.

Flavoring Substances

Flavorings can be either natural or man-made substances. Some flavorings are simple and composed of only one chemical, but

many others are complex mixtures of several substances. When properly compounded, these mixtures provide the fragrance and taste perception of a specific flavor, such as butter or strawberry. There are more than 2,000 substances used in flavoring manufacturing (17). The FDA regulates flavorings to ensure they are safe when eaten. Many flavorings have been in longstanding use and are classified by the FDA as "Generally Recognized as Safe" (GRAS) to eat (39). However, the FDA does not require testing for other routes of exposure, such as inhalation.

The Flavor and Extract Manufacturers Association (FEMA), a trade association for the flavorings industry, has identified a number of flavoring substances that may have the potential to pose respiratory hazards in flavoring-manufacturing workplaces (17). These substances are presented in Table 2 with information regarding OSHA permissible exposure limits (PELs) and various analytical methods. Most have applications in addition to use as flavorings. In Table 2, FEMA has identified 34 "high priority" flavoring substances that may pose a respiratory hazard in the workplace and "merit a higher degree of attention" including consideration of work practice controls, engineering controls, and personal protective equipment (PPE). In Table 2, FEMA has also identified 49 " low priority" substances which may pose a respiratory hazard depending on the circumstances of exposure or use (e.g., using very large volumes of a substance or heating or blending a substance in a manner resulting in high air concentrations). In these situations, more attention is recommended regarding workplace exposure control and safety measures (17). Diacetyl, acetoin, and acetaldehyde are examples of FEMA high priority substances found in flavorings and NIOSH investigators have identified these chemicals in microwave popcorn and flavoring manufacturing facilities (2, 5, and 7).

Diacetyl

Diacetyl (2,3-butanedione), a diketone, is used to produce a variety of flavors in foods, particularly dairy flavors (e.g., butter and cheese flavors) and brown flavors (e.g., caramel and butterscotch). It also occurs naturally in some foods (e.g., dairy products, wine, and beer) (17, 18, 19), and may be found in other types of flavorings. For example, a NIOSH investigation of a California flavoring-manufacturing facility found diacetyl was used in the production of a vanilla flavoring powder (7). Table 1 lists a number of flavors that may contain diacetyl. NIOSH identified diacetyl as one of the most common air contaminants found during investigations of microwave popcorn and flavoring manufacturing facilities.

There is no OSHA PEL for diacetyl and there is no NIOSH Recommended Exposure Level (REL). Based on the concerns for worker's safety and health, OSHA has initiated rulemaking on occupational exposure to diacetyl and food flavorings containing diacetyl, pursuant to its authority under Section 6(b) of the OSH Act.

Diacetyl has been detected and used as a marker for flavoring exposure in NIOSH investigations of microwave popcorn and flavoring manufacturing facilities where cases of fixed obstructive lung disease, including bronchiolitis obliterans, have been diagnosed (5, 7). The mean airborne concentration of diacetyl in mixing areas with affected workers (either personal or area measurements) ranged from 0.02 to 37.8 parts per million (ppm).[2] In one plant with an affected worker, the average mixing area air concentration of diacetyl was 0.2 ppm, but real-time monitoring in a worker's breathing zone revealed peak levels of 80 ppm during a process where liquid butter flavor was poured

into heated mixing tanks (5).

Diacetyl Substitutes

According to FEMA, some flavoring manufacturers are using alternative substances for diacetyl in formulating butter flavorings and possibly other food flavorings (48). These compounds are acetoin (discussed in the following section), acetyl propionyl (2,3 pentanedione), and diacetyl trimer. Like diacetyl, these are 'GRAS' substances that are approved for use in food. While it is presently uncertain whether they pose health risks upon inhalation, their chemical structures are very similar to diacetyl. For this reason, precautionary measures including engineering controls, work practice controls and respiratory protection are strongly recommended to protect workers exposed to flavorings that contain diacetyl substitutes (44, 45).

2,3 Pentanedione has been used as a diacetyl alternative in a reformulated liquid buttermilk flavoring (44, 49). 2,3 Pentanedione is structurally related to diacetyl and is considered a respiratory irritant-airway reactive compound. Preliminary studies at NIOSH indicate that inhaled 2,3 pentanedione injures airway epithelium (tissue) in rats, predominately in the nose, but also affects deeper airways (50). Additionally, recent studies at NIEHS indicate that inhaled 2,3 pentanedione causes upper respiratory tract toxicity in rodents with features similar to that of diacetyl (51).

2,3 Hexanedione and 2,3 heptanedione are also structurally related to diacetyl. While both have been suggested as possible substitutes for diacetyl, there are also concerns about the potential for adverse health outcomes (49).

Diacetyl trimer is also a readily available substitute for diacetyl in flavorings. There is concern that diacetyl may be released from the diacetyl trimer under certain manufacturing conditions that involve heat and the presence of water as well as in the moist environment of the respiratory tract after inhalation.

Additional Flavoring Substances Identified

In addition to diacetyl, over 150 volatile organic compounds (VOCs) were identified in a study analyzing emissions from 40 samples of butter flavorings from six microwave popcorn facilities during a 3-year period (26). Air sampling was conducted for diacetyl and for total and respirable dust during the mixing of powder, liquid or paste flavoring with heated soybean oil. This section discusses some of those VOCs.

Acetoin (acetyl methyl carbinol) is a ketone that has been consistently found during investigations of microwave popcorn manufacturing plants. It has also been used to replace diacetyl in flavorings. NIOSH identified acetoin as a predominant chemical in the production room of a California flavoring manufacturing plant. Airborne concentrations in workers' breathing zones ranged from 0.023 ppm to 0.894 ppm (7). Acetoin was also found in the diacetyl chemical manufacturing facility where four workers developed bronchiolitis obliterans (10). Acetoin is very similar in chemical structure to diacetyl. It is anticipated that some diacetyl may be metabolized to acetoin in humans. The National Toxicology Program is conducting inhalation toxicology studies on acetoin as part of a testing nomination for artificial butter flavoring and its ingredients (27). OSHA does not have a PEL for acetoin but the substance is irritating to the skin, eyes, mucous membranes, and respiratory tract (2).

Furfural and acetic acid were also identified during the study of VOCs emitted from butter flavorings sampled (26). Studies of rats exposed to furfural 6 hours/day, 5 days/week for 28 days reported changes in nasal tissue at concentrations as low as OSHA's PEL of 5 ppm for furfural (28). In an earlier study, rats exposed to furfural concentrations of 38 ppm for 1 hour/day; 5 days/week for 30 days had tissue changes in the lungs around the bronchioles and small blood vessels (29).

Acetic acid is irritating to the skin, eyes, and the respiratory tract. In the Jasper microwave popcorn manufacturing plant, acetic acid levels of up to 12.4 ppm were detected in the mixing room (2). NIOSH reported acetic acid was also a predominant airborne chemical in the production room of a California flavoring manufacturing plant, although levels never exceeded the ACGIH TLV, NIOSH REL and OSHA PEL of 10 ppm. (7, 53, and 54).

Acetaldehyde, another common flavoring substance, has been identified in air samples in several microwave popcorn production facilities at concentrations lower than the OSHA PEL of 200 ppm (1, 26). Acetaldehyde is highly irritating to the eye, nose, and throat (2). Occupational exposure to acetaldehyde was reported in a flavor manufacturing facility where five workers developed fixed airways obstruction. One of these workers reported developing respiratory signs and symptoms (shortness of breath and coughing) after pouring acetaldehyde into a flavoring mixture. Two months later the worker developed shortness of breath with exertion and lung function testing indicated that the worker had fixed airways obstruction. Four other workers at this flavoring manufacturing company also developed fixed airways obstruction (4). Diacetyl- containing flavorings were also manufactured at this plant.

In addition to VOCs, respirable dust (i.e., very fine particles less than 10 micrometers in diameter) may be produced from the handling of powdered flavoring formulations or spices. Inhalation of these particles may result in flavoring exposure directly to the small airways of the lung (26).

Health Effects

The initial signs and symptoms of flavoring-related fixed airways obstruction, including bronchiolitis obliterans, may be subtle. The signs and symptoms seen in affected workers include cough, fatigue, and shortness of breath with exertion. Signs and symptoms generally do not improve on weekends or vacations (1, 2). Signs and symptoms may have a gradual onset, but in some cases severe signs and symptoms have occurred suddenly with rapid progression of lung disease (4, 8). Workers may be misdiagnosed with other lung diseases such as asthma or chronic obstructive pulmonary disease (16). Even when diagnosed correctly, workers with flavoring-related fixed airways obstruction, including bronchiolitis obliterans, have not had improved lung function with medical treatment. While a few workers have noticed gradual improvement in their cough several years after removal from flavoring exposure, their pulmonary function generally has not improved and they continue to have shortness of breath with exertion. Some of these workers have developed such severe, disabling lung disease that they have been placed on lung transplant waiting lists (3).

The flavorings related lung disease identified in the NIOSH investigations of popcorn and flavoring-manufacturing plants is usually characterized by findings of fixed airways obstruction on spirometry. Airways obstruction is diagnosed when the person tested has difficulty blowing air out of the lungs. Fixed airways

obstruction means that spirometry shows little or no improvement in lung function after administration of medication (2, 4). Sometimes early loss of lung function may have minimal or no signs or symptoms (4). For example, during a NIOSH investigation of a flavoring facility, one worker had a very large decline in lung function over a 4.5-month period even though this worker did not report any signs or symptoms (8). In addition to fixed airways obstruction, a few workers in both the microwave popcorn and flavoring manufacturing industries have demonstrated lung function tests consistent with restriction, which is a decreased ability to expand the lungs (2, 4, and 8).

Bronchiolitis obliterans is a rare and potentially life-threatening form of obstructive lung disease characterized by cough, shortness of breath with exertion, and spirometry findings of fixed airways obstruction (13). Constrictive bronchiolitis obliterans occurs when the smallest airways of the lung become inflamed and scarred, resulting in thickening and narrowing of the airways. Agents that may cause bronchiolitis obliterans by inhalation include toxic fumes and vapors, grain dusts, mineral dusts, and irritant gases (4, 14, and 15). The diagnosis of bronchiolitis obliterans is usually confirmed by additional medical tests, including paired inspiratory and expiratory high-resolution computerized tomography scans.

In addition to lung disease, exposed workers have also experienced irritation of the eyes, nose, and throat (2, 4, 7, 8, and 42). For example, in a 2007 investigation of a flavoring manufacturing plant NIOSH found "approximately half of the current production and office workers and all current laboratory and warehouse workers reported having experienced nasal irritation. Approximately half of current office workers and warehouse workers and approximately 80% of current production

and laboratory workers reported experiencing eye irritation. Skin problems were most common in current production workers (36%), especially in workers who mostly made liquid flavorings (60%)" (7).

In 2002, NIOSH conducted initial animal exposure studies in which rats were exposed to vapors from a butter flavoring mixture containing diacetyl for a single six-hour period. The rats exposed to butter flavorings with diacetyl levels above 285 ppm were found to have lung airway tissue injury and necrosis (cell death). The authors concluded that acute exposure to butter-flavoring vapors containing diacetyl was capable of causing severe airway injury in laboratory animals (23). A later NIOSH animal study demonstrated a single six-hour exposure to pure diacetyl vapors caused tissue inflammation, injury and necrosis in the nose and large airways of rats (24). Diacetyl vapor exposure at 294.6 ppm or higher, whether administered continuously or as four brief, intense bursts, caused airways injury and inflammation (trachea, bronchi). The airway tissue injury after exposure to pure diacetyl vapors was similar, but somewhat less extensive than the airway damage seen in the rats exposed to butter flavoring vapors in the 2002 study. Based on this finding, it is possible that butter flavoring components other than diacetyl may contribute to the occupational lung disease found in some workers exposed to butter flavorings (5, 24).

A 2008 animal study by the National Institute of Environmental Health Sciences (NIEHS) evaluated repeated inhalational exposures of mice to diacetyl. Both continuous daily six-hour exposure to subchronic diacetyl concentrations (e.g., 100 ppm 12 weeks) and shorter, intermittent exposures to higher levels of diacetyl (e.g., 1,200 ppm twice daily for four weeks) resulted in damage to the nose and larynx as well as inflammation of the

bronchi that occasionally reached the lower airways. The authors concluded that the airways tissue injury and inflammation found in the study supported the hypothesis that occupational exposure to diacetyl may contribute to the development of lung disease in humans (25).

Toxicologic research continues to explore the inhalational toxicity of diacetyl and other butter flavoring chemicals to determine if the airways injury found in the diacetyl animal studies will progress to bronchiolitis obliterans (24, 50-52).

OSHA Recommendations: Introduction

OSHA does not have specific PELs for most substances used for flavorings manufacturing purposes, including diacetyl and acetoin. Based on the findings of lung disease in some flavoring manufacturing workers, OSHA is making recommendations in this document to assist employers in addressing safety and health concerns regarding each workers exposure to butter flavorings and other flavoring substances containing diacetyl or its substitutes. In addition to fixed airways obstruction and bronchiolitis obliterans, other lung diseases including chronic bronchitis and asthma have been reported in workers who work with spices and food flavorings other than butter flavorings and flavorings containing diacetyl (11, 30-32, and 39). OSHA strongly recommends that all flavoring and food manufacturers review and consider implementing applicable recommendations including engineering and work practice control measures, medical surveillance, workplace monitoring, and use of appropriate PPE to minimize each worker's exposure to flavoring substances.

Several sections of this SHIB present important information directed at the control and reduction of exposure to diacetyl, and

food flavorings containing diacetyl or its substitutes. These sections address recommendations for engineering controls and work practices, and applicable OSHA standards that address respiratory protection and PPE. Other sections of the SHIB cover pulmonary function testing, exposure monitoring, and training that are also key components in an overall program to protect the health of workers in flavoring and food manufacturing facilities. There are many different types of flavorings and most have not been tested for respiratory toxicity. Consequently, all facilities that manufacture flavorings and food products should consider applying the safety and health recommendations in this document (2). Flavoring manufacturing facilities are subject to a wide range of OSHA mandatory occupational safety and health standards. Later sections of this SHIB describe applicable OSHA standards that are particularly relevant to protecting workers from potentially hazardous flavoring substances including diacetyl.

Substitution of a less hazardous material is an excellent means of reducing an existing hazard. However, because there is limited hazard information about the occupational toxicity of many flavoring substances in all forms (liquids, pastes, and powders), selecting substitute flavoring compounds should be done with caution (17), and, even after substitution, employers should still consider the use of engineering controls. For example, some alternative substances have chemical structures very similar to diacetyl but have not been tested for their health effects. NIOSH noted in a recent Interim Report that the toxicology of other flavoring ingredients, including diacetyl substitutes, is poorly described and NIOSH concurs with precautionary steps such as engineering controls and respiratory protection to reduce inhalational exposures (44, 45).

A study comparing the concentration of diacetyl emissions from

heated butter flavoring powders, pastes, and liquids found that the heated liquids and pastes produced higher airborne concentrations of diacetyl (26). However, substitution of a flavoring based only on its form as a powder should be done with caution. During a NIOSH investigation of a California flavoring manufacturing plant, the highest airborne exposure to diacetyl and acetoin occurred in the powder flavoring production area (7). Inhalation of respirable particles containing powdered flavoring substances may deliver flavoring substances deep into the lung. Further study is needed to determine the effects of these particles, including their potential to contribute to adverse respiratory effects (26). Employers should minimize each worker's exposure to all forms (powder, liquid or pastes) of diacetyl, butter flavorings, or other flavorings containing diacetyl.

OSHA Recommendations: Engineering and Work Practice Controls

Engineering and work practice controls are the primary methods for controlling exposures to hazardous chemicals in the workplace. Implementation of appropriate control measures is an important aspect of minimizing exposure to hazardous flavoring substances and respirable dust. Examples of important engineering control measures include use of local exhaust ventilation to remove contaminants, isolation of the processes or sources of hazardous materials, and restricted access to areas where hazardous materials are used or stored. Experience has shown that occupational exposure in most situations can be controlled by the use of these methods. Based on findings of severe lung disease in some workers exposed to certain flavorings, OSHA strongly recommends that facilities implement control measures to eliminate or minimize each worker's exposure when they manufacture butter flavorings and other food

flavorings containing diacetyl or its substitutes or food products that use these flavors. Employers also may want to consider engineering and work practice controls when workers are exposed to other flavoring substances.

NIOSH investigations in microwave popcorn manufacturing facilities found a higher prevalence of respiratory symptoms and airways obstruction in workers working in mixing rooms, in areas near or adjacent to open or non-isolated tanks of oil and butter flavorings, and in quality control areas where large numbers (many dozens of bags) of product were popped. After the initial 2000 evaluation, NIOSH conducted seven medical and environmental surveys of a plant in Jasper, Missouri, while control measures were being implemented in the facility. Engineering controls such as isolation of the mixing processes and the heating tanks appeared to protect most workers who were part of the follow-up investigations. NIOSH's January 2006 final report on the Jasper plant investigation states that analysis of the data from these surveys "provide some indication that control of exposures to butter-flavoring substances has decreased the risk to most workers" (2).[3]

Operations or work practices that may expose flavor or food manufacturing workers to intermittent, high concentrations of flavor substances include working in production areas where flavors are manufactured, used, blended, mixed, heated, dried, poured, tested or dispensed into containers (5, 7). While final food products often contain only minute quantities of flavor (a few ppm), food industry workers may be exposed to relatively high concentrations of food flavorings when in the vicinity of the process of adding or mixing flavorings into foods. Food flavorings may be added in dry, paste or liquid forms, and processes for adding flavoring vary widely and include spraying, enrobing

(applying a coating using a process similar to a waterfall) flavorings or mixtures containing flavorings onto products, and simply adding flavorings to tanks and mixers. Food industry workers may also be exposed when flavorings or foods containing flavorings are heated, particularly if large quantities are heated or if heating occurs in an enclosed space.

Facilities that manufacture or use flavorings can vary greatly in size and operations. Not every recommended engineering control or work practice control may be appropriate for every workplace. Respiratory signs and symptoms (i.e., eye, nose, throat or skin irritation) or evidence of lung disease in workers exposed to butter flavorings, diacetyl, or food flavorings containing diacetyl indicate that processes or operations need to be evaluated and may need to be addressed with engineering and work practice controls. Engineering and work practice controls recommended for facilities that manufacture or use flavor substances in powder, paste, and liquid forms are discussed in NIOSH Health Hazard Evaluation Report #2000-0401-2991 (2, 8); NIOSH Alert: Preventing Lung Disease in Workers Who Use or Make Flavorings (4); and FEMA: Respiratory Health and Safety in the Flavor Manufacturing Workplace (17).

Plant engineers, industrial hygienists, and ventilation specialists can provide recommendations to employers on measures to control each worker's exposure to hazardous substances or respirable dust. Additional information on the topics of ventilation and other engineering controls, including specific types of ventilation systems, can be found in several of the sources listed in the references section of this document (8, 33 and 34).

Flavoring and Food Manufacturing Workplaces (17)

Engineering Controls[4]:

- Isolate flavoring production and handling areas with structurally sound walls, doors or other appropriate barriers.
- Provide separate ventilation systems in the production room and all other areas where flavorings or heated flavored products are handled.
- Maintain negative air pressure (0.04". w.g. ± 0.02" w.g. relative to the rest of the plant) in the production room with respect to adjoining or adjacent rooms or areas. This will prevent the migration of contaminated air from the production room to other areas of the plant.
- Install local exhaust ventilation (LEV) systems where powder or liquid flavorings are manually blended, weighed, mixed, poured, transferred, packed, or handled (e.g., ingredient batching tanks, tank or blender filling operations, powder dumping operations, drum pouring operations, quality control operations, and compounding operations). At a minimum, LEV should achieve a capture velocity of 100 feet per minute (fpm) for liquids and a minimum of 200 fpm for powders between the emission source and hood opening.
    - Install an indicator device such as a manometer or pressure gauge fitted on the ducting near the hood inlet to provide a way to verify that the ventilation device is working properly.
    - Use enclosing or partially enclosing hoods such as ventilated workstation benches where possible.
    - Use moveable exhaust hoods (flexible exhaust duct) to capture contaminants when enclosing hoods cannot be used. Care must be taken to position the inlet as close to the process as possible (within at least 6 to 12 inches).

    - Direct ventilation exhaust outside of the plant (away from doors, windows, and air intakes) in a manner that is compliant with environmental regulations.
    - Supply air to replace air exhausted by the LEV. General dilution ventilation is not a substitute for LEV.
- Avoid relying on recirculating filtration systems to control flavor vapors. These systems capture dusts and protect flavor and food integrity but do not protect workers from vapors. In addition, recirculating filtration systems can spread vapors to other parts of the facility.
- Equip the headspace of flavoring blenders and tanks (i.e., where flavorings are compounded, held in pure form, or flavors are processed) with LEV.
    - Ensure LEV is maintained at a minimum of 100 fpm for liquids and 200 fpm for powders across the opening of the tank (face).
    - Alternatively, use closed processes such as pumps and direct piping to transfer ingredients to blenders or tanks, eliminating the need to open them to add ingredients.
- Use general dilution ventilation such as axial flow wall or ceiling fans. (As with LEV, dilution ventilation requires adequate tempered makeup air during extreme temperatures.)
- Reduce the operating temperature of holding and mixing tanks to ambient temperature or the lowest temperature the process will allow.
    - Add flavoring substances at room temperature or, if preheating is necessary, transfer the heated flavoring to the mixing tank using a pumping system rather than manual transfer. These actions will minimize the release of flavoring vapors into the workroom air but are not a substitute for LEV.

- Install tank lids with small openings for adding flavoring substances through funnels. This recommendation is not a substitute for LEV in processes where flavoring substances are added manually.
- Maintain hoppers under negative air pressure at all times while flavorings are added.
    - Maintain a minimum LEV face velocity of 100 fpm for liquids and 200 fpm for powders at the opening of the hopper.
- Install commercially available bag-dumping stations equipped with LEV (e.g., three-sided canopy hood) and bag disposal to reduce dust exposure.
- Control exposure to flavoring powders during collection or dispensing of final product.
    - Secure collection bags to the outlet and use LEV continuous liners to control exposures to flavoring dust and vapors.
- Maintain laboratory hood LEV at a minimum face velocity of 100 fpm for liquids and 200 fpm for powders across the opening of the hood in quality control/quality assurance (QC/QA) areas where flavoring products are compounded or weighed and exposure to vapors or respirable dust may occur.
- Use a closed system cleaning process (e.g., Clean-In-Place) for tanks and blenders.
- Maintain and store volatile flavoring substances (i.e., powders, liquids, and pastes) in a cooled storage facility. An optimum practice would include storing flavoring substances in an area with negative air pressure, preferably in a room with its own air handler.

Work Practice Controls:

- Restrict access to areas where flavorings are mixed, stored, or openly handled only to workers who work in those areas.
- Compound or dispense flavorings when fewer workers are in the area.
- Eliminate flavor weighing and measuring steps by obtaining flavoring substances in sealed pre-measured containers suitably sized for routine production batches. Alternatively, adjust batch size to be compatible with flavoring container size.
    - Produce flavorings under controlled conditions.
- Seal containers tightly when storing or transferring flavorings.
    - Replace lids on empty or partially used containers immediately after adding flavorings in a batch process.
- Pour flavoring substances slowly and use funnels to reduce exposures, splashes, and spillage.
- Minimize manual transfer of flavoring substances. Do not use a shovel to transfer powdered flavoring substances.
- Establish standard procedures to minimize each worker's exposure to flavoring substances when cleaning work areas, tanks, containers, and spills.
    - Promptly clean up spills such as from overflowing tanks or from leaks in seals and fittings.
    - Perform operations requiring workers to enter tanks or containers in compliance with OSHA's Permit-Required Confined Spaces standard (29 CFR 1910.146)
- Do not use compressed air or dry sweeping to clean surfaces and remove powdered flavoring substances because they may become airborne.
- Use room temperature or cold water to pre-rinse mixing containers and tanks before cleaning with hot water or sanitizing. Steam or hot water may release volatile flavoring substances during cleaning.

- Change work clothes and wash skin immediately if flavoring substances are spilled or splashed on them.

OSHA Recommendations: Exposure Monitoring

Flavor and food manufacturing often involves the handling of multiple different flavorings, each composed of multiple substances. Exposure monitoring can provide useful information to employers about each worker's exposure to flavoring substances and whether control measures are working effectively (4). Before conducting exposure monitoring, workplace control measures and work practices should be reviewed. This review will identify processes and work areas where workers may be exposed to flavoring chemicals. An environmental health professional or industrial hygienist can assist employers with this review as well as with conducting appropriate workplace monitoring.[5]

Industries that manufacture flavorings containing diacetyl and/or other butter flavorings; and food manufacturers who use these flavorings should monitor the workplace for airborne diacetyl, 2,3 pentanedione, and acetoin (2, 7). When applicable, air monitoring should also include sampling for particulates (total and respirable dust) and flavoring substances that have OSHA PELs. If appropriate, additional monitoring can include the collection of air samples for other FEMA high priority flavorings (17).

Air samples collected before engineering and work practice controls are implemented can be used to identify areas where such controls may be needed to reduce or eliminate potential exposure to diacetyl and other VOCs. Once controls have been implemented, monitoring at regular intervals can provide

information about the continuing effectiveness of these control measures in reducing exposure to flavoring substances (4, 17).

OSHA strongly recommends that employers collect personal full-shift samples in order to accurately measure workplace air concentrations of diacetyl and acetoin, particulates (total and respirable dust), and other flavoring substances. Personal full-shift monitoring provides information about each worker's exposure during workplace operations. Short-term personal sampling is also recommended for operations that involve open handling of flavoring substances (i.e., pouring, blending, mixing, transfer, and packing operations).

Area sampling is not a substitute for personal sampling. However area sampling can supplement personal sampling by providing information about background concentrations of flavoring substances or measure emissions of diacetyl, acetoin, other VOCs, and dust from specific sources (38). After implementation of engineering controls, area sampling also can be used to provide information about the effectiveness these controls.

OSHA strongly recommends that all areas of the plant be evaluated initially for possible worker exposure to flavoring substances. Exposure monitoring should be conducted if there is a possibility that workers may be exposed to flavoring substances, including butter flavorings, diacetyl, and other food flavorings containing diacetyl. It is of particular importance that air samples be collected in the following processes or areas of the facility:

- Flavoring production rooms;
- Areas where compounding (i.e., mixing/blending) and packing/packaging operations occur;

- Any areas where flavorings are handled manually or openly;
- Any areas/rooms where mixing tanks and storage tanks are located;
- During maintenance and cleaning operations;
- Monitoring in laboratories engaged in the laboratory use of hazardous chemicals which is covered under the Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450). "Laboratory use" means handling and use of the chemicals are done on a laboratory scale (i.e., containers used for handling substances are designed to be easily and safely done by one person), multiple chemicals or chemical procedures are used, the procedures are not part of a production process and do not simulate a production process, and protective laboratory practices and equipment are available and in common use to minimize potential employee exposure (29 CFR 1910.1450(b)). Generally, research laboratories are covered by 29 CFR 1910.1450; and
- QA/QC laboratories, facilities or processes that are adjuncts of production operations and typically perform repetitive procedures for the purpose of assuring reliability of a product or process, which are monitored pursuant to applicable standards at 29 CFR Part 1910 Subpart Z. Most QA/QC laboratories do not come within the scope of 29 CFR 1910.1450.

OSHA's Fully-Validated Sampling and Analytical Methods for Diacetyl and Acetoin

OSHA has two fully-validated air sampling methods for diacetyl and acetoin. Exposures to both chemicals can be determined either separately or simultaneously from the same air sample. Air samples are collected on two one-section sampling tubes

connected in series with flexible tubing. The two sampling tubes must be protected from light during sampling because light will decompose diacetyl and acetoin. A protective tube cover must be used, especially when sampling near food products to prevent glass shards from the air sampler from contaminating the foodstuffs. If the protective tube cover is opaque it may be sufficient to protect the sampling tubes from light, otherwise the sampler should be wrapped with aluminum foil. The two tubes also must be separated, capped, and protected from light with aluminum foil or other opaque material after sampling.

OSHA's two sampling methods, Method 1012 and Method 1013, have been fully validated at two different levels for the analysis of samples. OSHA Method 1012 has been optimized for levels of about 50 parts-per-billion and uses post sampling chemical derivatization and analysis by gas chromatography with electron capture detection. OSHA Method 1013 has been streamlined for levels of about 500 parts-per-billion, and uses solvent extraction and analysis by gas chromatography with flame ionization detection. Samples are stable for at least two weeks before analysis, and up to 80% relative humidity in the sampled air has no effect on sample results when the specified sampling and analytical procedures are followed. A third OSHA method (PV2118) is available, but it is only a partially-validated method; thus, persons wishing to sample for diacetyl may find it more convenient to use either OSHA Method 1012 or Method 1013. Both Methods 1012 and 1013 permit samples to be collected for as short a time as 15 minutes or as long as three hours. Both methods are posted on OSHA’s website; diacetyl; acetoin.

(photo of courtesy of NIOSH)

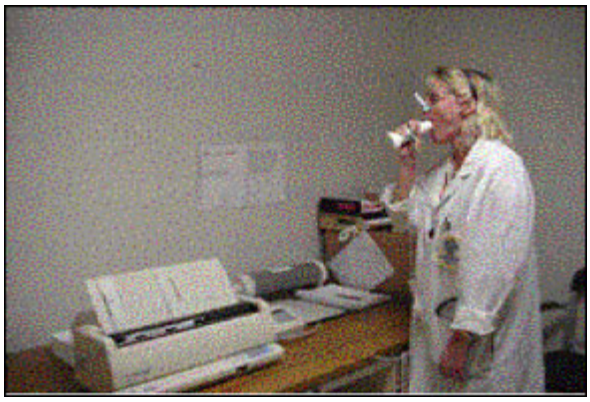
This figure shows how the air sampling device should be connected to the worker when using OSHA Methods 1012 and 1013.

OSHA Recommendations: Medical Surveillance and Spirometry

Establishing a medical surveillance program that includes spirometry will enable employers to identify workers experiencing adverse health effects from exposure to flavorings, including food flavorings containing diacetyl. The goals of medical screening are early identification of exposure-related problems in the workplace and identification of signs and symptoms before they progress to disease (35, 36). Employers can utilize information from medical screening to identify work areas or processes where intervention is needed to prevent or control occupational exposures and adverse health effects (4, 7).

Spirometry measures the breathing capacity of the lungs and is the best available test for early detection of decreasing or abnormal lung function among exposed workers. Spirometry is

particularly important because decreased lung function has been observed before the onset of signs and symptoms in workers exposed to butter flavorings and flavorings containing diacetyl (4). Spirometry should follow criteria established by the American Thoracic Society (ATS) guidelines, which is available through the ATS website [413 KB PDF, 20 pages]. Spirometry should be conducted by technicians who have completed a NIOSH-approved training course. Information about this training can be found at the NIOSH website.



Spirometer

OSHA strongly recommends that employers arrange to provide a medical examination to all newly-hired workers in flavoring and food manufacturing facilities before they start work in areas where butter flavorings, diacetyl, and food flavorings that contain diacetyl are used. The examination should include a health questionnaire focused on respiratory symptoms and a history of preexisting lung disease in order to provide baseline information for comparison during subsequent evaluations. Questionnaires used by NIOSH during investigations of flavoring manufacturing facilities and microwave popcorn manufacturing plants are found in the NIOSH Health Hazard Evaluations (e.g., see Health Hazard Evaluation Report # 2006-0303-3043, Health Hazard Evaluation Report 2003-0112-2949, (7, 42). In addition to the questionnaire, the medical examination should include baseline spirometry

before workers initially begin work in areas where they may be exposed (4). This initial evaluation also provides an opportunity for the healthcare professional to educate new workers about potential workplace hazards and the signs and symptoms (e.g., cough, wheezing and shortness of breath) of occupational lung disease. The examining physician should provide the employer with information about the worker's ability to wear appropriate PPE as well as any specific work restrictions, but must maintain appropriate confidentiality of pre-existing medical conditions.

OSHA strongly recommends, at a minimum, that employers make medical examinations that include spirometry and evaluation (health questionnaire) available every six months for workers who have regular exposure to butter flavorings, diacetyl, and food flavorings containing diacetyl or its substitutes. The six-month periodicity of medical surveillance can be adjusted (shorter or longer) for specific workplace exposures based on recommendations from health professionals who have expertise in occupational lung disease and flavoring exposure. Because of the rapid onset of severe fixed airways obstruction in some exposed workers, decreasing the interval between spirometry tests is indicated if workers report respiratory signs and symptoms, develop spirometry abnormalities, or have an accelerated decline in lung function (4). In those instances where investigations have demonstrated uncontrolled flavoring exposure or evidence of lung disease in workers, NIOSH recommends spirometry testing every three months (4, 7). Abnormal spirometry or respiratory signs and symptoms, such as cough or shortness of breath with exertion, or evidence of eye, nose, throat or skin irritation, may indicate adverse health effects from occupational exposures and indicate a need for further evaluation and workplace investigation (7). Workers should be educated about adverse health problems such as respiratory symptoms and

eye and skin irritation. Because of the severe nature and rapid onset of lung disease in some individuals, it is important that workers are informed of the importance of early reporting of respiratory or other (e.g., eye, skin) signs and symptoms (4).

Workers with respiratory symptoms or evidence of skin or eye irritation should have further medical evaluation (4, 17). Because patients with fixed airways obstruction, including bronchiolitis obliterans, are often misdiagnosed with asthma, bronchitis, or emphysema, it is important that medical surveillance programs be supervised by a healthcare provider familiar with flavoring-related occupational lung disease and include a plan to refer workers with abnormal spirometry or rapidly declining lung function to a specialist (i.e., pulmonologist) for additional evaluation. Also, employers need to provide evaluating physicians with information (i.e., this SHIB) about occupational exposures to flavoring substances and their health risks (37). This will help the evaluating physician correctly diagnose and treat the condition and recommend appropriate workplace restrictions. These recommendations can specify use of PPE (e.g., ability to use a respirator), restriction of each worker's exposure, and frequency of subsequent medical evaluations. It is important that the evaluating healthcare provider(s) communicate recommendations or restrictions in writing to both the worker and the employer (4).

Healthcare providers can get additional information about adverse health effects of flavorings and report suspected cases of flavorings-related lung disease, including bronchiolitis obliterans, at the NIOSH website. Healthcare providers should also report these cases to local and state public health departments.

Applicable OSHA Standards

Facilities that manufacture flavorings or food products containing flavorings are subject to a wide range of OSHA occupational safety and health standards. The following discussion focuses on applicable OSHA standards that are particularly relevant to protecting workers in those facilities from potential hazardous substances.

In addition to OSHA standards, Section 5(a)(1) of the OSH Act (General Duty Clause) requires each employer to "furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm." The General Duty Clause applies where there is no standard regulating the particular hazard.

OSHA Applicable Standards: OSHA PELs

Table Z-1 of 29 CFR §1910.1000 lists exposure limits for a number of hazardous substances that OSHA regulates. Employers who use or manufacture substances listed in Table Z-1 must comply with those exposure limits by means of engineering and work practice controls to the extent feasible (29 CFR 1910.1000(e)). Information about specific contaminants listed in the standard is available at Table Z-1 Limits for Air Contaminants. If airborne concentrations of the hazardous substances remain above the applicable exposure limits after employers have implemented all feasible engineering and work practice controls, then PPE, such as respirators, also must be used. As discussed in the following section, OSHA's Respiratory Protection standard may require employers to provide respirators to protect workers from substances for which no OSHA PEL has been established.

OSHA Applicable Standards: Respiratory Protection

Engineering controls are the preferred method for protecting workers from hazardous respiratory exposures in the workplace. Respirators are the least favored method to protect workers from respiratory hazards, because they are inherently less reliable than engineering and work practice controls. However, if the respiratory hazards remain after employers have implemented all feasible engineering and work practice controls, OSHA's 29 CFR 1910.132 standard requires employers to provide workers with respirators that will protect them from the harmful airborne substances. Employers also must provide respirators while they are in the process of implementing engineering controls, during emergencies, and in other situations where the employer determines respirators are necessary to protect workers. The employer must provide respirators at no cost to employees that are "applicable and suitable for the purpose intended" (29 CFR 1910.132(h), .134(a)(2)).

The NIOSH study of severe lung disease in workers at several microwave popcorn manufacturing plants and flavoring manufacturing facilities demonstrates that certain flavoring substances may pose severe respiratory hazards in some circumstances. Different formulations (powder, liquids or pastes) of butter flavorings, diacetyl, and flavorings containing diacetyl may represent potential respiratory hazards via inhalation of volatile chemicals or respirable particles (31). Accordingly, flavoring and food manufacturing facilities using these substances must determine whether respirators are necessary to protect their workers' health (29 CFR 1910.134(d)). Where a substance is present that may pose a respiratory hazard, the employer must assess the nature and magnitude of the hazard in the conditions

of use in its workplace, considering normal operating conditions and reasonably foreseeable emergencies, and determine whether respirators are necessary. See 29 CFR 1910.134(d)(1)(iii) and 63 Fed. Reg. 1152, 1198-99 (January 8, 1998) (preamble to the Respiratory Protection final rule). This assessment will guide the employer in selecting the appropriate respirator(s).

Employers in flavoring and food manufacturing facilities that manufacture or use flavorings containing diacetyl must conduct the evaluation required by the Respiratory Protection standard (29 CFR 1910.134(d)(1)(iii)). The hazard evaluation requirement is performance-oriented, and the employer may use a variety of estimation techniques to characterize each worker's exposure, depending upon the nature of the substances they use, processes, operating environment, and other factors. The preamble to the Respiratory Protection final rule contains further guidance on the hazard evaluation requirement, and outlines several alternative estimation techniques that may be useful (63 Fed. Reg. 1198-1200, see discussion in Paragraph (d) – Selection of Respirators).

Employers must ensure that the hazard evaluation results in a reasonably accurate estimate of the nature and extent of the respiratory hazards in the workplace (see 29 CFR 1910.134(d)(1)(iii)). Because there is no PEL for diacetyl or its substitutes, employers need to consider a variety of factors when performing their evaluations. They should consider relevant available information from OSHA, NIOSH and other sources on the hazards of diacetyl and other flavoring substances and use informed professional judgment in estimating the nature and magnitude of the hazards to workers under existing plant conditions. Additional information is provided below:

- Information on the health effects of exposure to flavoring substances in microwave popcorn processing plants and flavoring manufacturing facilities is found in this document and the NIOSH investigations of microwave popcorn and flavoring manufacturing plants (2, 4, 7 and 8). Employers should evaluate this and other available relevant information to determine whether their manufacturing processes pose a potential respiratory hazard to workers. Flavor compounding, blending and product packaging processes may be particularly important processes where workers may be exposed to flavorings chemicals (38). However, other production processes where there is potential worker exposure to flavorings dusts, aerosols, and/or vapors should also be evaluated.

- Respiratory signs and symptoms and eye, nose, or throat irritation in exposed workers may be a significant indication of a hazard requiring controls. If workers develop abnormal spirometry findings, have spirometry evidence of accelerated loss of lung function, or are diagnosed with lung disease, employers should take appropriate steps (see section on OSHA Recommendations: Medical Surveillance and Spirometry) to determine whether workers exposed to flavorings have developed respiratory disease. The recommendations in the Medical Surveillance and Spirometry section of this SHIB may assist employers in identifying relevant health effects.

- In performing the hazard evaluation, employers can use a variety of methods to estimate each worker's exposure to airborne concentrations of flavoring substances. OSHA strongly recommends that employers conduct exposure monitoring to measure the concentration of diacetyl and

other potential respiratory hazards in the workplace. Air sampling results may also be used to gauge the effectiveness of environmental and work practice controls in reducing each worker's exposure to flavoring substances. Guidelines for collecting and using air samples are contained in the Exposure Monitoring section of this SHIB, above.[6]

- As part of their investigations of flavoring manufacturing plants, NIOSH recommended the use of respirators for workers who work as flavoring mixers or who work or enter flavoring production areas (7, 8). Given that lung disease has been found in some workers exposed to butter flavorings, diacetyl, and flavorings containing diacetyl, and given that no exposure limits have been established at this time for butter flavorings and diacetyl, OSHA strongly recommends that employers should err on the side of caution when evaluating whether workers need to wear respirators, especially when workers work in such situations as flavoring mixing/blending; packaging; QA/QC laboratories; or near open or non-isolated tanks or containers of butter flavorings, diacetyl, or flavorings containing diacetyl.

As mentioned, employers must select suitable respirators in accordance with the criteria in 29 CFR 1910.134(d)(2) and (3). Based on the NIOSH investigations of microwave popcorn plants and flavorings manufacturing facilities, a NIOSH-certified air-purifying respirator equipped with organic vapor cartridges in combination with particulate filters should provide the minimum recommended level of protection. Supplied-air respirators can also be used in these facilities. Powered air-purifying respirators with organic vapor cartridges and particulate filters are also acceptable alternatives and may be easier for workers to wear in

hot work environments (4). If air-purifying respirators are provided, employers must implement a change-out schedule for canisters and cartridges to ensure that they do not exceed their service life (29 CFR 1910.134(d) (3)(iii)).

Employers must also develop and implement a respiratory protection program outlining how respirators will be selected, used, and maintained. In addition, employers must ensure that workers are trained, medically evaluated, and fit tested before using respiratory protection. The elements required in the written program are outlined in 29 CFR 1910.134(c) (medical evaluation (paragraph (e)), fit testing requirements (paragraph (f), and training and other employee information requirements (paragraph (k)). OSHA has a number of useful resources related to respiratory protection on the Agency's website at www.osha.gov.

Half-mask air-purifying respirator

Spirometer

OSHA Applicable Standards: Eye and Skin Protection

In addition to inhalation hazards, flavorings may also create eye and skin hazards for workers. NIOSH indicated that workers exposed to flavorings may also experience eye, nose, throat, and skin irritation. In some cases, workers have experienced chemical eye burns that have required medical treatment (4). NIOSH identified eye irritation when workers at one microwave popcorn plant were exposed to vapors from a new butter flavoring mixture. These vapors may affect the eyes and skin due to their irritant properties. NIOSH also indicated that workers at the Jasper plant reported the development of skin problems, such as rashes (4). A worker from the Jasper plant developed a severe skin allergy (dermatitis), in addition to his fixed airways obstructive disease (3).

OSHA's PPE standards require employers to assess their workplaces to determine if eye and skin hazards are present, or are likely to be present, that necessitate the use of PPE (29 CFR 1910.132). If such hazards are present, or likely to be present, employers must ensure that employees use the appropriate PPE

to protect their eyes, face, hands, and extremities, depending on the nature of the hazard (29 CFR 1910.132, .133 and .138). The employer is accountable both for the quality of the hazard assessment and for the adequacy of the PPE selected (59 Fed. Reg. 16334, 16336-37 (April 6, 1994) (preamble discussion of 1910.132(d)). In addition, OSHA requires that employers provide their employees with PPE at no cost to the employees when such equipment is necessary to protect employees from job-related injuries, illnesses and fatalities (72 Fed. Reg. 64342 (November 15, 2007)).

Employers should consider a variety of factors when performing their hazard assessments, including the degree of eye and skin exposure to flavorings, relevant information from NIOSH and other sources on the eye and skin hazards associated with flavorings, diacetyl, and butter flavoring substances, and the presence of eye or skin irritation in exposed workers. If the results of the hazard assessment indicate that PPE is necessary to protect workers from eye or skin hazards, the employer must ensure that workers are provided with and use appropriate PPE. Employers must ensure that workers use chemical goggles or other appropriate eye protection when working with diacetyl and food flavorings containing diacetyl or its substitutes when exposure to these substances is likely to cause injury to the eye (29 CFR 1910.133). Goggles that fit over corrective lenses are available. Chemical-resistant gloves and sleeves, or other protection for exposed skin, must be used when handling liquid, paste, or powdered flavoring substances that could cause dermal (skin) injury. The employer must also provide training for each worker required to use PPE as indicated in 29 CFR 1910.132(f). Since flavorings vary among manufacturers, employers should communicate with both their flavoring manufacturer/supplier and glove vendor to select the appropriate glove material.

OSHA Applicable Standards: Hazardous Chemicals in Laboratories

OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450) may apply to certain types of laboratories that use diacetyl or other flavoring chemicals. The standard applies to laboratories that are engaged in the laboratory use of hazardous chemicals. "Laboratory use" means handling and use are done on a laboratory scale (i.e., containers used for handling substances are designed to be easily and safely used by one person), multiple chemicals or chemical procedures are used, the procedures are not part of a production process and do not simulate a production process, and protective laboratory practices and equipment are available and in common use to minimize potential employee exposure (29 CFR 1910.1450(b)). Generally, the standard covers research laboratories but not QA/QC laboratories, facilities and processes that are adjuncts of production operations. Under this standard, a covered laboratory is required to produce a Chemical Hygiene Plan that addresses the specific hazards found in its facility and its approach to control them. The plan contains work practices, procedures, and policies that provide a safe and healthy environment. [29 CFR 1910.1450].

OSHA Applicable Standards: Training

The Hazard Communication standard requires employers to inform and train their employees on the hazards of chemicals in the workplace (29 CFR 1910.1200(h)(3)). Employers must ensure that all Material Safety Data Sheets (MSDSs) are available to workers and must provide training to workers who may be exposed to potentially hazardous flavoring substances. This

training must include information about the potential for respiratory, eye, and skin problems from workplace exposure to flavoring substances, as well as the signs and symptoms of flavoring-related lung disease (see section on Health Effects, above). In addition to training workers on the importance of engineering controls and proper work practices, employers must also train workers on what PPE is appropriate, and when and how to use this PPE. Employers must provide information on the need for, and the limitations, maintenance, and care of, the PPE in accordance with 29 CFR 1910.132 and .134.

Additional information can be found in the OSHA guidance document Hazard Communication Guidance for Diacetyl and Food Flavorings Containing Diacetyl.

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[1]Appendix A

[2] NOTE: Recent investigations suggest that the method (Method 2557 [73 KB PDF, 3 pages]) used by NIOSH to sample diacetyl in the NIOSH studies cited in this bulletin is affected by humidity. Preliminary data suggest that high humidity levels result in an underestimation of true concentrations. A laboratory study {PDF] is underway to investigate these factors and determine whether, and at what humidity levels, this phenomenon occurs.

[3]Additional information and recommendations for employers and employees in the microwave popcorn manufacturing industry can be found in the OSHA Safety and Health Information Bulletin: Respiratory Disease Among Employees in Microwave Popcorn Processing Plants

[4]The references for the ventilation specifications are from *Industrial Ventilation: A Manual of Recommended Practices* (33).

[5] Since the composition of butter flavorings or flavorings containing

diacetyl can vary, workplaces that use these flavorings may need to review material safety data sheets (MSDSs) and if necessary, consult with the flavoring manufacturer to determine the concentration of diacetyl.

[6]OSHA's Salt Lake Technical Center (SLTC) has two fully-validated sampling and analytical methods for diacetyl and acetoin (OSHA Method 1012 and 1013) and recommends that employers use them for conducting air sampling for both diacetyl and/or acetoin. Both methods described in this SHIB are posted on OSHA's website. Currently, NIOSH is reviewing Method 2557 for sampling diacetyl.

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TABLE 1

DIACETYL - BASED FLAVORS

The following flavors may contain diacetyl

Dairy Flavorings	Hybrid Dairy Flavorings (Contains a substantial dairy content)	Brown Flavorings	Alcohol Flavorings	Other Flavorings	Fruit Flavorings
Butter	Butter Pecan	Butterscotch	Brandy	Nutmeg	Strawberry
Cheese	Strawberry Crème	Caramel	Rum	Honey	Cranberry
Cream Cheese	Vanilla Crème	Vanilla	Whisky	Graham Cracker	Raspberry
Cheesecake	Other Crème Flavors	Coffee	Pina Colada	Vinegar	Blackberry
Milk	Root Beer Float	Tea		Meat flavors (e.g. gravy	Boysenberry

Yogurt	Chai	Toffee		Malt	Other berry flavors
Ice Cream		Chocolate (esp. milk chocolate)		Wine	Fruit flavors - nearly any kind (e.g., banana, apple, grape, pear)
Egg		Cocoa		Beer	Cider
Ranch Dressing		Cocoa Butter		Tequila	Tomato
Sour Cream		Maple			
Buttermilk		Brown Sugar			
Mayonnaise		Marshmallow			
		Peanut Butter			
		Praline			
Starter Distillate or Butter Starter Distillate		Hazelnut & other nut flavors			

TABLE 2

FLAVORING SUBSTANCES									
FEMA No. and Priority [1]	**CAS No. and OSHA IMIS [2] No**	**Substance**	**Synonyms**	**PEL**	**IDLH [3]**	**Respiratory Acute [3,4]**	**Analytical Method [2]**	**Sampling Medium [2]**	**Air Volume and Sampling Rate [2]**
1231 Low	78-92-20461	*sec*-Butyl alcohol	2-Butanol; Butylene hydrate; 2-Hydroxybutane; Methyl ethyl carbinol [3]	TWA 150 ppm (450 mg/m^3)	2000 ppm	Irritating to respiratory tract	NIOSH 1401	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2003 High	75-07-00010	Acetaldehyde	Acetic aldehyde; ethanal; ethyl aldehyde [3]	TWA 200 ppm (360 mg/m^3)	2000 ppm	Mildly irritating to respiratory tract	OSHA 68	HMP-coated XAD-2 tube (450/225 mg)	3 L 0.05 L/min
2006 High	64-19-70020	Acetic acid	Acetic acid (aqueous); glacial acetic acid (pure compound); ethanoic acid; methane-carboxylic	TWA 10 ppm (25 mg/m^3)	50 ppm	Pulmonary edema	OSHA PV2119	Charcoal tube (100/50 mg)	48 L 0.2 L/min

			acid [3]						
2008 High	513-86-0 A624	Acetoin	Acetyl methyl carbinol; 1-hydroxyethyl methyl ketone; gamma-hydroxy-beta oxybutane; 3-hydroxy-2,3-butanone; 2,3-butanolone; dimethylketol [2]	None	No Data in NPG		OSHA 1012 or OSHA 1013	Two specially dried silica gel tubes in series (600 mg)	9 L 0.05 L/min 3 L 0.2 L/min
2035 High	870-23-5	Allyl mercaptan	2-Propene-1-thiol [5]	None	No Data in NPG				
2053 High	12124-99-1	Ammonium sulfide	Ammonium sulfide; ammonium sulphide; ammonium hydrogen sulfide; ammonium hydrosulfide; ammonium mercaptan; ammonium sulfhydrate; monoammonium sulfide [6]	None	No Data in NPG	Strong irritant to skin and mucous membranes[5]			
205	123-	Isoamyl	Banana oil;	TWA	1000	Irritati	OSH	Charc	10 L

5 Low	92-21530	acetate	isopentyl acetate; 3-methyl-1-butanol acetate; 3-methylbutyl ester of acetic acid; 3-methyl-butyl ethanoate [3]	100 ppm (525 mg/m^3)	ppm	ng to respiratory tract	APV2142	oal tube (100/50 mg)	0.2 L/min
2057	123-51-31532	Isoamyl alcohol	Primary isoamyl alcohol; fermentation amyl alcohol; fusel oil; isobutyl carbinol; isopentyl alcohol; 3-methyl-1-butanol [3]	TWA 100 ppm (360 mg/m^3)	500 ppm	Irritating to respiratory tract	NIOSH 1402	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2127 High	100-52-7B105	Benzaldehyde	Benzoic aldehyde; benzenecarbonyl; benzene carbaldehyde [3]	None	No Data in NPG				
2147 Low	100-53-8	Benzyl mercaptan	a-Toluenethiol; benzylthiol [5]	None	No Data in NPG	Toxic by inhalation and ingestion;			

						irritant to tissue [5]			
2170 Low	78-93-30430	2-Butanone	Ethyl methyl ketone; MEK; methyl acetone; methyl ethyl ketone [3]	TWA 200 ppm (590 mg/m^3)	3000 ppm	Irritating to respiratory tract	OSHA 1004	Anasorb CMS (150/75 mg) SKC 575-002 Passive Sampler 3M 3520 Organic Vapor Monitor	12 L 0.05 L/min 5 to 240 min 5 to 240 min
2174 Low	123-86-40440	Butyl acetate	n-Butyl acetate; n-butyl ester of acetic acid; butyl ethanoate [3]	TWA 150 ppm (710 mg/m^3)	1700 ppm [10 %LEL]	Irritating to respiratory tract	OSHA 1009	Charcoal tube (100/50 mg) SKC 575-	10 L 0.2 L/min 15-240 min

								002 Passive Sampler 3M 3520 Organic Vapor Monitor	15-240 min
2175 Low	110-19-0 1534	Isobutyl acetate	Isobutyl ester of acetic acid; 2-methylpropyl acetate; 2-methylpropyl ester of acetic acid; b-methylpropyl ethanoate [3]	TWA 150 ppm (700 mg/m^3)	1300 ppm [10 %LEL]	Irritating to respiratory tract	OSHA 1009	Charcoal tube (100/50 mg) SKC 575-002 Passive Sampler 3M 3520 Organic Vapor Monitor	10 L 0.2 L/min 15-240 min 15-240 min
217	71-36-3	Butyl alcohol	n-Butyl alcohol; 1-	TWA 100	1400 ppm	Irritating to	NIOSH	Charcoal	10 L 0.2

8 Low	0460		butanol; n-butanol; 1-hydroxy-butane; n-propyl carbinol [3]	ppm (300 mg/m^3)	[10 %LEL]	respiratory tract	1401	tube (100/50 mg)	L/min
2179 Low	78-83-1 1536	Isobutyl alcohol	IBA; isobutanol; isopropylcarbinol; 2-methyl-1-propanol [3]	TWA 100 ppm (300 mg/m^3)	1600 ppm	Irritating to respiratory tract	NIOSH 1401	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2219 Low	123-72-8	Butyraldehyde	Butaldehyde; *n*-butanal; *n*-butylaldehyde; butyric aldehyde [5]	None	No Data in NPG		NIOSH 2539 (OSHA modified)	HMP-coated XAD-2 tube (150/75 mg)	5 L 0.05 L/min
2220 High	78-84-2 R237	Isobutyraldehyde	2-Methylpropanal; isobutyric aldehyde; isopropylformaldehyde; isobutnal; methyl propanal; valine aldehyde; isobutaldehyde; 2-methylpropion	None	No Data in NPG		NIOSH 2539 (OSHA modified)	HMP-coated XAD-2 tube (150/75 mg)	5 L 0.05 L/min

			aldehyde [3]						
2221 High	107-92-6 B709	Butyric acid	Butanoic acid; ethylacetic acid; propylformic acid [3]	None	No Data in NPG		SLTC in-house literature file	Silica Gel tube (520/260 mg)	18 L 0.1 L/min
2222 High	79-31-2	Isobutyric acid	2-Methylpropanoic acid [3]	None	No Data in NPG				
2230 Low	76-22-2 0522	Camphor	2-Camphonone; Synthetic camphor; Gum camphor; Laurel camphor [3]	2 mg/m^3	200 mg/m^3	Irritating to respiratory tract, skin, and eyes	NIOSH 1301	Charcoal tube (100/50 mg)	24 L 0.2 L/min
2286 Low	104-55-2	Cinnamaldehyde	3-Phenylpropenal; cinnamyl aldehyde; cinnamic aldehyde[5]	None	No Data in NPG				
2370 High	431-03-8 D740	Diacetyl	Biacetyl; 2,3-butanedione; 2,3-diketobutane; dimethyldiketone; dimethylglyoxal; glyoxal, dimethyl [2]	No PEL	No Data in NPG		OSHA PV2187	Two silica gel tubes in-series (150/75 mg	3 L 0.05 L/min

								each)	
2370 High	431-03-8 D740	Diacetyl	Biacetyl; 2,3-butanedione; 2,3-diketobutane; dimethyldiketone; dimethylglyoxal; glyoxal, dimethyl [2]	No PEL	No Data in NPG		OSHA 1012 or OSHA 1013	Two specially dried silica gel tubes in series (600 mg)	9 L 0.05 L/min 3 L 0.2 L/min
2414 Low	141-78-6 1040	Ethyl acetate	Acetic ester; acetic ether; ethyl ester of acetic acid; ethyl ethanoate [3]	TWA 400 ppm (1400 mg/m^3)	2000 ppm [10 %LEL]	Irritating to respiratory tract	NIOSH 1457	Charcoal tube (100/50 mg); ship cold to lab	6 L 0.2 L/min
2418 High	140-88-5 1050	Ethyl acrylate	Ethyl acrylate (inhibited); ethyl ester of acrylic acid; ethyl propenoate [3]	TWA 25 ppm (100 mg/m^3) [skin]	Ca [300 ppm]	Irritating to respiratory tract	OSHA 92	TBC coated Charcoal tube (110/55 mg)	12 L 0.05 L/min
2419 Low	64-17-5 1060	Ethyl alcohol	Alcohol; ethanol; EtOH; grain alcohol;	TWA 1000 ppm (1900	3300 ppm [10 %LE	Irritating to respiratory	OSHA 100	Two Anasorb 747	12L 0.05 L/min

			cologne spirit [3]	mg/m^3)	L]	tract		tubes in-series (400/200 mg); separate tubes after sampling	
2434 Low	109-94-4 1155	Ethyl formate	Ethyl ester of formic acid; ethyl methanoate [3]	TWA 100 ppm (300 mg/m^3)	1500 ppm	Irritating to respiratory tract	NIOSH 1452	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2487 High	64-18-6 1310	Formic acid	Formic acid (85%–95% in aqueous solution); hydrogen carboxylic acid; methanoic acid [3]	TWA 5 ppm (9 mg/m^3)	30 ppm	Corrosive, Pulmonary edema	OSHA ID 186SG	Charcoal tube (400/200 mg) ship cold to lab	48 L 0.2 L/min
2489 High	98-01-1 1325	Furfural	Fural; 2-furancarboxaldehyde; furfuraldehyde; 2-furfuraldehyde [3]	TWA 5 ppm (20 mg/m^3) [skin]	100 ppm	Irritating to respiratory tract	OSHA 72	Petroleum-base Charcoal tube (100/50)	180 L 1.0 L/min

2491 Low	98-00-01330	Furfuryl alcohol	2-Furylmethanol; 2-hydroxymethylfuran [3]	TWA 50 ppm (200 mg/m^3)	75 ppm	Irritating to respiratory tract	NIOSH 2505	Porapak Q tube (150/75 mg)	25 L 0.05 L/min
2525	56-81-5 1363	Glycerol	Glycerin (anhydrous); glycyl alcohol; 1,2,3-propanetriol; trihydroxypropane [3]	TWA 15 mg/m^3(total) TWA 5 mg/m^3(resp)	No Data in NPG	Irritating to respiratory tract	OSHA PV2121	Tared 37-mm low-ash PCV filter	960 L 2.0 L/min (Total Dust) 10-mm Nylon Clycl one; 816 L 1.7 L/min (Respirable Fraction)
2544	110-43-0 1675	2-Heptanone	Amyl methyl ketone; n-amyl methyl ketone; methyl (n-amyl) ketone [3]	TWA 100 ppm (465 mg/m^3)	800 ppm	Irritating to respiratory tract	NIOSH 1301	Charcoal tube (100/50 mg)	25 L 0.2 L/min

2676 Low	79-20-91650	Methyl acetate	Methyl ester of acetic acid; methyl ethanoate [3]	TWA 200 ppm (610 mg/m^3)	3100 ppm [10 %LEL]	Irritating to respiratory tract	NIOSH 1458	Charcoal tube (100/50 mg)	7 L 0.2 L/min
2691 Low	96-17-3	2-Methylbutr-aldehyde	2-Methylbutanal [5]	None	No Data in NPG				
2692 Low	590-86-3 I201	3-Methylbutyr-aldehyde	Isovaleral; isovaleral; isovaleric aldehyde; 3-methylbutyraldehyde [5]	None	No Data in NPG		SLTC in-house literature file	Three DNPH-coated filters; two stacked, one separated by a cassette ring; store collected samples in dark	3 L 0.05 L/min
2716	74-93-1	Methyl mercapt	Mercaptomethane;	C 10 ppm	150 ppm	Irritating to	OSHA 26	Mercuric	20 L 0.2

High	1643	an	methanethiol; methyl sulfhydrate [3]	(20 mg/m^3)		respiratory tract		acetate-coated 37-mm glass fiber filter	L/min
2731 Low	108-10-1385	4-Methyl-2-pentanone	Isobutyl methyl ketone; methyl isobutyl ketone; MIBK; hexone [3]	TWA 100 ppm (410 mg/m^3)	500 ppm	Irritating to respiratory tract	OSHA 1004	Anasorb CMS (150/75 mg) SKC 575-002 Passive Sampler 3M 3520 Organic Vapor Monitor	12 L 0.05 L/min 5 to 240 min 5 to 240 min
2742 Low	554-12-1	Methyl propionate	Propionic acid, methyl ester; methyl propanoate; methyl propylate; propanoic	None	No Data in NPG				

			acid, methyl ester [6]						
2746 High	75-18-3 D650	Methyl sulfide	Dimethyl sulfide; dimethyl sulphide; thiobismethane; DMS; methylthiomethane; 2-thiopropane; 2-thiapropane [3]	None	No Data in NPG		SLTC in-house literature file	Charcoal tube (100/50 mg)	5 L 0.1 L/min
2841	600-14-6 P110	2,3-Pentanedione	Acetyl propanal; acetyl propionyl; β,γ-dioxopentane; beta, gama-dioxopentane; 2,3-pentadione [2]	None	No Data in NPG		OSHA 1016 (in-review as of 07-2010)	Two specially dried silica gel tubes in series (600 mg)	10 L 0.05 L/min 3 L 0.2 L/min
2842 Low	107-87-9 2010	2-Pentanone	Ethyl acetone; methyl propyl ketone; MPK [3]	TWA 200 ppm (700 mg/m^3)	1500 ppm	Irritating to respiratory tract	NIOSH 1300	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2908 High	110-89-4 R269	Piperidine	Cyclopentimine; azacyclohexane; cypentil;	None	No Data in NPG				

			hexahydropyridine; hexazane; pentamethyleneimine; pentaethyleneimine;pyridine, hexahydro [3]						
2923 High	123-38-6 P129	Propionaldehyde	Propanal; propyl aldehyde; propionic aldehyde [5]	None	No Data in NPG	suffocating odor [5]	NIOSH 2539 (OSHA modified)	HMP-coated XAD-2 tube (150/75 mg)	5 L 0.05 L/min
2925 Low	109-60-4 2180	Propyl acetate	n-Propyl acetate; n-propyl ester of acetic acid [3]	TWA 200 ppm (840 mg/m^3)	1700 ppm	Irritating to respiratory tract	NIOSH 1450	Charcoal tube (100/50 mg)	10 L 0.2 L/min
2926 Low	108-21-4 1540	Isopropyl acetate	Isopropyl ester of acetic acid; 1-methylethyl ester of acetic acid; 2-propyl acetate [3]	TWA 250 ppm (950 mg/m^3)	1800 ppm	Irritating to respiratory tract	NIOSH 1454	Charcoal tube (100/50 mg)	9 L 0.2 L/min
2928 Low	71-23-8 2170	Propyl alcohol	n-Propyl alcohol; ethyl carbinol; 1-propanol; n-	TWA 200 ppm (500	800 ppm	Irritating to respiratory	NIOSH 1401	Charcoal tube (100/	10 L 0.2 L/min

			propanol [3]	mg/m^3)		tract		50 mg)	
2929 Low	67-63-01560	Isopropyl alcohol	Dimethyl carbinol; IPA; isopropanol; 2-propanol; sec-propyl alcohol; rubbing alcohol [3]	TWA 400 ppm (980 mg/m^3)	2000 ppm [10 %LEL]	Irritating to respiratory tract	OSHA 109	Two Anasorb 747 tubes in-series (400/200 mg); separate tubes after sampling; ship cold to lab	18 L 0.2 L/min
2943 Low	110-74-7	Propyl formate	Pormic acid, propyl ester; propyl methanoate; propylformate [6]	None	No Data in NPG				
2944 Low	625-55-8	Isopropyl formate	Formic acid, isopropyl ester; isopropyl formate; isopropyl methanoate; isopropylform	None	No Data in NPG				

			ate [6]						
2966 High	110-86-1 2220	Pyridine	Azabenzene; azine [3]	TWA 5 ppm (15 mg/m^3)	1000 ppm	Irritating to respiratory tract	SLTC in-house file	Two XAD-7 tubes in-series (100/50 mg); separate tubes after sampling	10 L 0.1 L/min
3039 High	7446-09-5 2290	Sulfur dioxide	Sulfurous acid anhydride; sulfurous oxide; sulfur oxide [3]	TWA 5 ppm (13 mg/m^3)	100 ppm	Irritating to respiratory tract	NIOSH 6004 Use OSHA 1011 if also sampling for hydrogen sulfide	MCEF filter followed by Na2CO3 - coated cellulose filter Special sampling tube containing uncoa	200 L 1.5 L/min 12 L 0.05 L/min 7.5 L 0.5 L/min ceiling 5 L 0.5 L/min

								ted GFF followed by Na2CO3 - coated GFF followed by two AgNO3 - coated silica gel beds (200/200 mg)	H2S peak
3173 Low	5077-67-8	1-Hydroxy-2-butanone		None	No Data in NPG				
3217 High	764-40-9	2,4 Pentadienal		None	No Data in NPG				
3218 High	764-39-6	2-Pentenal		None	No Data in NPG				
321	107-	Isopenty	1-Amino-3-	None	No				

9 High	85-7	lamine	methylbutane [6]		Data in NPG				
3223 High	108-95-2 2040	Phenol	Carbolic acid; hydroxybenzene; monohydroxy-benzene; phenyl alcohol; phenyl hydroxide [3]	TWA 5 ppm (19 mg/m^3) [skin]	250 ppm	Corrosive, Pulmonary edema	OSHA 32	XAD-7 tube (100/50 mg)	24 L 0.1 L/min
3233 Low	100-42-5 2280	Styrene	Ethenyl benzene; phenylethylene; styrene monomer; styrol; vinyl benzene [3]	TWA 100 ppm Ceiling 200 ppm 600 ppm (5-minute maximum peak in any 3 hours)	700 ppm	Irritating to respiratory tract	OSHA 89 OSHA 1014	TBC-coated Charcoal tube (100/50 mg) SKC 575-006 Passive Sampler 3M 3520 Organic Vapor Monitor	12 L 0.05 L/min 15 to 240 min 15 to 240 min

3326 Low	67-64-10040	Acetone	Dimethyl ketone; ketone propane; 2-propanone [3]	TWA 1000 ppm (2400 mg/m^3)	2500 ppm [10 %LEL]	Irritating to respiratory tract	OSHA 69	Carbosieve S-III tube (130/65 mg)	3 L0.05 L/min
3368 Low	141-79-71635	4-Methyl-3-penten-2-one	Isobutenyl methyl ketone; isopropylidene acetone; methyl isobutenyl ketone; mesityl oxide [3]	TWA 25 ppm (100 mg/m^3)	1400 ppm [10 %LEL]	Irritating to respiratory tract	NIOSH 1301	Charcoal tube (100/50 mg)	10 L 0.2 L/min
3382 Low	1629-58-9	1-Penten-3-one	Ethyl vinyl ketone [6]	None	No Data in NPG				
3407 Low	497-70-0	2-Methyl-2-butenal		None	No Data in NPG				
3417 Low	625-33-2	3-Penten-2-one	Ethylidene acetone; methyl propenyl keto [6]	None	No Data in NPG				
3478 Low	109-79-50480	1-Butanethiol	Butanethiol; n-butanethiol; 1-mercaptobutane; n-butyl mercaptan [3]	TWA 10 ppm (35 mg/m^3)	500 ppm	Irritating to respiratory tract	SLTC in-house literature	Mercuric acetate-coated 37-	20 L 0.2 L/min

							file	mm glass fiber filter	
3521 High	107-03-9	Propanethiol	3-Mercapto-propane;propane-1-thio;propyl mercaptan; n-propyl mercaptan [3]	None	No Data in NPG				
3523 High	123-75-1	Pyrrolidine	Azacyclopentane, prolamine, pyrrole, tetrahydro-; tetrahydropyrrole, tetramethyleneimi [6]	None	No Data in NPG				
3536 Low	624-92-0	Dimethyl disulfide	Methyl disulfide; dimethyl disulfide; dimethyldisulphide, dimethyldisulfide, disulphide, dimethyl; disulfide, dimethyl; 2, 3-dithiabutane; DMDS Evolution [6]	None	No Data in NPG		SLTC in-house literature file	Charcoal tube (100/50 mg)	10 L 0.1 L/min

3537	108-83-8 0924	2,6-Dimethyl-4-heptanone	Diisobutyl ketone; DIBK; sym-diisopropyl acetone; isovalerone; valerone [3]	TWA 50 ppm (290 mg/m^3)	500 ppm	Irritating to respiratory tract	NIOSH 1300	Charcoal tube (100/50 mg)	25 L 0.2 L/min
3553 Low	78-59-1 1538	Isophorone	Isoacetophorone; 3,5,5-trimethyl-2-cyclohexenone; 3,5,5-trimethyl-2-cyclohexen-1-one [3]	TWA 25 ppm (140 mg/m^3)	200 ppm	Irritating to respiratory tract	NIOSH 2508	Petroleum-based Charcoal tube (100/50 mg)	12 L 0.2 L/min
3584 Low	616-25-1	1-Penten-3-ol	Ethyl vinyl carbinol; 1-pentenol-3 [6]	None	No Data in NPG				
3646 Low	107-86-8	3-Methyl-2-butenal	3-Methyl-2-butenal; 3, 3-dimethylacrylaldehyde; 3, 3-dimethylacrolein; 3-methylcrotonaldehyde; senecioaldehyde [6]	None	No Data in NPG				
3647 Low	556-82-1	3-Methyl-2-buten-1-ol	2-Buten-1-ol, 3-methyl-; dimethylallyl alcohol;	None	No Data in NPG				

			gamma, gamma-dimethylallyl alcohol; 3, 3-dimethylallyl alcohol; prenol; prenyl alcohol [6]						
3667 Low	101-84-8 2047	Diphenyl ether	Diphenyl oxide; phenoxy benzene; phenyl oxide; phenyl ether [3]	TWA 1 ppm (7 mg/m^3)	100 ppm	Irritating to respiratory tract	SLTC in-house file	XAD-7 tube (100/50 mg)	20 L 0.2 L/min
3779 High	7783-06-4 1480	Hydrogen sulfide	Hydrosulfuric acid; sewer gas; sulfuretted hydrogen [3]	C 20 ppm 50 ppm [10-minute maximum peak]	100 ppm	Irritating to respiratory tract, Pulmonary edema	OSHA 1008	Special sampling tube containing uncoated GFF followed by Na2CO3 -coated GFF followed by two AgNO3 -	12 L 0.05 L/min 7.5 L 0.5 L/min ceiling 5 L 0.5 L/min Peak

								coated silica gel beds (200/200 mg)	
3860 Low	624-89-5	Methyl ethyl sulfide		None	No Data in NPG				
3897 High	75-33-2 S248	2-Propanethiol	Isopropanethiol; 2-propanethion; 2-mercaptopropane [3]	None	No Data in NPG				
3898 High	5724-81-2	1-Pyroroline		None	No Data in NPG				
3909 Low	108-94-1 0830	Cyclohexanone	Anone; cyclohexyl ketone; pimelic ketone [3]	TWA 50 ppm (200 mg/m^3)	700 ppm	Irritating to respiratory tract	OSHA 1	Chromosorb 106 tube (100/50 mg)	10 L 0.2 L/min
3946 Low	583-60-8 1765	2-Methylcyclo-hexanone	*o*-Methylcyclohexanone [3]	TWA 100 ppm (460 mg/m	600 ppm	Irritating to respiratory tract	NIOSH 2521	Porapak Q tube (150/75	6 L 0.05 L/min

				^{3}) [skin]				mg)	
3965 Low	78-96-6 A606	1-Amino-2-Propanol	Isopropanolamine; 1-aminopropan-2-ol; aminopropyl alcohol; 2-hydroxypropylamine [3]	None	No Data in NPG		OSHA PV2122	NTIC-coated XAD-2 tube (80/40 mg)	20 L 0.1 L/min
	Not applicable 9135	Particulates not otherwise regulated (Total Dust)	PNOR (Total Dust)	15 mg/m^{3}			OSHA PV2121	Tared 37-mm low-ash PCV filter	960 L 2.0 L/min
	Not applicable 9130	Particulates not otherwise regulated (Respirable Fraction)	PNOR (Respirable Fraction)	5 mg/m^{3}			OSHA PV2121	Tared 37-mm low-ash PCV filter	10-mm Nylon Cyclone; 816 L 1.7 L/min

† OSHA Method PV2118 is suitable for diacetyl, but it would be more convenient to use either OSHA Method 1012 or Method 1013 posted on OSHA's website (diacetyl); (acetoin).

Notes: [1] The high/low Priority notations were assigned by the Flavoring Extract Manufacturers Association (FEMA). The priority

levels were assigned based on inhalation exposure data, chemical structure, and volatility. FEMA stated that the higher priority chemicals pose a greater risk of respiratory injury, whereas, the lower priority chemicals pose a hazard only in more extreme circumstances of exposure.

NPG = NIOSH Pocket Guide to Chemical Hazards (referenced below)

References:

[2] OSHA Chemical Sampling Information

[3] NIOSH Pocket Guide to Chemical Hazards

[4] International Chemical Safety Cards

[5] Lewis, R.J. Hawley's Condensed Chemical Dictionary, 14th Edition [CD-ROM] Wiley Interscience: New York, 2002.

[6]ChemWatch Material Data Safety Sheet. http://osha.chemwatch.us/" (accessed May 22, 2007 by paid subscription).

APPENDIX A

[Code of Federal Regulations]
[Title 21, Volume 2]
[Revised as of April 1, 2009]
[CITE: 21CFR101.22]

TITLE 21 --FOOD AND DRUGS
CHAPTER I--FOOD AND DRUG ADMINISTRATION
DEPARTMENT OF HEALTH AND HUMAN SERVICES
SUBCHAPTER B--FOOD FOR HUMAN CONSUMPTION

PART 101 -- FOOD LABELING

Subpart B--Specific Food Labeling Requirements

Sec. 101.22 Foods; labeling of spices, flavorings, colorings and chemical preservatives.

(a) (1) The term *artificial flavor or artificial flavoring* means any substance, the function of which is to impart flavor, which is not derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, diary products, or fermentation products thereof. Artificial flavor includes substances listed in 12.515 (b) and 182.60 of this chapter except where these are derived from natural sources.

(3) The tern *natural flavor or natural flavoring* means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating, or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, diary products, or fermentation products thereof, whose significant function in food is flavoring rather than nutritional. Natural flavors include the natural essence or extractives obtained from plants listed in 182.10, 182.20, 182.40, and 182.50 and part 184 of this chapter, and the substances listed in 172.510 of this chapter.