This is not a peer-reviewed article.

Paper Number: 034140
An ASAE Meeting Presentation

Assessment of Moisture Control and Additives for Odor Reduction from Open-Lot Feedyard Surfaces

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Written for presentation at the
2003 ASAE Annual International Meeting
Sponsored by ASAE
Riviera Hotel and Convention Center
Las Vegas, Nevada, USA
27- 30 July 2003

Abstract. *Amendments for reducing odor from open-lot beef cattle feedyards were evaluated in the laboratory. Manure was placed in small Tupperware® containers. Water and amendments were added to the manure surface and the containers were attached to a vacuum pump that continually passed 2.5 L/min of carbon-filtered air over the surface. Eleven different amendments were tested, at two different concentrations, in a series of five experiments. Odor samples were collected 3 times during a 10-day period in each experiment and were analyzed by trained panelists for detection threshold (DT), intensity and hedonic tone. None of the amendments showed any overwhelming evidence of greatly reducing odor from simulated open-lot feedyard surfaces.*

Keywords. Cattle, beef, hedonic tone, intensity, odor, olfactometer, manure, waste

Introduction

As larger numbers of people move from heavily populated urban areas to less populated rural areas, concentrated animal feeding operations (CAFOs) are being surrounded and are experiencing a rise in complaints about odor and dust. As complaints have increased, so has the possibility of nuisance lawsuits and government regulation of odor. Currently, many state and local governments have implemented regulations covering odor, as no current EPA regulations exist (Redwine and Lacey, 2000).

Literature Review

When studying odor and the effects of odor on people living near CAFO's, the odor must be described and measured. Five characteristics are 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. Two common methods for measuring odor detection threshold are a scentometer (a small hand held device) and an olfactometer (a laboratory device). Both the scentometer and olfactometer add a stream of fresh air to odorous air and determine a detection threshold (sometimes called dilution threshold). The detection threshold (DT) is measured by the amount of pure air that must be mixed with the odorous air for the panelist to detect but not necessarily recognize the odor (Mackie et al., 1998).

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. 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, 1997; Sweeten, 1991). Ammonia, volatile fatty acids and hydrogen sulfide are among the most commonly reported odorants (Zhang, 2001; Mackie, 1997; 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).

Odor Management

Many CAFOs have manure management systems in place that include some type of odor management plan. Anaerobic digesters, feed additives, and soil and lagoon amendments have all been tried as means for controlling odor. The use of anaerobic digestion is one of the methods used to treat animal wastes. Anaerobic digestion of swine manure has been shown to reduce odor intensity and the required dispersion time (Sweeten, 1991). To reduce the odor further, amendments can be added to the effluent of the anaerobic digesters.

However, Powers et al. (1998) found that most commercially available products did not reduce odor and several seemed to increase it. Powers et al. (1998) and Amon et al. (1996) also found that feed additives had little to no effect on the odor of manure from chickens or dairy cows and, in some cases, the odor of the broiler houses increased. McCrory and Hobbs (2000) found that many additives for feed and for lagoons had little or no effect on the intensity or offensiveness of the odor. Amon et al. (1996) found that amendments added to the litter of broiler houses did not lower the concentration of odor. Both odor and ammonia concentrations were higher in treated rooms than in the control. Shi et al. (2001) found amendments could reduce ammonia emissions, a possible contributor to odor. However, no specific tests for odor were conducted.

The objective of this experiment was to determine if amendments could be used to reduce odors emitted from simulated beef cattle feedyard surfaces.

Materials and Methods

Manure was collected from the West Texas A&M University Research Feedyard prior to each experiment. A limb chipper was used to break the dried manure into small uniform pieces. The manure was placed into 16 cm x 16 cm x 17 cm sealed Tupperware® plastic containers. The manure in each container weighed 800 g and was 7.5 cm in depth with a surface area of 256 cm^2. Filtered, non-chlorinated drinking water was added to bring the moisture content to 50% across all treatments and the control.

The containers were attached to a vacuum pump (Precision Vacuum Pump, Model D75) and 2.5 L/min of activated carbon filtered air was continually passed over the surface of the manure in each container.

Table 1 shows how the amendments were grouped for each experiment. Amendments were tested in groups of four to six at a time. A total of 5 experiments were conducted. Experiments 4 and 5 contained the products with the lowest DT's from the previous experiments.

Amendments were applied directly to the manure surface without any mixing. The amendment NBPT was dissolved in 10 ml of filtered, non-chlorinated drinking water and applied over the surface of the manure with a spray bottle. The amendments $CaCl_2$ and alum were applied as a dry powder over the surface of the manure. An additional 10 ml of water was then added to these containers and to the control so that all containers received the same amount of added water.

Odor samples were collected 3 times on days 2, 6,and 9 using a portable vacuum chamber (St. Croix Sensory, Inc., Lake Elmo, MN). The samples were collected in 10-L Tedlar® bags. 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). Odor samples were presented to trained panelists and analyzed for DT using an AC'Scent International Olfactometer (St. Croix Sensory, Lake Elmo, MN).

Samples were also 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. The average intensity was calculated for the panel using the arithmetic mean.

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 -5 to +5, with -5 being very unpleasant, 0 being neutral, and +5 being very pleasant. The average hedonic tone was calculated for the panel using the arithmetic mean.

Prior to each session, 8 or 9 odor panelists were screened with an equipment blank and an n-butanol standard gas on the olfactometer. Those panelists who were noticeably outside the range of the other panelists, whether they were too sensitive or not sensitive enough, were dismissed for the session. The remaining odor panelists were limited to 8 additional samples for each session to ensure quality and reduce panelist fatigue.

Data Analysis

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. Panel intensities and hedonic tones were calculated as the arithmetic mean of the individual panelist values.

Results and Discussion

Odor DTs vary with the sensitivity of individual panelists. Therefore, results could not be statistically analyzed in the usual way. Changes in weather, panelist health, and which panelists worked on a given day caused a wide range of variability in the results. Samples were not replicated each day due to the limited number of samples the odor panel could process without compromising quality. Therefore, data was analyzed for each day and experiment separately. Comparisons between experiments were avoided.

Experiment 1

When samples from Experiment 1 were analyzed, panelists were only able to determine the detection threshold, as they were not yet trained to record intensity or hedonic tone. Panel DTs for day two ranged from 128 to 334 (Fig. 1). Only two amendments, NBPT at 2 kg/ha and alum at 9000 kg/ha, had DTs lower than the control. These slight differences appear to show a reduction in odor at the 48-hour mark. Samples analyzed on day six had far different results. None of the amendments reduced the DT to levels below the control. For the NBPT at 1 kg/ha, the DT was about equal to the control. After six days, none of the amendments appeared to have a reducing effect on the DT of the sample. For day nine of the experiment, the DT for the control was 107. Both treatments of NBPT and alum had DTs lower than the control. However, at a DT of 91 for NBPT at 1 kg/ha and 76 at 2 kg/ha, the reductions were quite small. The alum had a much larger reduction in the DT, 22 at 4500 kg/ha and 53 at 9000 kg/ha. These reductions seem to show a fairly desirable odor reduction after nine days.

The n-butanol values presented in the Figures 1-5 are for the 40 ppm n-butanol standard. A DT of about 500 to 1000 is the target panel DT based on the European standard.

Experiment 2

Panel DTs from day two ranged from 14 to 39 (Fig. 2). At a DT of 25 for the control, all of the amendments except two had lower DTs. The Natural Odor Control (NOC) had the greatest reduction in DT at 14 for the 52 L/ha application. At a DT of 15, the Cast Out at 7.8 L/ha also appeared to show a significant odor reduction. The two applications of the Bio-Catalyst also had lower DTs, 17 at 204 L/ha and 23 at 102 L/ha, but the odor reduction did not appear to be meaningful. For samples taken on day six, only two amendments had DTs lower than the 26 of the control. Cast Out at 7.8 L/ha and the Bio-Catalyst at 204 L/ha had DTs of 21 and 22, respectively. Neither of these treatments appeared to show a large reduction in odor. When panelists tested these odors for intensity and hedonic tone, the difference appears much greater. The intensity of the control was 2.5 and the hedonic tone was –1.6. For the Cast Out at 7.8 L/ha, the intensity was 1.1 and the hedonic tone was –1.1 and for the Bio-Catalyst, at 204 L/ha, the intensity was 1.9 and the hedonic tone was 0. Though the reductions all seem small, when combined together, the amount and unpleasantness of the odor appeared to improve overall at the six-day mark. On day nine, the control had a DT of 49, an intensity of 2.4, and a hedonic tone of –1.4. The Cast Out, 7.8 L/ha, had a DT equal to the control, an intensity of 2, and a hedonic tone of zero. Because the odor was less intense and less unpleasant, the Cast Out seems to work well at the nine-day mark.

Another amendment that showed reductions in intensity and hedonic tone was the Bio-Catalyst at the 102 L/ha application rate. For days 2 and 6 the DTs were approximately equal to the control. However, the intensity on day 6 was a 2, lower than 2.5 for the control, and the hedonic tone was –1.1, better than –1.6 for the control. For day 9 the intensity was 2, lower then 2.4 for the control, and the hedonic tone was -0.1, better than –1.4 for the control. Because intensity and hedonic tone were reduced, the Bio-Catalyst appeared to be another effective amendment despite the DTs being very similar.

Experiment 3

All of the amendments of experiment 3 had a distinct odor when they were applied. Flo-Scent and Actamine had a sweet candy-like smell. The Solvex had a chemical and petroleum smell. On day two, all of the odor samples had a DT above the 6 of the control (Fig. 3). Intensities and hedonic tones varied widely. At an application rate of 1.53 L/ha the Actamine had a DT of 10, an intensity of 1.1 and a hedonic tone of -0.8. Both intensity and hedonic tone were slightly lower than the control at 1.3 and -0.9 respectively. At the same application rate, Flo-Scent had a higher DT (11), a higher intensity (1.6), and a worse hedonic tone (-1.6) and Solvex had a higher DT (8), a lower intensity (0.7) and a worse hedonic tone (–1.1). At an application rate of 0.78 L/ha, Actamine had a DT of 10, a lower intensity of 0.8, and a worse hedonic tone (-1.1). At the same application rate, the Flo-Scent numbers were all worse than the control with a DT of 15, an intensity of 1.5, and a hedonic tone of –1.1. Though the Solvex had a higher DT (32) at the 0.78 L/ha concentration, the lower intensity of 0.94 and the hedonic tone of -0.5 appeared to indicate a less intense and less offensive odor.

On day six, the DT of the control had risen to 32, the intensity had risen to 2.3, and the hedonic tone had worsened to a –2.5. Only the Actamine at 0.78 L/ha and the Flo-Scent at 1.53 L/ha had lower DTs (29 and 23 respectively). However, neither amendment had lower intensity or better hedonic tone. At an application rate of 0.78 L/ha, the Flo-Scent had a significantly higher DT (76), however, the intensity was lower at 2.0 and the odor appeared to be less unpleasant with a hedonic tone of –2.0.

The DT of the control was 83 on day nine. The intensity of the control was 3.4 and the hedonic tone was -3.5. Actamine and Flo-Scent at the 1.53 L/ha application rate had DTs higher than the control, 128 and 91 respectively. Because intensity and hedonic tone numbers varied little between these samples and the control, any odor reducing ability of these amendments appears to have decreased.

The Solvex, at both application rates, appeared to reduce odor the most on day nine. At the 0.78 L/ha application rate, Solvex had a DT of 38, intensity of 2.3, and hedonic tone of –2.3. At the higher application rate, the Solvex had a DT of 54, intensity of 2.0, and hedonic tone of -1.8.

Experiment 4

The amendments of experiment 4 were tested in previous experiments and chosen for this experiment based on previous performance. The odor sample from the control had a DT of 304, an intensity of 4.8, and a hedonic tone of –3.8 on day two (Fig. 4). The lowest DT was 181 for alum at an application rate of 4500 kg/ha. The alum appeared to reduce odor based on DT; however, this conclusion seemed debatable based on the high intensityand low hedonic tone of the sample. The amendment that appeared to perform best on day two was the Bio-Catalyst at an application rate of 204 L/ha. Though the DT of 216 was not the lowest for the day, this application of the Bio-Catalyst had the lowest intensity of 3.6 and the best hedonic tone of –0.3.

On day six, the control had a DT of 256, an intensity of 4.3 and a hedonic tone of –4. With a DT of 99, an intensity of 2.5, and a hedonic tone of –2.3, the alum appeared to be the best at reducing odor after 6 days. The only other amendment that appeared to reduce odors after six days was the Bio-Catalyst at the 204 L/ha application rate. With a DT of 235, an intensity of 3.2, and a hedonic tone of -3.0, the Bio-Catalyst appeared to have a minimal reducing effect on the odor of the sample.

On day nine, the DT of the control was 197, the intensity was 2.8, and the hedonic tone was –2.8. The only amendment that appeared to reduce odor was alum at the 4500 kg/ha application rate. Though the hedonic tone of the alum at –3.0 was slightly worse than the control, the DT was much lower at 99 and the intensity was the same. No other amendment had reductions in DT, intensity or hedonic tone. Therefore, only the alum appeared to have a positive affect on odor at the nine-day mark.

Experiment 5

Of interest in experiment 5 is that the upper range of the DTs was much higher than in any of the previous four experiments. DTs as high as 8,000 to 10,000 were observed in some of the treatments, with a maximum DT of 860 for the control (Fig. 5). This was the highest DT for any control. The cause of the elevated DTs is unknown. Because new manure was collected for each experiment, it is possible that this manure was more odorous than previous manure collections.

The amendments of experiment 5 were tested in previous experiments and were chosen to be retested in experiment 5 based on previous performance. On day two, the control had a DT of 256, an intensity of 4.5, and a hedonic tone of –3.8 (Fig. 6). None of the amendments in this group had a lower DT than the control on day two. The Cast Out, at an application rate of 11.7 L/ha, had the lowest DT (395) of all the amendments, however, its intensity (5) was among the highest and the hedonic tone (–4) the worst. The humate, at an application rate of 9000 kg/ha, had the lowest intensity (1.8) and the best hedonic tone (-1.8). Though the DT of 1022 was four times higher than the control, the humate still appeared to have a positive effect on the odor by reducing it's strength and unpleasantness.

On day six, the DT of the control was 860, the intensity was 4.4, and the hedonic tone was –4.0. Actamine appeared to have the greatest affect on the odor samples for this day. The DT of the Actamine treated sample was a very low 71, the intensity was 1.2, and the hedonic tone was –2.0. At the six-day mark, only two other amendments showed any possibility of improving odor by seeming to reduce the intensity of the odor. Humate and Cast Out both had higher DTs than the control, 6395 and 1022 respectively. The humate also had a much lower intensity of 2.3 and a better hedonic tone of –1.5. The intensity of the Cast Out at 4.3 was lower than the control, however, both had a hedonic tone of –4.0.

The control sample on day nine had a DT of 790, an intensity of 4.0 and a hedonic tone of –3.5. Humate, at the 9000 kg/ha application rate, seemed to have the greatest affect on the odor sample with a DT of 470, an intensity of 1.9 and a hedonic tone of –1.5. Cast out, at the 11.7 L/ha application rate, was the only other amendment that showed an apparent odor reduction. The DT, 667, and intensity, 3.1, of the Cast Out were both lower than the control and the hedonic tone, -2.3, was improved. The other three amendments in this group had DTs and intensities much higher than the control on day nine. The hedonic tone was also the same or worse. Therefore, these amendments appeared to increase rather than decrease the odor of the sample nine days after application.

Conclusions

Only a few amendments appeared to have a potential effect of reducing the odor from the manure surface. Humate and alum were sometimes effective at lowering the DT, intensity and hedonic tone of the odor. However, the reducing effect was not apparent on all days or for all application rates. Reductions in intensity and/or hedonic tone often occurred without a reduction in the DT of the sample. Some samples showed a reduction in DT, intensity, or hedonic tone alone.

Amendments that had a strong chemical odor, such as Actamine, Solvex, and Flo-Scent, caused a rise in the DT when applied to manure. However, the manure treated with these amendments often had lower intensities and higher hedonic tones indicating the odor was more pleasant with the amendments than without.

Variability in the panel members, panel health, and external environmental factors made comparing samples between days and experiments inappropriate. Therefore, each experiment was analyzed separately. The fact that some amendments appeared to further reduce odor over time could not be confirmed statistically. Amendments that showed slight reductions in DT, intensity, or hedonic tone could not be statistically analyzed to confirm if the reductions were truly significant. None of the amendments showed any overwhelming evidence of greatly reducing odor from simulated open-lot feedyard surfaces.

Table 1. Amendments used in the five experiments.

Experiment No. 1	4500 kg/ha $Al_2(SO_4)_3$ (alum) [f]	9000 kg/ha $Al_2(SO_4)_3$ (alum) [f]	1kg/ha NBPT[a] (urease inhibitor)	Control
	4500 kg/ha $CaCl_2$ (calcium chloride) [f]	9000 kg/ha $CaCl_2$ (calcium chloride) [f]	2 kg/ha NBPT[a]	Container blank
Experiment No. 2	102 L/ha Microbial Bio-Catalyst[b]	52 L/ha Natural Odor Control Liquid[c]	7.8 L/ha Cast Out [d]	Control
	204 L/ha Microbial Bio-Catalyst[b]	20 L/ha Natural Odor Control Liquid[c]	11.7 L/ha Cast Out [d]	Container blank
Experiment No. 3	1.5 L/ha Flo Scent[d]	1.5 L/ha Actamine[d]	1.5 L/ha Solvex concentrate[d]	Control
	0.78 L/ha Flo Scent[d]	0.78 L/ha Actamine[d]	0.78 L/ha Solvex Concentrate[d]	Container blank
Experiment No. 4	4500 kg/ha $Al_2(SO_4)_3$ (alum)	4500 kg/ha Zeo Crystal powder	9000 kg/ha Zeo Crystal powder	Control
	4500 kg/ha black humate	204 L/ha Microbial Bio-Catalyst[b]	102 L/ha Microbial Bio-Catalyst[b]	Container blank
Experiment No. 5	11.7L/ha Cast Out[d]	0.78 L/ha Solvex[d]	Control	Container blank
	7.8 L/ha Actamine[d]	0.78 L/ha Flo-Scent[d]	9000 kg/ha Humate[e]	

[a] Crescent Technology In., Belle Chasse, Louisiana
[b] U.S. Microbes, Ozona, Texas
[c] Zeo Crystal Industries, Crestwood, Illinois
[d] CHEMSEARCH, Irving, Texas
[e] Humatech Inc., Mesa, Arizona

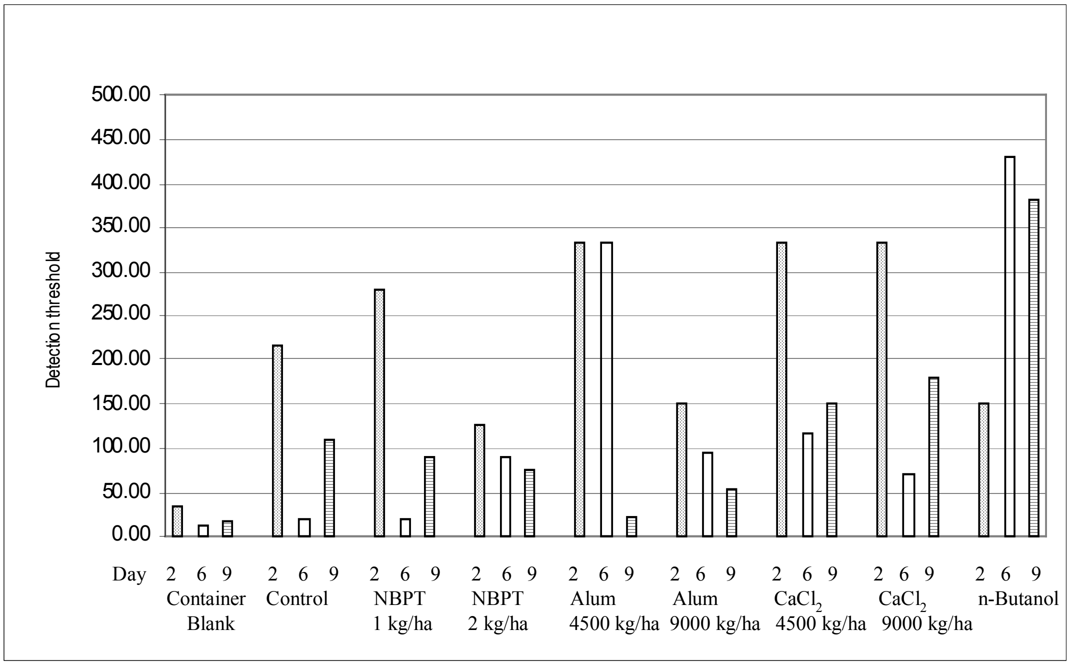

Figure 1. Detection thresholds for amendments in experiment 1.

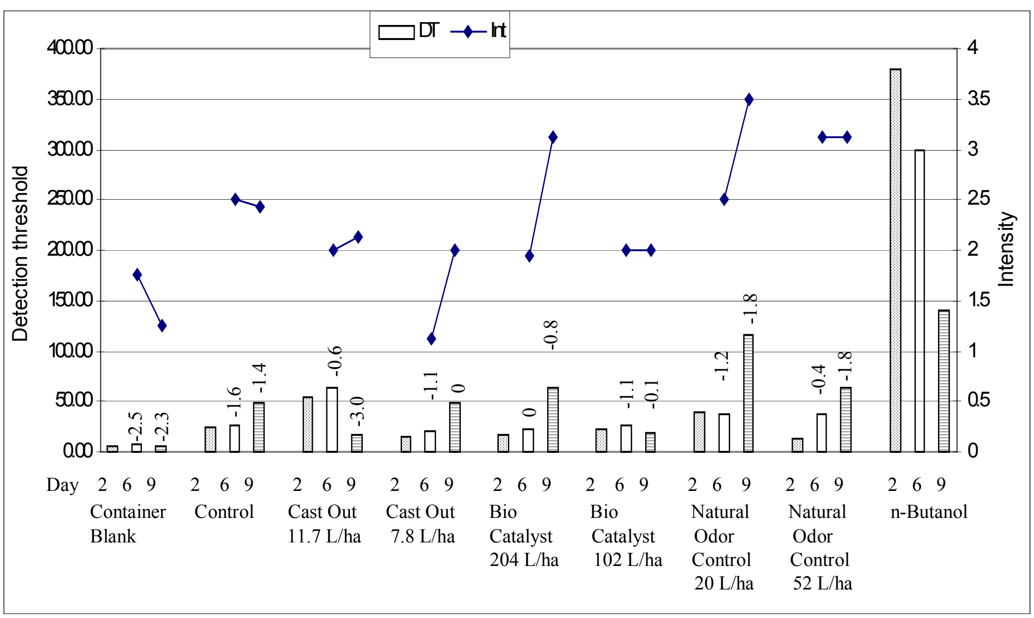

Figure 2. Detection thresholds, intensities, and hedonic tones for experiment 2. The numbers above the bars show the hedonic tone. No intensities or hedonic tone scores were available for day 2.

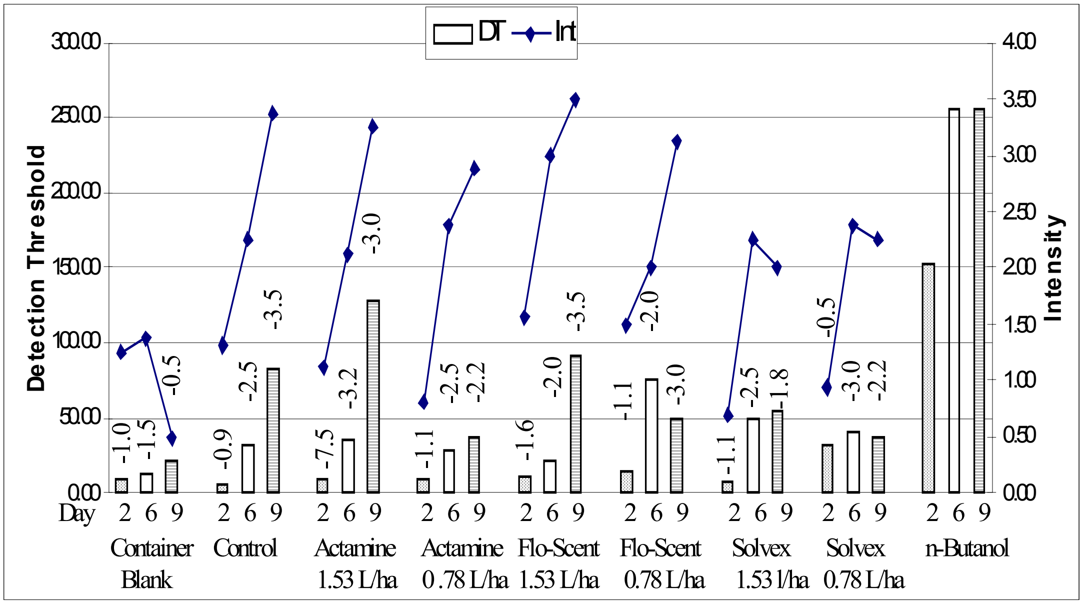

Figure 3. Detection thresholds, intensities, and hedonic tones for experiment 3. The numbers above the bars show hedonic tone.

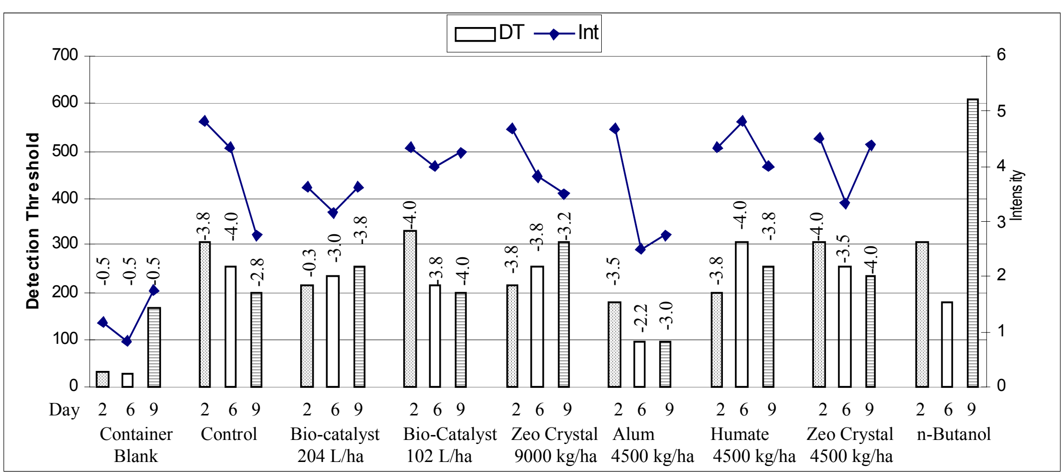

Figure 4. Detection thresholds, intensities, and hedonic tones for the amendments in experiment 4. Numbers above the bars show hedonic tone.

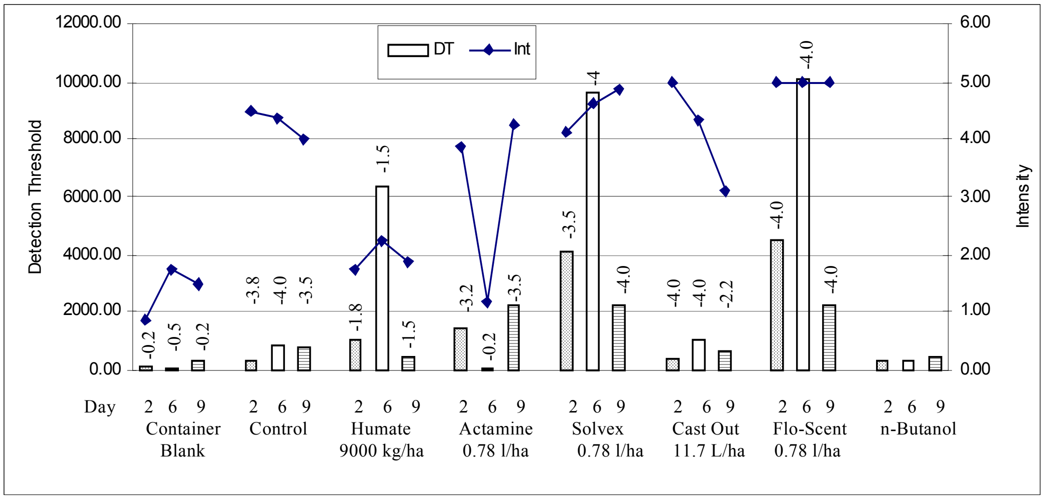

Figure 5. Detection thresholds, intensities, and hedonic tone for amendments of experiment 5. Numbers above the bars show hedonic tone.

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