Characterization of Naturally-Occurring Alpha-Diketone Emissions and Exposures at a Coffee Roastery and Associated Retail Café

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Introduction

Alpha-diketones such as diacetyl and 2,3-pentanedione are used as flavoring compounds in a variety of industries and are generated in roasted food products such as coffee. Exposure to these compounds has been associated with bronchiolitis obliterans, a rare and severe respiratory disease characterized by inflammation of the small airways of the lungs.

In 2011, NIOSH proposed a recommended exposure limit (REL) of 5 ppb (TWA) for diacetyl and a short-term exposure limit (STEL) of 25 ppb for a 15-minute time period. NIOSH also proposed an REL of 9.3 ppb (TWA) and an STEL of 31 ppb for a 15-minute period for 2,3-pentanedione. There is evidence from previous studies that coffee production workers have been exposed alpha-diketone emissions at levels above recommended limits. One study at a large-scale manufacturer reported area diketone concentrations of 10-60 ppb in the roasting area, 200-400 ppb in the grinding area, and 30-80 ppb in the control room and packing area. There is a need for more research on how widespread this exposure risk is and what process elements are associated with the highest levels of exposure. There are reports showing that the highest exposures are associated with work tasks involving grinding and packaging ground coffee. It is thought that grinding increases the surface area of the roasted bean, leading to increased emissions of volatile organic compounds (VOCs). However, production practices are widely variable throughout the industry and levels of diacetyl in smaller craft coffee roasters or coffee shops where roasting, grinding, and brewing take place are largely unknown.

Specific Aims

- Characterize employee exposure to alpha diketones and determine which parts of the production process are associated with the highest alpha-diketone emissions
- Determine the extent to which lower –cost direct reading instruments can serve as surrogate measurements for diacetyl concentrations
- Quantify the effect that roast type has on alpha-diketone emissions during grinding

Methods

Field data were collected over 4 days of sampling in October 2019

Integrated personal and area air samples for diacetyl and 2,3-pentanedione were collected associated using OSHA methods 1013/16 with a few modifications

Collected direct reading instruments (DRIs) were deployed to measure continuous total VOC, CO, and CO₂ concentrations at the roasting, grinding, and packaging stations

White coffee, medium espresso, espresso, and French roast beans were ground in an emissions test chamber

Results

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>Sample Duration (min)</th>
<th>Diacetyl (ppb)</th>
<th>2,3-Pentanedione (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/15</td>
<td>236</td>
<td>9.1</td>
<td>4.8</td>
</tr>
<tr>
<td>10/15</td>
<td>316</td>
<td>21.0</td>
<td>11.4</td>
</tr>
<tr>
<td>10/16</td>
<td>408</td>
<td>13.4</td>
<td>5.8</td>
</tr>
<tr>
<td>10/16</td>
<td>352</td>
<td>8.2</td>
<td>3.5</td>
</tr>
<tr>
<td>10/28</td>
<td>148</td>
<td>1.9</td>
<td>0.9</td>
</tr>
<tr>
<td>10/29</td>
<td>329</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>10/30</td>
<td>359</td>
<td>13.7</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Table 1: Diacetyl and 2,3-Pentanedione Exposure Results

Discussion

- 5 of 7 personal samples were elevated compared to the NIOSH REL for diacetyl and one personal sample exceeded the NIOSH REL for 2,3-pentanedione
- Diacetyl and 2,3-pentanedione emissions where highest at the packaging and grinding stations
- There is a strong, positive correlation between TVOC emissions and diacetyl emissions
- French roast was associated with the highest mass emission rate of diacetyl

Conclusions

- Areas with the highest emissions are the hopper and the grinder
- Coffee production workers at this facility are being exposed to alphadiketones above NIOSH recommended guidelines
- The relationship between diacetyl and TVOC emissions can be used to predict the concentration of diacetyl knowing the concentration of TVOCs
- Because the difference in diacetyl mass emissions is small between the darker roasts, engineering controls may be more effective than fine-tuning the production process in reducing exposure to alpha diketones

Acknowledgements

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