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Odor Characterization at Open-Lot Beef Cattle Feedyards Using Triangular Forced Choice Olfactometry

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Abstract. *Odor samples were collected two to four times per month over a one-year period in 2002-2003 at three large open-lot beef cattle feedyards in the Texas panhandle. Samples were collected using a vacuum chamber in 10 L Tedlar bags upwind of the feedyard, downwind of the pens, and downwind of the runoff storage pond. Samples were analyzed in the odor lab for detection threshold (DT) using triangular forced choice olfactometry with trained human odor panelists. Full-strength odor samples were also analyzed for intensity and hedonic tone. Weather data was collected on-site at each of the feedyards for correlation to odor characteristics. At two of the feedyards, mean upwind DTs were similar to DTs downwind of the pens and storage pond, ranging from 24 to 30. At the third feedyard, the mean upwind DT was 25, compared to 48 downwind of the pens and 84 downwind of the pond. Results of the research indicate that DT alone may not be a good indicator of odor characteristics and offensiveness from beef cattle feedyards.*

Keywords. Odor, detection threshold, cattle, feedyard, intensity, hedonic tone.

Introduction

More than 7 million cattle are fed annually in Texas Panhandle feedyards, representing 30% of the nation's fed beef (TCFA, 2000). As houses encroach upon rural areas once occupied by agriculture, there is a growing concern over odor nuisances from beef cattle feedyards (Chen et al., 1999; Sweeten, 1991; Sweeten, 1995; Sweeten and Miner, 1993). Odors are not regulated in Texas, though many other states are already governing these nuisances (CAQCC, 1999; Lacey and Redwine, 2000). In Texas, these issues are left to nuisance complaints leading to lawsuits and litigation.

The objective of this research was to determine current baseline odors downwind of pen surfaces and storage ponds at commercial beef cattle feeding operations as related to time of year and atmospheric conditions.

When studying odor and the effects of odor on people living near CAFO’s, the odor must be described and measured. Five characteristics are typically used to describe odor: 1) frequency or how often the odor occurs, 2) intensity or detection threshold, which measures the strength of the odor, 3) duration, or how long the odor is present, 4) offensiveness or character of the odor, and 5) hedonic tone, or the relative pleasantness or unpleasantness of an odor (Sweeten, 1995; Mackie et al., 1998; Redwine and Lacey, 2000).

When measuring odor, intensity receives the most attention in nuisance complaints (Redwine and Lacey, 2000; Mackie et al., 1998). Mackie et al. (1998) states that odor intensity can be measured by direct sensory methods involving trained human panelists.

A standard method for quantifying odors using human panelists is known as dynamic forced choice olfactometry. Panelists are presented with 3 air samples, only one of which contains the odor sample, and are asked to identify the sample they believe contains the odorous air. The dilution ratio of clean air to odorous air at which a human can detect but not necessarily recognize the odor is called the detection threshold (DT) (Mackie et al., 1998). Clanton et al. (1999) states that the use of human panelists surpasses the combination of high-resolution gas chromatography and mass spectrometry when quantifying and identifying odorous compounds in small amounts. When tests are duplicated in the same laboratory and compared to other analytical techniques, the human panelists will vary only 12-17% (Clanton et al., 1999). One of the problems with this method, according to Sweeten et al. (1983), is that the odor detection threshold is not a consistent number but will vary, within a specific range or zone, with each individual panel. Also, the DT of an air sample cannot be directly correlated to the intensity of an odor. The intensity of the odor must be determined indirectly by comparing the odorous air sample to known concentrations of n-butanol (C_4H_9OH) in water (Sweeten et al., 1983). Several standard concentrations are formulated and used to compare with an odor sample.

Cause of Odors

Odors from CAFOs are caused by a group of nearly 200 different compounds, which are generated by the anaerobic decomposition of manure (Zhang, 2001; Mackie et al., 1998; Sweeten, 1991). Ammonia, volatile fatty acids and hydrogen sulfide are among the most commonly reported odorants (Zhang, 2001; Mackie et al., 1998; Sweeten, 1991). Warm and wet conditions will cause increased anaerobic decomposition causing increased odors. When moisture content (wet basis) is 50% or greater a definite odor can easily be detected from the manure (Jacobs, 1994). Odors are carried down wind where they can become a nuisance to neighbors (Sweeten, 1991). An odor becomes a nuisance when it interferes with normal use and enjoyment of property (Redwine and Lacey, 2000).

Objectives

The objectives of this research were to:

1) Determine baseline odor detection thresholds at large open-lot beef cattle feedyards,
2) Determine if odor could be correlated to manure moisture content and weather conditions, and
3) Determine if detection threshold was correlated with intensity or hedonic tone.

Materials and Methods

Odor Sample Collection

Odor samples were collected from three commercial beef cattle feedyards with capacities of 25,000 to 55,000 head. Odor samples were collected two to four times per month from May, 2002 through April, 2003. Odor samples were collected at three locations at each feedyard: 1) immediately upwind of the feedyard, 2) immediately downwind of the feedyard pens, and 3) immediately downwind of the runoff storage pond. Odor samples were collected in 10-L Tedlar® bags at a height of 1.0 m above the ground surface. To reduce ambient bag odor, each bag was heated for 24 hours at 100°C and purged with odor free air before the odor samples were collected (Parker et al., 2003). Samples were transported by automobile to the odor laboratory at West Texas A&M University, and were analyzed within 24 hrs. All odor laboratory procedures followed general guidelines developed by scientists and engineers at Iowa State University and the University of Minnesota (ISU/UM, 2000). Odor samples were presented to trained panelists and analyzed for detection threshold (DT), intensity, and hedonic tone. DTs were measured throughout the 12-month study. Intensity and hedonic tone were measured only during the last three months of the study.

Detection Threshold

DT was measured using triangular forced-choice olfactometry with an AC'Scent International Olfactometer (St. Croix Sensory, Lake Elmo, MN). Panel DTs were calculated following the guidelines of ASTM (1991). The DT for each individual panelist was calculated as the geometric mean of the concentration at which the last incorrect guess occurred and the next higher concentration at which the odor was correctly detected. The panel DT was calculated as the geometric mean of the individual panelist DTs.

Intensity

Samples were analyzed for intensity by comparison to five standard n-butanol solutions. Solutions consisted of 0.25, 0.75, 2.25, 6.75, and 20.25 ml n-butanol per L of water, which corresponded to intensities of 1.0, 2.0, 3.0, 4.0, and 5.0, respectively. The intensity of the odor was determined by each panelist by comparing the full strength odorous air sample from the Tedlar® bag to known concentrations of n-butanol mixed with water. Scores ranged from 0.5 for an odor sample weaker than the lowest n-butanol concentration to 5.5 for an odor stronger than the highest concentration, in increments of 0.5. The average intensity was calculated for the panel using the arithmetic mean.

Hedonic Tone

Hedonic tone was determined in a similar manner by sniffing the full strength odor sample. Panelists were asked to subjectively assign a score for hedonic tone on a scale of -4 to +4, with -4 being very unpleasant, 0 being neutral, and +4 being very pleasant. The average hedonic tone was calculated for the panel using the arithmetic mean.

Manure Samples

Manure samples were collected from within two pens at each feedyard. The same two pens were utilized at each sampling event. Each pen was sampled at three locations: 1) immediately below the concrete bunk apron, 2) at the top of the mound (or middle of the pen if no mound was present), and 3) near the bottom of the pen. Samples were collected at two depths at each location, the loose surface material which varied from about 2-5 cm in thickness, and the hardpack subsurface manure of about 2-10 cm depth. Samples were oven dried at 100°C for 24 hrs to determine gravimetric moisture content on a wet weight basis (weight of water divided by total weight).

Weather Data

Climatic data was collected from stationary Unidata weather stations located at each feedyard. The weather stations were placed at the southwest corner of the feedyard, which was typically upwind based on the predominant wind direction from the southwest. Data was collected every 2 minutes, stored in a Starlogger datalogger, and downloaded every two weeks. Data included air temperature, wind speed, wind direction, rainfall, and soil temperatures at 5 and 15 cm depths.

Quality Assurance/Quality Control

Prior to each odor session, 8 or 9 odor panelists were screened with an n-butanol standard gas preparation and an equipment blank on the olfactometer. An n-butanol gas sample was prepared by filling a Tedlar bag with 40 ppm n-butanol. Individual panelist DTs were determined using the n-butanol gas standard. Those panelists who were noticeably outside the target range were dismissed for the session. In all cases, panelists were dismissed because they were not sensitive enough. Ideally, a geometric mean DT for the n-butanol standard of about 500 to 1500 was targeted. This corresponds to n-butanol detection at 20 to 80 ppb as recommended by the Draft European Odor Standard (CEN, 1999). In actuality, most panelists could not detect the n-butanol at the recommended range. Most panelists consistently detected the n-butanol standard at DTs of about 200 to 500.

An equipment blank was also used at each panel session. The equipment blank was prepared by filling an odorless Tedlar bag with air from the olfactometer outlet. The equipment blank was used to determine if there were any odors emanating from the olfactometer tubing, valves, or filters.

Odor panelists were limited to 8 samples in addition to the blank and n-butanol for each session to reduce panelist fatigue and ensure quality.

Results and Discussion

Quality Assurance/Quality Control

The mean panel DT over the 12-month period for the n-butanol standard was 121. Panel DTs increased slightly over the first 6 months before stabilizing near about 200 (figure 1). A panel DT of 200 corresponds to an n-butanol concentration of about 200 ppb. The Draft European Odor Standard recommends that individual panelists detect the n-butanol at concentrations ranging from 20 to 80 ppb (CEN, 1999). Only a small percentage, less than 10%, of all panelists tested in our odor panel were able to routinely detect n-butanol at less than 80 ppb, even with intensive training. At this time, we are unsure as to why most panelists could not detect n-butanol at the recommended ranges, but it is possible that the dry conditions (relative humidity typically 10-30%) found in west Texas are not conducive to reaching these n-butanol goals.

Panel DTs for the blank were generally less than 30, with a mean of 9.8 over the 12-month period (figure 2). Two occurrences of elevated blank DTs occurred near the end of the study, though the cause is unknown. It is possible that a filter or tubing became contaminated with odor. Interestingly, some of the highest DTs measured during the study came during this same time period.

Detection Threshold

Upwind panel DTs ranged from a minimum of 4.8 to a maximum of 256 (table 1). Panel DTs dowwind of the pens ranged from 5.7 to 431, and those downwind of the pond ranged from 5.7 to 865. There were relatively few occurrences of high DTs, as evidenced by the low medians. There was little difference in mean DTs for upwind and downwind at feedyards A and B, with panel DTs ranging from 24 to 31. Mean panel DT downwind of the pond was higher than upwind or downwind of the pens for feedyard C (table 1).

Panel detection thresholds for the three feedyards over time are shown in Figures 3, 4, and 5. There were no obvious trends observable over time. Short term spikes of higher DTs can be observed over the entire 12-month period at all three feedyards. In many instances, upwind DTs were higher than downwind. Elevated upwind DTs could be a result of many things, but the most likely causes are probably weeds/pollen and freshly cut hay.

Panel DTs increased at all 3 feedyards in March and April, including upwind. It is unknown whether odor actually increased at the feedyard, or whether odor carried onto the feedyard from an upwind location was the cause of the elevated DTs. It could be that springtime brought more odor from offsite sources, resulting in higher DTs upwind and downwind of the feedyards.

Correlation Between DT, Manure Moisture Content, and Weather Parameters

Pearson correlation coefficients were calculated for feedyard surface moisture contents and weather conditions at the time of sampling. The highest correlations with DT occurred with moisture content (MC) of the manure pack (table 2). Figures 6-8 show how panel DTs relate to feedyard surface moisture content. In feedyards A and B, correlations were higher for surface MC than subsurface MC. At feedyard C, DT was more highly correlated to subsurface MC. Manure was scraped and removed more frequently at feedyard C than the other two feedyards, and as a result there was usually less loose manure on the surface at feedyard C. All correlations between DT and MC were positive, indicating that DT increased with increasing MC. DT was negatively correlated with air temperature, indicating that DT decreased with increasing air temperature. This does not necessarily mean that there is a cause-effect relationship between DT and air temperature, as air temperature was also negatively correlated to moisture content (r=-0.4 to -0.6).

Relationship Between DT, Intensity, and Hedonic Tone

There was a small positive correlation between panel detection threshold and intensity (r=0.36) (figure 9). There was no correlation between detection threshold and hedonic tone (figure 10). There was a negative correlation between intensity and hedonic tone (r=-0.68) (figure 11), indicating that hedonic tone increased as intensity decreased.

Investigating The Cause of High DTs

One of the long term goals of most CAFO odor research is to make strides toward understanding odors so that they can be reduced or eliminated. In a preliminary attempt to determine if stronger odors occurred at a particular range of manure moisture contents or weather conditions, DT was plotted against each parameter, and the range of highest DTs was visually determined from the graphs. A summary of the range of values, and the associated range in which the highest panel DTs were observed, is presented in table 3. High DTs occurred across most of the range of all parameters, indicating that any single parameter is not responsible for the high DTs. As is so common in most biological systems, it is likely that high odors are a result of a combination of many items including current and past manure characteristics and weather conditions.

Conclusions

The following conclusions were drawn from this research:

1) Panel DTs downwind of feedyard pens ranged from 5.7 to 431, with a mean of 35.6 and median of 17.2. Panel DTs downwind of feedyards ponds ranged from 5.7 to 865, with a mean of 48.6 and median of 17.3. Two of three feedyards had mean upwind DTs similar to downwind DTs.
2) DT was positively correlated with manure moisture content. Two of three feedyards had higher correlations with surface manure moisture content, while the third was higher correlated to subsurface moisture content. The third feedyard had more frequent manure removal management practices than the other two feedyards.
3) DT was positively correlated with intensity (r=0.36), with little to no correlation with hedonic tone. Intensity was negatively correlated with hedonic tone (r=-0.68).

Table 1. Summary statistics of panel detection thresholds at three beef cattle feedyards.

Feedyard and Location	Min	Max	Median	Mean	Std Dev
Feedyard A Upwind	5.7	256	16.0	29.1	41.6
Feedyard A Downwind Pens	5.7	166	15.3	26.1	29.0
Feedyard A Downwind Pond	5.7	256	16.0	30.3	45.4
Feedyard B Upwind	5.7	256	13.9	31.5	47.2
Feedyard B Downwind Pens	5.7	117	19.0	28.4	27.1
Feedyard B Downwind Pond	5.7	256	13.1	23.6	40.7
Feedyard C Upwind	4.8	181	16.0	25.1	32.0
Feedyard C Downwind Pens	5.7	431	18.0	48.4	93.6
Feedyard C Downwind Pond	5.7	865	32.0	83.7	144.8
Overall Upwind	4.8	256	16.0	28.1	39.9
Overall Downwind Pens	5.7	431	17.2	35.6	63.4
Overall Downwind Pond	5.7	865	17.3	48.6	98.9

Table 2. Pearson correlation coefficients relating panel detection threshold, manure moisture content, and various weather parameters.

	Surface Moisture Content	Subsurface Moisture Content	Air Temp	5 cm Soil Temp	15 cm Soil Temp	Wind Speed
Feedyard A	0.40*	0.10	-0.05	0.02	0.04	-0.33*
Feedyard B	0.46**	0.08	-0.002	0.10	0.19	-0.028
Feedyard C	0.27	0.49**	-0.34*	-0.24	-0.21	0.06

* - Correlation is significant at the 0.05 level.
** - Correlation is significant at the 0.01 level.

Table 3. Range of values and range in which the highest panel detection thresholds occurred (in parenthesis).

Feedyard	Surface Moisture Content (%)	Subsurface Moisture Content (%)	Air Temp (C)	5 cm Soil Temp (C)	15 cm Soil Temp (C)	Wind Speed (m/s)
A	5-63 (10-58)	5-40 (15-33)	2-35 (10-30)	3-28 (15-24)	3-27 (15-24)	0.5-8.5 (1.5-4.2)
B	6-69 (55-69)	8-48 (24-40)	-1-37 (15-30)	-1-37 (20-30)	-7-30 (23-38)	0.5-10.5 (4-6)
C	5-60 (10-58)	16-50 (22-50)	1-34 (3-30)	2-35 (3-32)	5-29 (7-27)	6-9 (1-8)

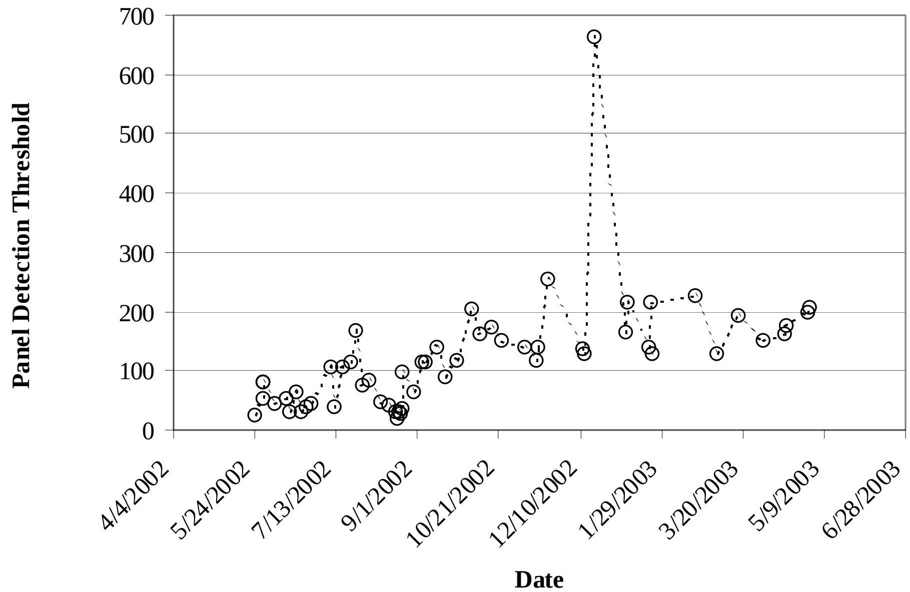

Figure 1. Panel detection thresholds determined for a bag filled with 40 ppm n-butanol standard gas.

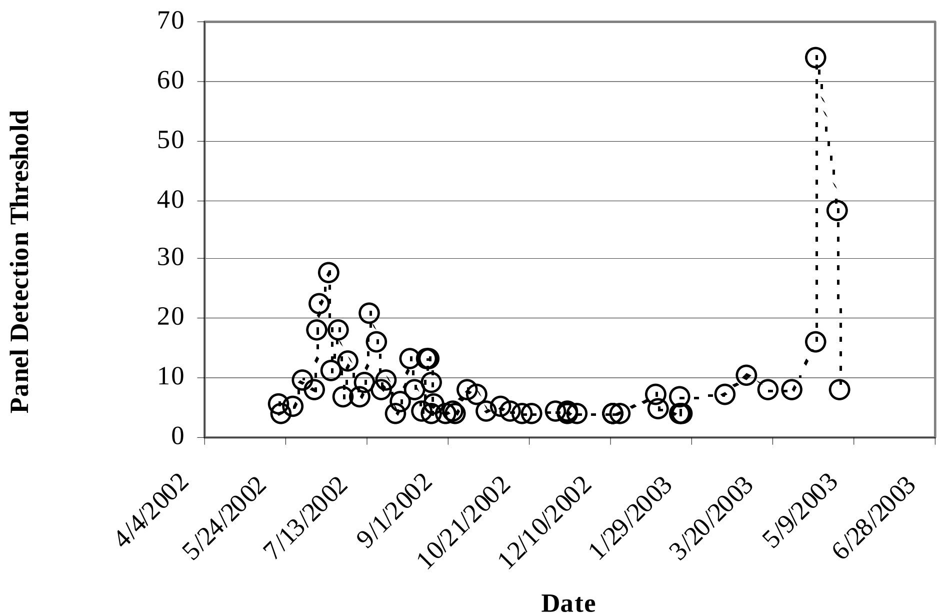

Figure 2. Panel detection thresholds were determined for a blank (odorless bag filled with airstream from the olfactometer outlet) prior to each odor panel session.

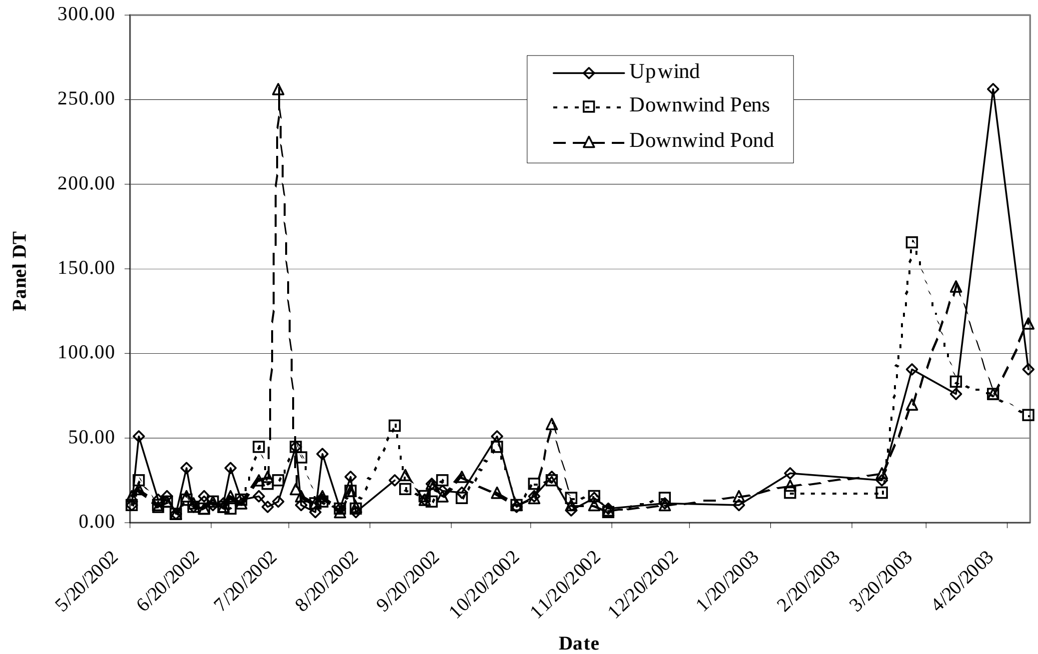

Figure 3. Detection thresholds for Feedyard A over a 12-month period for upwind of the feedyard, immediately downwind of the pens, and immediately downwind of the storage pond.

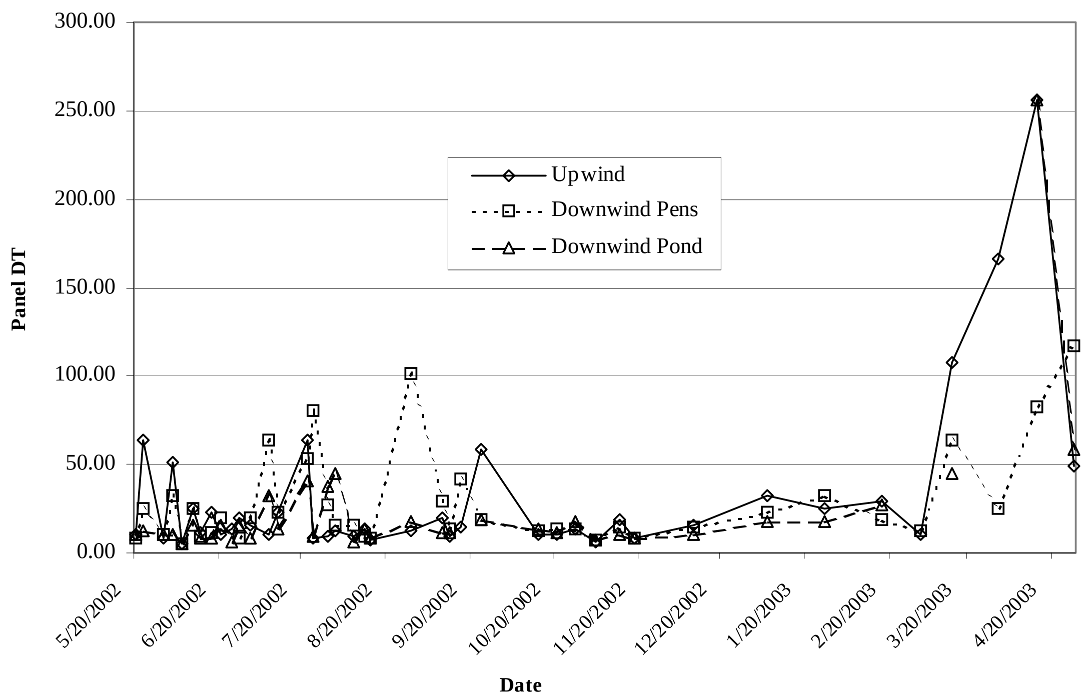

Figure 4. Detection thresholds for Feedyard B over a 12-month period for upwind of the feedyard, immediately downwind of the pens, and immediately downwind of the storage pond.

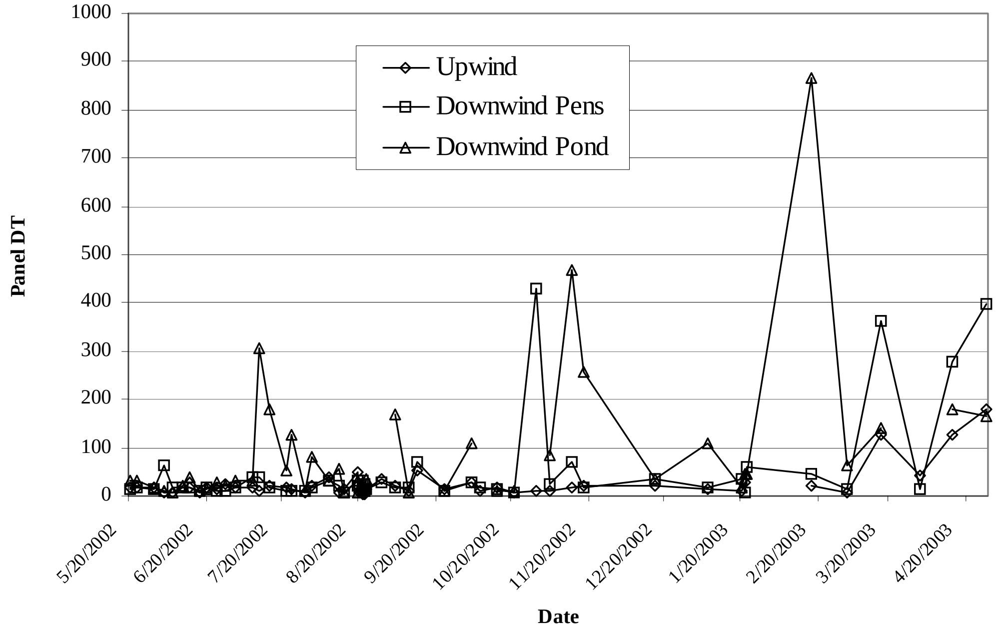

Figure 5. Detection thresholds for Feedyard C over a 12-month period for upwind of the feedyard, immediately downwind of the pens, and immediately downwind of the storage pond.

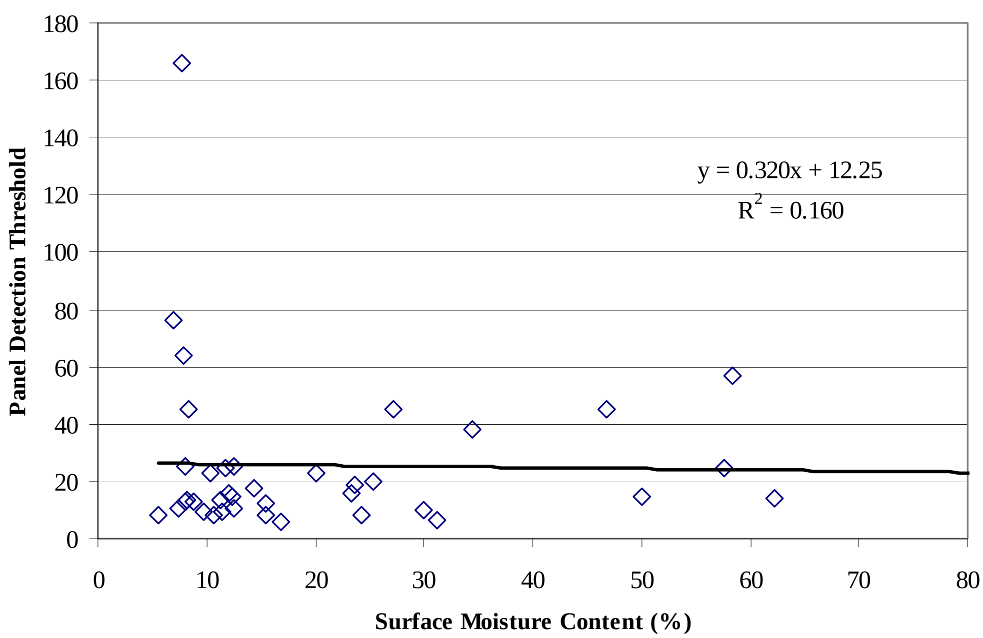

Figure 6. Relationship between panel detection threshold immediately downwind of pens and feedyard surface moisture content (wet weight basis) for Feedyard A.

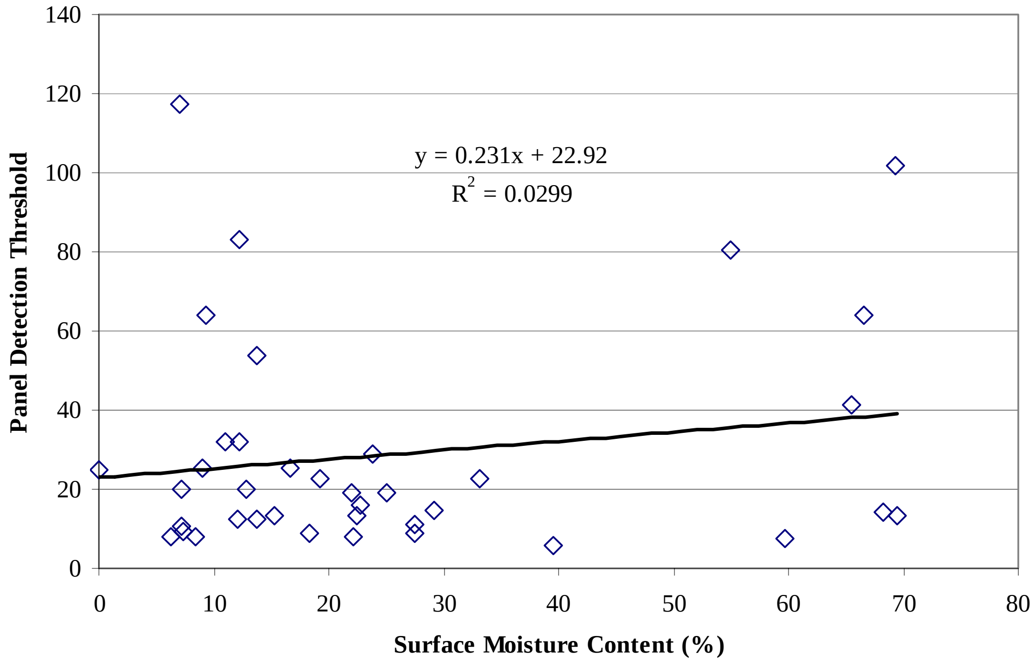

Figure 7. Relationship between panel detection threshold immediately downwind of pens and feedyard surface moisture content (wet weight basis) for Feedyard B.

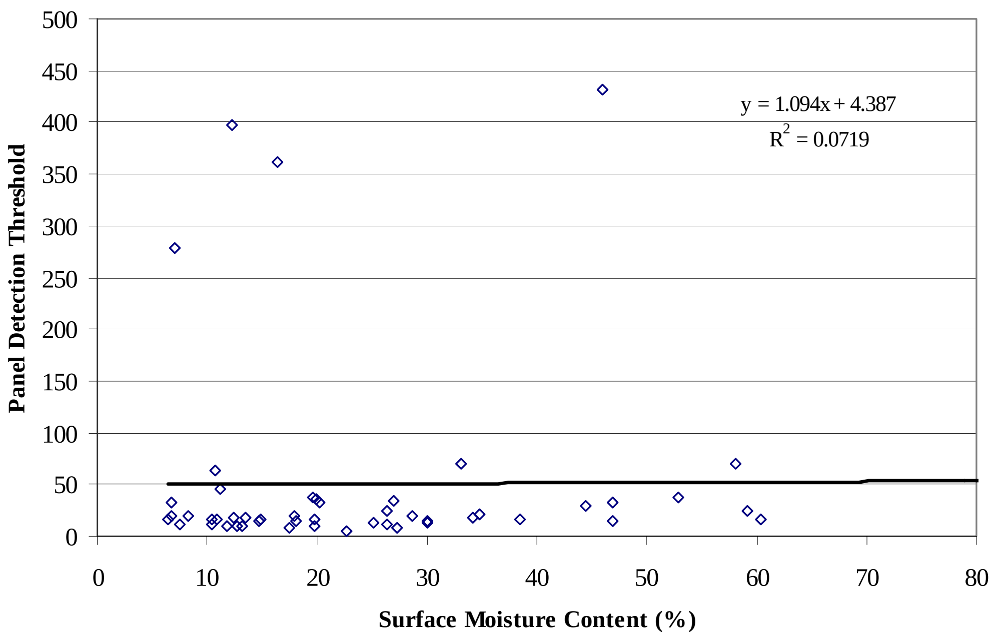

Figure 8. Relationship between panel detection threshold immediately downwind of pens and feedyard surface moisture content (wet weight basis) for Feedyard C.

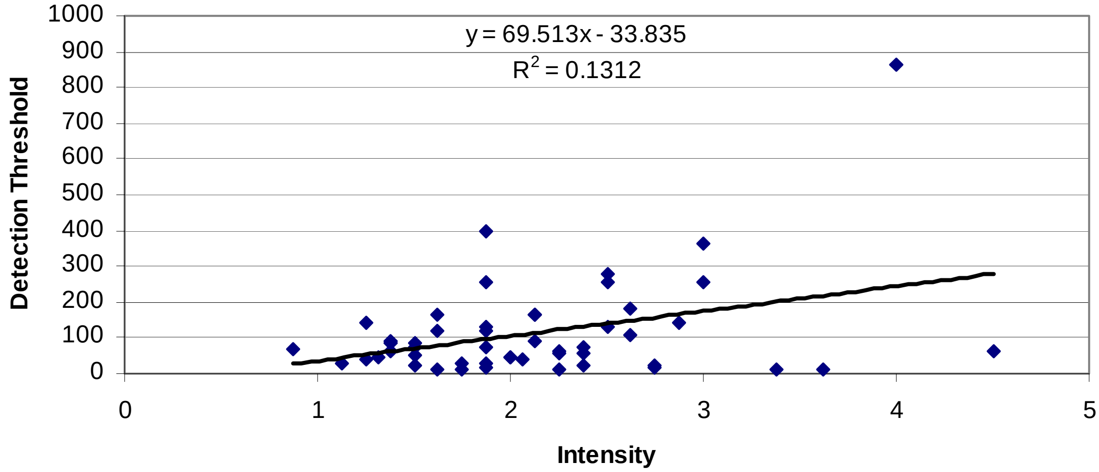

Figure 9. Relationship between panel detection threshold and intensity for all three feedyards and three locations per feedyard together.

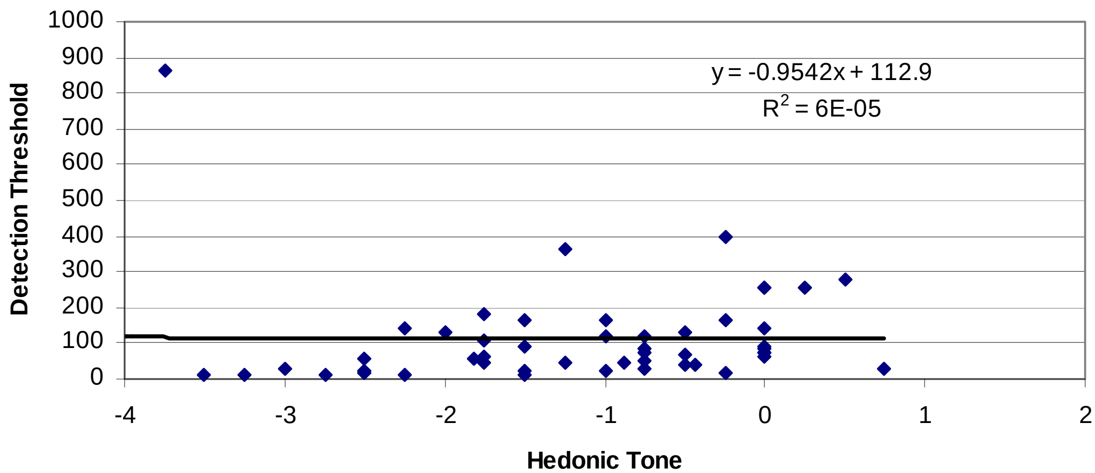

Figure 10. Relationship between panel detection threshold and hedonic tone for all three feedyards and three locations per feedyard together.

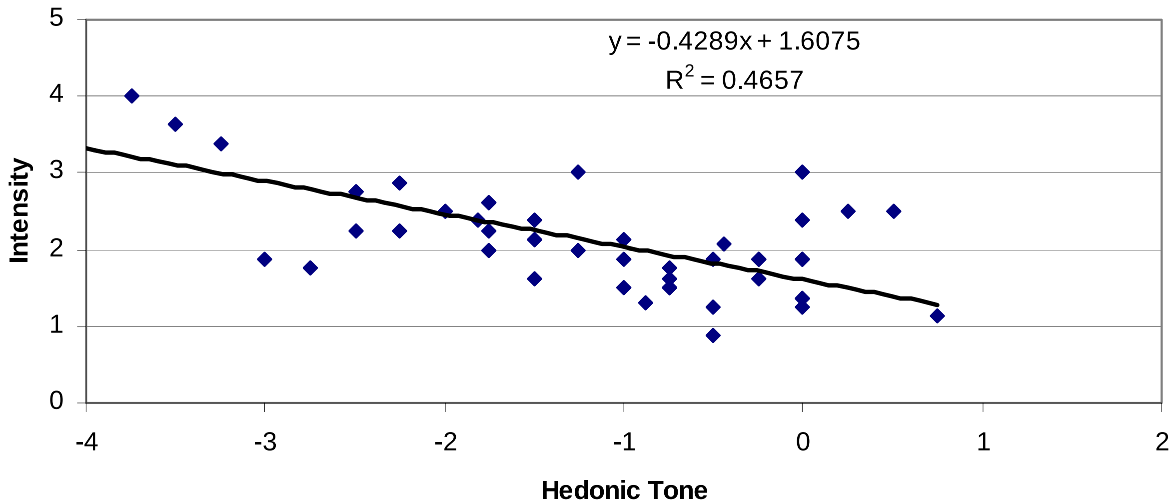

Figure 11. Relationship between intensity and hedonic tone for all three feedyards and three locations per feedyard together.

References

ASTM. 1991. E697-91. Standard practice for determining odor and taste thresholds by force-choice concentration series method of limits. In Annual Book of ASTM Standards. Philadelphia, PA.:American Society of Testing and Materials.

CAQCC. 1999. Colorado Air Quality Control Commission Regulation No. 2, March 30, 1999.

CEN. 1999. Determination of odor intensity using dynamic serial dilution olfactometry. Draft European Standard CEN/TC264. January 21, 1999.

Chen, Y., D.S. Bundy, S. Hoff and J. Steven. 1999. Using olfactometry to measure intensity and threshold dilution ratio for evaluating swine odor. Journal of the Air and Waste Management Association 49(7):847-853.

Clanton, C.J., D.R. Schmidt, R.E. Nicolai, P.R. Goodrich, L.D. Jacobson, K.A. Janni, S. Weisberg, J.A. Buckel. 1999. Dynamic olfactometry variability in determining odor dilutions-to-threshold. Transactions of the ASAE 42(4):1103-1112.

ISU/UM. 2000. Odor laboratory operating procedure. Iowa State University, Ames, IA and University of Minnesota, Minneapolis, MN. Revised September, 2000. 20 pp.

Jacobs, P. and Associates Ltd. 1994. Odor control guidelines for livestock operators. Canada-Nava Scotia Agreement on the Agricultural Component of the Green Plan.

Lacey, R. and J. Redwine. 2000. A summary of state odor regulations pertaining to confined animal feeding operations. In Air Pollution from Agricultural Operations, October 9-11, 2000, Des Moines, IA, pp. 33-41, American Society of Agricultural Engineers, St. Joseph, MI.

Mackie, R.I., P.G. Stroot, V.H. Varel. 1998. Biochemical identification and biological origin of key odor components in livestock waste. Journal of Animal Science. 76:131-1342.

Parker, D.B., Rhoades, M.B., Koziel, J. and Spinhirne, J. 2003. Background odors in Tedlar® bags used for CAFO odor sampling. ASAE Paper No. 034144.

Sweeten, J.M. 1991. Odor and dust from livestock feedlots. Texas Agricultural Extension Service Bulletin No. B-5011. 8pp. Texas A&M University.

Sweeten, J.M. 1995. Odor measurement technology and applications: A state-of-the-art review. In Seventh International Symposium on Agricultural and Food Processing Wastes, C.C. Ross, Ed., June 18-20, 1995. 214-229. American Society of Agricultural Engineers, St. Joseph, MI.

Sweeten, J.M. and J.R. Miner. 1993. Odor intensities at cattle feedlots in nuisance litigation. Bioresource Technology 45:177-188.

Sweeten, J.M., D.L. Reddell, A.R. McFarland, R.O. Gauntt, J.E. Sorel. 1983. Field measurement of ambient odors with a butanol olfactometer. Transactions of the ASAE 26(4):1206-1216.

Texas Cattle Feeders Association (TCFA). 2000. The Impact of Cattle Feeding on the TCFA Area Economy. Available at: http://www.tcfa.org/impact.html. Accessed January 12, 2000.

Zhang, Q. 2001. Odour emissions from confined swine production. Department of Biosystems Engineering, University of Manitoba. Available at: http://www.gov.mb.ca/agriculture/livestock/livestockopt/papers/zhang.pdf. Accessed on 12 April 2003.