CORRELATION OF SENSORY ANALYSIS WITH ELECTRONIC NOSE DATA FOR SWINE ODOR REMEDIATION ASSESMENT

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ABSTRACT

This article presents an evaluation of the electronic nose technology as an alternative to sensory analysis for assessing the effectiveness of biofilters. An AromaScan® A32S electronic nose and a human panel at Duke University's Taste and Smell Research Lab were used to measure typical volatile compounds from swine confinement buildings. Chemometrics techniques were employed to predict the olfactory scores of the human panel from the electronic nose data. The cross-sensitivity of the sensor array to the humidity of the samples is discussed. Our results indicate that the electronic nose generates responses that are correlated with sensory analysis ratings of swine malodors at different concentrations.

1 INTRODUCTION

Sensitive measurement techniques are important for characterizing and documenting swine odors, as well as evaluating the effectiveness of methods for reducing odor. At present, olfactometry, in which a human odor panel evaluates the odors, is the most precise approach for quantifying odors since the nose can detect compounds at concentrations that cannot be detected by any other method. Human assessment, however, can be time-consuming and expensive. In addition, odor samples degrade rapidly so human panels must perform evaluations shortly after collection for accurate assessment. Since swine odor abatement research is being conducted all around the world on a 24-hour basis, odor testing with human panels is often impractical. For this reason, it would be helpful to determine if an electronic nose can substitute for human odor panels in evaluating methods for odor reduction. This article summarizes a series of studies undertaken at Duke University and North Carolina State University to find a cost-effective odor measurement method for evaluating the efficacy of biofilters as an odor remediation technique.

2 EXPERIMENTAL

In order to rapidly screen the performance of various odor remediation materials a bench-top biofilter setup was developed at NC State. The biofilter material consisted of earth, wood chips, small twigs and straw. This material was placed in a 1" diameter PVC tube, which was cut to a length of 3.9". This length was selected because of the desire to have the air within the filter for a residence time of 15 seconds. A 15-second residence time matches the specifications of field units at the NC State Animal and Poultry Waste Management Center. The tube was cemented on each end to a PVC fitting which had screw threads and an O-ring to produce an airtight seal with the connecting piece. Wire mesh was placed on each end of the cemented tube fitting in order to prevent the biofilter material from spilling out of the tube.

To test this biofilter setup, we conducted an odor remediation experiment with a synthetic slurry following the concoction of Persaud et al. [1]. Serial dilutions (1/1, 1/3, 1/9, 1/27 and 1/81) of the headspace above the slurry, as well as serial dilutions of the biofiltered synthetic slurry and biofiltered blank air (room air as a control) were presented to both a human panel and the electronic nose. The experimental setup is depicted in Figure 1.

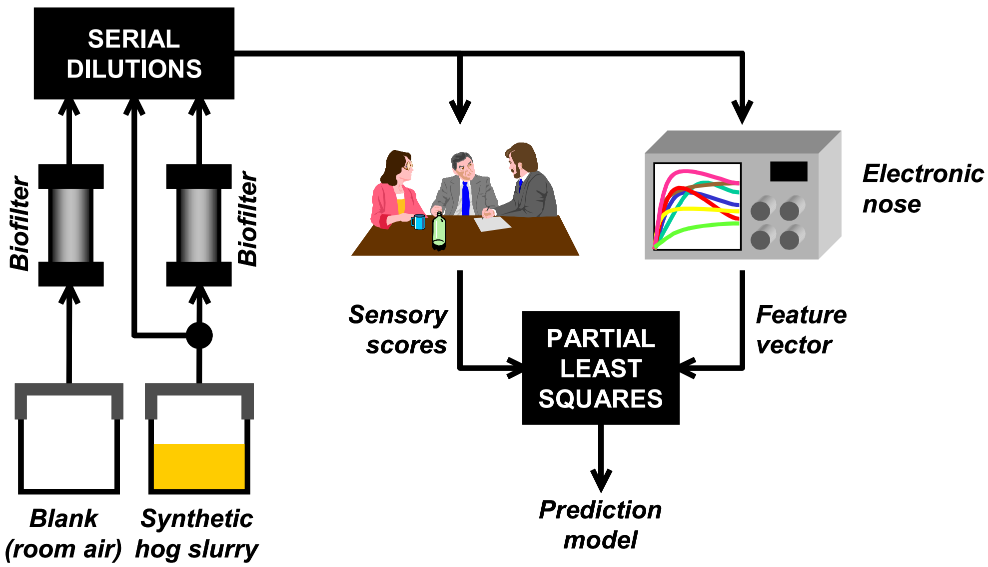

Figure 1. Experimental setup for malodor biofiltration assessment

To measure the human perception to the different odors and dilutions, the subjects were asked to generate scores for Intensity, Irritation and Pleasantness using the 9-point scale shown in Table 1. The electronic nose signals were preprocessed by computing the fractional change in resistance of each sensor with respect to its baseline resistance in reference air (steady-state $\Delta R/R$). The final response of each sensor was extracted to form a 32-dimensional feature vector.

Table 1. Hedonic tone odor rating scales

Scale	Odor Intensity	Irritation Intensity	Pleasantness
8	Maximal	Maximal	Extremely Unpleasant
7	Very Strong	Very Strong	Very Unpleasant
6	Strong	Strong	Moderately Unpleasant
5	Moderately Strong	Moderately Strong	Slightly Unpleasant
4	Moderate	Moderate	Neutral
3	Moderately Weak	Moderately Weak	Slightly Pleasant
2	Weak	Weak	Moderately Pleasant
1	Very Weak	Very Weak	Very Pleasant
0	None at all	None at all	Extremely Pleasant

3 RESULTS

The average response of the human panel and the 32 e-nose sensors for each of the 15 dilutions (5 dilutions for each of three odor sources) is shown in Figure 2**.** Each sensor was compressed down [2] to one feature as reported above (steady-state ΔR/R). Note for the human panel, biofiltering reduced the intensity, irritation, and unpleasantness of the odor. However, the panel's ratings of the biofiltered slurry and blank air were quite similar.

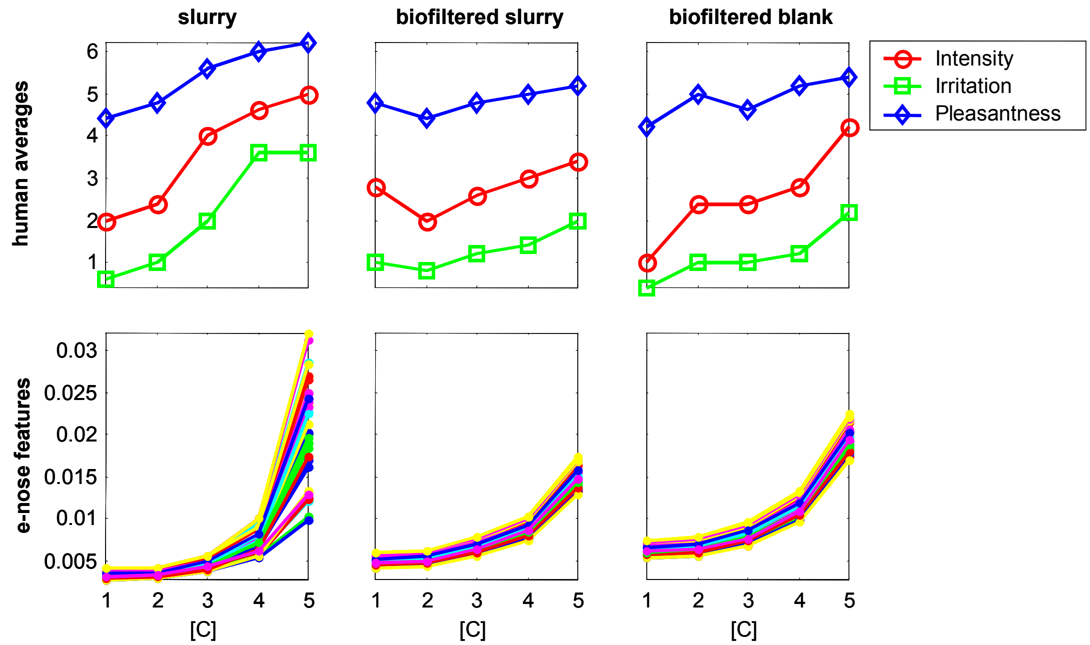

Figure 2. Average human and e-nose response in the biofiltration experiment

In order to establish whether the electronic nose could be used to replace a human panel in odor-remediation scenarios, we performed Partial Least Squares regression [3] to predict the average response of the human panel from the 32-dimensional average response of the electronic nose. To establish the predictive accuracy of this model we performed cross-validation, in which one of the fifteen dilutions was removed from the training data and predicted only after the PLS model had been obtained. Figure 3 shows the performance of the model on test data for the fifteen leave-one-out validation runs. The correlation coefficient between predictions and true values on test data for Intensity, Irritation and Pleasantness are 0.90, 0.94 and 0.86, respectively.

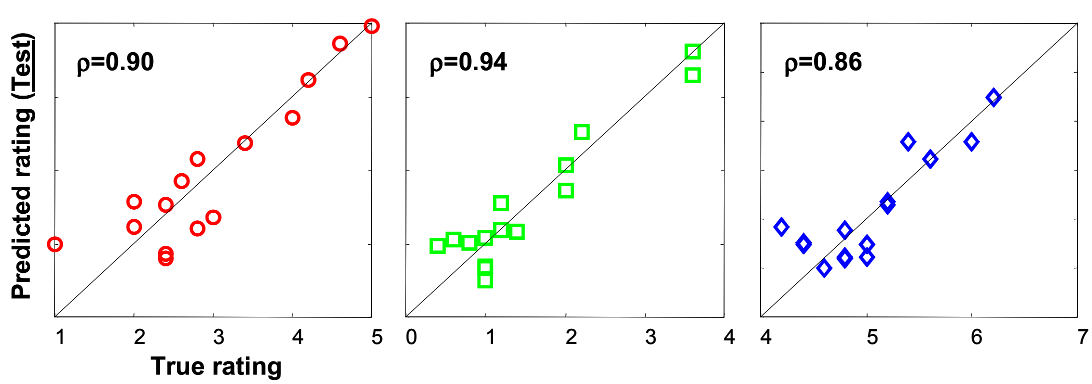

Figure 3. True vs. predicted human panel ratings using the odor sensor array

4 HUMIDITY EFFECTS

Given the notorious cross-sensitivity of conducting polymers to moisture, we decided to analyze the response of the built-in humidity sensor to the different odors and dilution ratios. The transient response of odor and humidity sensors to the fifteen samples is shown in Figure 4. Two observations can be made. First, looking at the humidity sensor response to the slurry before and after biofiltration, it can be concluded that the biofilter material is increasing the relative humidity of the samples. Second, as a result of serial dilutions, the humidity of the samples is significantly reduced.

Based on these results, it is necessary to determine if the electronic nose is just serving as a (very expensive) humidity sensor. A closer look at the data invalidates this hypothesis. First, the response of the sensor array to the synthetic slurry has a unique dynamic signature of the form $e^{+|\alpha|t}$, which is different from the exponential decay to the biofiltered samples. This indicates that, in spite of relative humidity, the odor sensors are able to detect the synthetic slurry. In addition, it the odor sensors were responding only to the humidity, the largest response of the sensor array would then occur with the 1/1 biofiltered blank, since this sample has the highest response on the humidity sensor.

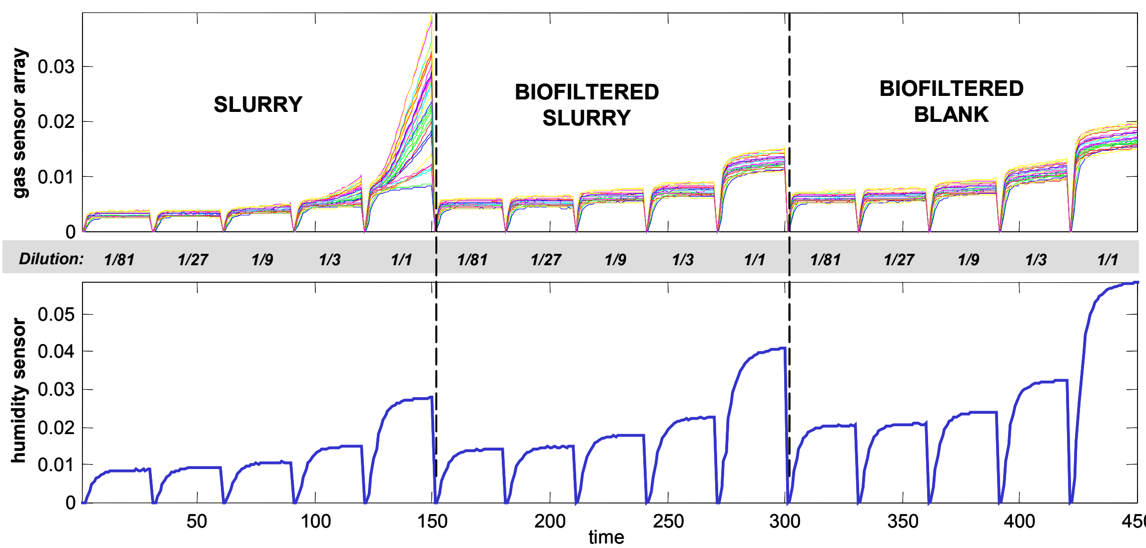

Figure 4. Transient response of the gas sensor array and the humidity sensor to five serial dilutions per odor

To further rule out the possibility that the e-nose is just detecting differences in moisture, we attempted to predict the human olfactory ratings from the humidity sensor response alone. The results are summarized in Figure 5. The correlation coefficients between predictions and true values on test data for Intensity, Irritation and Pleasantness drop down to 0.40, 0.31 and 0.29, respectively, proving that the response of the odor sensors contains information related to the presence of synthetic slurry.

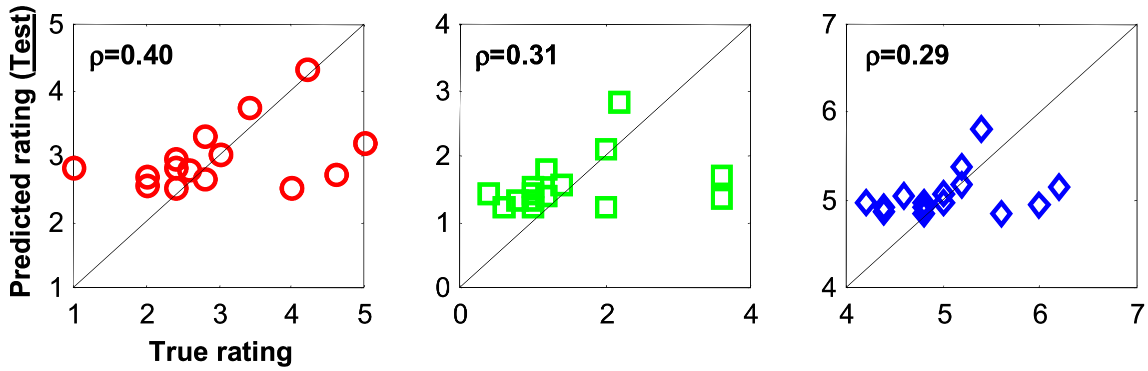

Figure 5. True vs. predicted human panel ratings using only the humidity sensor

5 CONCLUSIONS

The main findings of this study are that the AromaScan® A32S electronic nose can differentiate between different dilutions of the components of swine odor, and between synthetic slurry and biofiltered slurry/blank samples. The sensor array response can be used to predict the intensity and pleasantness olfactory ratings from a human panel. Moisture is shown to be a major interferent since biofiltration increases the relative humidity of the samples. This interference can be reduced by performing serial dilutions with a carrier gas having the same relative humidity as the odor samples.

6 ACKNOWLEDGMENTS

The authors wish to gratefully acknowledge financial support for this work by the National Pork Producers Council, the NCSU Agricultural Research Service, the US Department of Agriculture, and the National Science Foundation (NSF/CAREER award 9984426). Also the work would not have been possible without the collaboration and support of Dr. Mike Williams and the NCSU Animal and Poultry Waste Management Center.

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