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Research Paper

VOC emissions from beef feedlot pen surfaces as affected by within-pen location, moisture and temperature☆

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A laboratory study was conducted to evaluate the effects of pen location, moisture, and temperature on emissions of volatile organic compounds (VOC) from surface materials obtained from feedlot pens where beef cattle were fed a diet containing 30% wet distillers grain plus solubles. Surface materials were collected from the feed trough (bunk), drainage, and raised areas (mounds) within three feedlot pens. The surface materials were mixed with water to represent dry, wet, or saturated conditions and then incubated at temperatures of 5, 15, 25 and 35 °C. A wind tunnel and gas chromatograph-mass spectrometer were used to collect and quantify emissions of eight volatile fatty acids (VFAs), five aromatics and two sulfur-containing compounds. Pen location significantly ($P < 0.05$) affected measurements of 10 of the VOC with the largest values occurring for materials collected near the mound area. The largest VFA and aromatic emissions resulted for the dry moisture condition while wet and saturated conditions produced the largest sulfide emissions. Temperature affected emission of each VOC except indole, with values generally increasing as temperature increased. Odour activity value (OAV), which was the ratio of measured concentration of a single compound normalised to the odour threshold for that compound, was calculated for each compound. Four VFAs contributed 7.5% of the total OAV but only one aromatic, 4-methylphenol, was a major contributor to total OAV at 2.5%. In comparison, sulfide compounds contributed 87.3% of the total OAV. This research shows VOC emissions are affected by pen location, moisture condition, and temperature.

Abbreviations: AFOs, animal feeding operations; DMDS, dimethyl disulfide; DMTS, dimethyl trisulfide; OAV, odour activity value; VFAs, volatile fatty acids; VOCs, volatile organic compounds; WDGS, wet distillers grains with solubles.

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1. Introduction

Airborne pollutants from animal feeding operations (AFO) may be a health concern to downwind populations (Donham et al., 2007; Heederik et al., 2007; Katja et al., 2007; Thorne, 2007; Wright et al., 2005). Chronic exposure to these pollutants has been associated with increased incidence of respiratory diseases, particularly for those responsible for the care of animals (Mitloehner & Calvo, 2008; Omland, 2002). Typical airborne pollutants from AFOs are comprised of particulate matter, biological materials, and chemicals including malodorous compounds. Malodorous compounds consisting of alcohols, amides, aromatics, sulfides, and volatile fatty acids (VFAs) are emitted during the microbial degradation of manure (Mackie, Stroot, & Varel, 1998; Miller & Berry, 2005; Miller & Varel, 2001; Rappert & Muller, 2005; Trabue et al., 2011).

Researchers have examined the effects of feeding ethanol by-products, including wet distillers grains plus solubles (WDGS), on odour characteristics of excreted manure. Introduction of ethanol by-products as a feed ingredient for beef cattle has modified the emission characteristics of manure (Gralapp, Powers, Faust, & Bundy, 2002; Spiehs & Varel, 2009; Varel, Wells, Berry, & Miller, 2010; Varel et al., 2008). Spiehs and Varel (2009) found that increasing the amount of WDGS in beef cattle rations increased phosphorus (P), nitrogen (N), and sulfur (S) intake and excretion. As a result, there was an increased production of odorous compounds (primarily long- and branched-chain VFAs and phenol) as well as increased ammonia (NH_3) and hydrogen sulfide (H_2S) emissions from a feedlot. Conversely, Hales, Parker, and Cole (2012) measured emissions of volatile organic compounds (VOC) from faeces and urine of cattle fed steam-flaked corn diets containing 0, 15, 30, or 45% WDGS, and reported no difference in VOC flux among the varying diets. Many of the previous studies investigated emissions from freshly excreted manure, which comprises only a small portion of the manure in feedlot pens. The focus of the present investigation was emissions from aged manure thoroughly mixed with soil from the pen surface, which should provide more realistic information regarding the characteristics of odorous emissions from open-lot feedlots.

Substantial research has been performed using different approaches to measure odour emission characteristics and rates from AFO (Auvermann, Paila, Hiranuma, & Bush, 2007; Kyoung, Hunt, Johnson, Szogi, & Vanotti, 2007; Todd, Cole, Harper, & Flesch, 2008; Trabue, Scoggin, Li, Burns, & Xin, 2008). Flux chambers and wind tunnels have been used to determine emissions at specific points on a pen surface (Hudson et al., 2009; Meisinger, Lefcourt, & Thompson, 2001). However, point measurements obtained using flux chambers have been shown to alter surface conditions and the measurements may not accurately estimate emissions (Cole, Todd, Parker, & Rhoades, 2007). Additionally, point measures may not adequately estimate large area emissions, particularly when there is considerable spatial variability (Cole et al., 2007; Parker, Rhoades, Schuster, Kiziel, & Perschbacher–Buser, 2005; Parker et al., 2008, 2009).

Micrometeorological theories and associated measurement technologies have been effectively used to measure emissions from larger areas (Flesch, Wilson, Harper, & Crenna, 2005; Flesch, Wilson, Harper, Todd, & Cole, 2007; Harper, Denmead, Freney, & Byers, 1999; McGinn, Janzen, & Coates, 2003; Todd et al., 2008). These methods generally have minimal impact on the pen surface and, therefore, are better suited for estimating total emissions. However, these techniques lack the resolution necessary to develop precision management practices for mitigating emissions from pen surfaces.

Physical, chemical and microbiological composition of feedlot surface materials has been shown to vary greatly both spatially and temporally (Cole, Mason, Todd, Rhoades, & Parker, 2009; Miller et al., 2006; Miller, Curtis, Larney, McAllister, & Olson, 2008; Rice, Mason, Cole, & Clark, 2007). Established geophysical methods have demonstrated that topography, pen design and layout can influence the pattern of manure accumulations (Eigenberg, Lesch, Woodbury, & Nienaber, 2008, 2010; Woodbury, Lesch, Eigenberg, Miller, & Spiehs, 2009; Woodbury, Eigenberg, Varel, Lesch, & Spiehs, 2011). Geophysical methods are useful in providing estimates of the percentage of the pen surface that is most responsible for malodorous emissions; however, predicting types and amounts of gas emissions requires more information than is provided using these techniques.

Pen location, precipitation and temperature are three important parameters that may influence emission types and amounts for a given diet. The influence of temperature on odour emissions is intuitive and has been documented. However, the combined effects of moisture, temperature and location within a pen on the types of odour that are emitted are not well known. Commercial-sized feedlot pens have designs and slopes that can influence the areas where manure accumulates on the pen surface. Typically manure, including manure that has been recently excreted, accumulates in greater quantities behind the bunk apron and near the water trough. The base of the mounds can have a relatively large manure content and greater mixing with soil. Down-gradient zones may have substantial manure accumulations which can be detached and transported by overland flow. All of these physical characteristics can have profound impacts on odour characteristics.

The objective of this study was to determine the effects of moisture, temperature and location in a pen on the types and amounts of odorous emissions from feedlot surface materials generated from cattle fed a diet containing 30% WDGS. This information will provide an improved understanding of emission characteristics from commercial-size pens so targeted mitigation practices can be developed. Additionally, the information from this study can be used to design larger *in-situ* studies evaluating odour mitigation practices.

2. Materials and methods

2.1. Collection of feedlot surface materials

Unconsolidated feedlot surface materials (FSM) were collected from three adjacent feedlot pens located at the U.S. Meat Animal Research Center near Clay Center, Nebraska (Fig. 1). The 30 × 90 m pens contained a central mound constructed