CHEMICAL ENGINEERING TRANSACTIONS, Volume 15, 2008
Edited by Renato Del Rosso

Effect Of Oil Sprinkling In Swine Finishing Barns On Odor Characteristics And Emissions

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The effects of soybean oil sprinkling (SOS), misting of essential oils (MEO), and misting of essential oils and water (MEOW) on odor emitted from swine finishing houses were evaluated in tests at a commercial operation. Measurements were taken between 27 August 2002 and 21 July 2003 at two mechanically-ventilated barns that were flushed daily with lagoon wastewater. The tests consisted of four trials over three pig groups (cycles): SOS and SOS+ (with additional spray nozzles) for the first and second cycles, MEO for the second cycle, and MEOW for the third cycle. The barn treated with SOS resulted in 30% less odor than the control barn in one trial, and MEO and MEOW slightly improved hedonic tone of barn air. The mean odor concentration and emission were 519 OU/m^3 and 23.5 OU/s-AU (n=21). Odor increased for 4 to 8 min when pits were flushed with lagoon effluent.

1. Introduction And Objectives

According to the literature, odor emissions from swine finishing facilities range from 2 to 21 OU/s-m^2 (Lim et al., 2004; Zhang et al., 2001, Jacobson et al., 1999; Zhu et al., 2000; Heber et al., 1998), depending on the proximity.

The spraying or sprinkling of small quantities of vegetable oils on building interior surfaces has been viewed as a promising technique for particulate matter (PM) control in swine housing for several years (Maghirang et al., 1995) with 50 to 90% reductions in PM (Godbout et al., 2001; Zhang et al., 1996). In experimental research, canola oil is primarily used in Canada and Northern Europe whereas soybean oil is used in the United States. In both cases, it appears that 5.0 mL/m^2-d is the optimum dosage and both oils have similar cost (Takai and Pederson, 1999). Oil applications greater than 10 mL/m^2-d have created a hazardous working environment due to slippery surfaces (Zhang et al., 1996).

Whereas Lemay et al. (1999) sprinkled undiluted canola oil, Jacobson et al. (2001) sprayed soybean oil in water with a water-to-oil ratio of 5:1. Soybean oil in water requires an emulsifier or surfactant to facilitate cleaning the building between pig groups and to keep the nozzles unplugged. However, Nonnenmann et al. (2004) observed that a sticky film still accumulated on barn surfaces with a soybean oil and water mixture with surfactant. Automatic distribution systems are required before the oil sprinkling can be economically adopted (Zhang and Guativa, 1999).

Since PM carries gases and odor, it has been suggested that PM reduction from oil sprinkling may reduce odor (Hartung, 1986). However, studies of gas and odor reductions by controlling PM have shown mixed results. In canola oil tests in swine barns, Godbout et al. (2001) observed no reductions in NH_3 and H_2S while Zhang et al (1997) reported 30 and 27% reductions in NH_3 and H_2S, respectively. Hoff et al. (1997) observed odor reductions of 23 and 76% as particle counts were reduced by 47 to 98%.

Misting essential oils into odorous air is a commercially available method for controlling odor and is considerably less expensive than soybean oil. With this method, proprietary mixes of plant extracts and essential oils are atomized into the air. The odor control mechanisms include absorption of odorants into the tiny droplets with subsequent degradation and chemical reactions along with some potential masking.

The objectives of this field test were therefore to: 1) determine mean odor emissions from a fan-ventilated swine finishing barn with pit flushing, and 2) evaluate whether sprinkling soybean oil or misting essential oils can significantly abate odor emissions from swine finishing barns.

2. Methods and Procedures

A soybean oil sprinkling (SOS) system (Jacobson et al., 2001) automatically applied soybean oil daily to the treated barn. Second, essential oils (Odor Neutralizer™) were utilized by atomizing them into the treated barn. The essential oils application was later modified by atomizing a mixture of essential oils and water.

2.1 Site description

The two 61 m x 13.2 m mechanically-ventilated swine finishing barns were barns 7 and 8 in an 8,800-pig, 8-barn complex. Each barn housed 1,100 pigs, with a row of 24 pens on each side of a center alley. Manure was collected in four gutters beneath a concrete slatted floor. Each gutter was flushed 12 times per day with lagoon effluent for a total of 48 times per day. New pigs entered at a weight of about 25 kg and were fed for 4 to 5 months to a weight of about 123 kg.

Ventilation air typically entered the room through ceiling air inlets. During tunnel ventilation in warm weather, air entered the barn through 1.52-m high sidewall curtains at the east end (Heber et al, 2006). Four 1.22-m diameter belted exhaust fans (Model GPMA-36, Airstream Ventilation Systems (AVS), Assumption, IL) and one 0.91-m direct-drive variable speed fan (AVS Model MXB-4815) were located on the west end. Each barn was ventilated in five stages based on inside temperature (Heber et al., 2006).

2.2 Description of abatement methods

2.2.1 Soybean oil sprinkling (SOS)

The oil sprinkling system was installed in B8 in May 2002, and began operating on 1 July 2002 after testing and adjustment. Soybean oil was sprinkled for one minute at 2:00 pm each day to apply 5 mL/m^2-d, except for the first day dosage of 40 mL/m^2 (Tao, 2004). Oil was pumped from a 75-L storage drum using a water pump and timer-controlled motor. Manually-adjusted oil pressure was maintained with a check valve in the pump body and a solenoid valve, and was monitored with a 690-kPa pressure sensor.

The oil was distributed at 4 L/min and at 448 kPa via a 2.5-cm diameter PVC main line and laterals to fan-spray nozzles (XR 8001 VS Teejet) located 0.46 m from the sidewalls, 0.25 m below the ceiling, and 4.88 m on center above the pen partitions. The nozzles were directed toward the alley and produced a 2.4-m diameter horizontal spray pattern over the partitions between two pens. The nozzles were located to avoid ventilation fans, feeders and heaters.

In trial 2, the same overall application rate was achieved with 35 nozzles operating at 379 kPa and located along the edge of the pens next to the alley. The cost of the oil sprinkling system hardware was approximately $2,100 and the installation labor cost was $2,400. With the economies of scale, the total installation cost was estimated at $3,500 per barn (PSF, 2003). Annual operational costs were estimated at $1,200. Cost of installation and operation per pig space were $3.18 and $1.09, respectively.

2.2.2 Misting Essential Oils (MEO)

Unscented essential oil was heated to 60°C in a barrel drum heater, and evaporated into the drum headspace. A 0.25-kW regenerative blower continuously blew the vaporized essential oil vapors into a 5-cm diameter, 12-m long pipe near the middle of the barn at the ceiling above the pigs. The oil vapors were distributed evenly across the barn width through fifteen 0.63-cm holes distributed at 46-cm intervals (PSF, 2003). The cost of the MEO installation was about $1,625 and the annual operational costs were estimated at $925. Cost of installation and operation per pig space were $1.48 and $0.84, respectively.

2.2.3 Misting Essential Oils and Water (MEOW)

The essential oil and water system consisted of a 7.46-kW rotary screw air compressor that produced a vapor at a consistent pressure between 345 and 414 kPa to 32 nozzles. Each nozzle operated at 35 to 69 kPa. Two nozzles were placed 15.2 m from the front of the barn and 3.7 m apart. Two others were placed 15.2 m from the back of the barn and were 9.45 m apart. The dilution ratio was 150:1. The system operated continuously and each barn used about 0.87 L of oil and 133 L of water daily. The cost of the MEOW installation was estimated at $3,750 and the annual operational costs were estimated at $1,100 (PSF, 2003). Cost of installation and operation per pig space were $3.41 and $1.00, respectively.

2.3 Gas sampling configuration

The gas sampling system facilitated automatic sequential gas sampling from barn exhaust (Heber, et al., 2006). A 47-mm diameter, in-line Teflon filter holder at the sampling probe housed a 47-mm diameter, Teflon-laminated polypropylene membrane filter that removed particulate matter from sampled air. A heat tape wrapped around each tube prevented condensation. Each odor sample was collected through a needle valve in the gas sampling system after the selected gas stream flowed through a filtered Teflon tube, a Teflon solenoid valve, a Teflon manifold, a Teflon-lined pump, a stainless steel mass flow meter, and a Teflon flow restrictor. The exhaust air sampling location was inside the barn one meter away from the primary representative exhaust fan.

2.4 Odor concentration

Air samples were collected into 10-L Tedlar bags every two weeks, from exhaust air in triplicate and ambient air in duplicate. The bags were filled under pressure created by the sampling pump. Sample lines from each barn location were purged for 7 min prior to sample collection. To reduce absorption losses, 2-4 L of sample air were introduced into each bag, and removed, before filling it about 2/3 full with sample air.

Air samples were shipped overnight to Purdue University, West Lafayette, IN. Analysis of odor concentration was conducted using dynamic olfactometry (Lim et al., 2003) according to the quality control procedures and guidelines described in the European olfactometry standard EN13725 (CEN, 2002) except for the requirement of having two rounds per panelist per sample. Odor intensity of sample air was compared by panelists to an n-butanol-in-water reference scale and was expressed as equivalent concentration of n-butanol in water (ppm BIW). Hedonic tone (HT) and character were also subjectively assessed by panelists. The HT was subjectively rated from -10 (extremely offensive) to 0 (neither pleasant nor offensive) to +10 (extremely pleasant) and calculated as the arithmetic mean of individual HT values.

2.5 Barn Airflow

Barn airflow was estimated using measured barn static pressure with actual fan curves determined using a portable fan tester. A ±100 Pa pressure sensor (Model 267 MR, Setra

System, Boxborough, MA) was utilized to measure barn static pressure. The temperature and humidity of exhaust air were measured using capacitance sensors and thermocouples.

2.6 Experimental design and schedule

The barns were compared to evaluate effectiveness of abatement methods, while baseline emission rates were determined from overall measurements at B7. The trials were: 1) SOS with 15 nozzles in the first cycle, 2) SOS+ with 35 nozzles in the second cycle, 3) MEO in the second cycle, and 4) MEOW in the third cycle.

Using the automatic SOS system, oil was sprinkled for 78 days in B8 with 15 nozzles from 28 August to 25 November 2002. Oil was sprinkled for 33 days with 35 nozzles from 13 December 2002 to 28 February 2003 (Table 1). Essential oils were misted into B8 from 5 March to 10 April 2003. A mixture of essential oils and water was atomized in B8 from 24 June to 21 July 2003.

Table 1. Project schedule.

Trial	Abatement	Pig group	Installation in B8	Measurements
1	SOS	1	14 Aug.2002	27 Aug. – 25 Nov. 2002
2	SOS+	2	1 Dec. 2002	13 Dec. 2002 – 28 Feb. 2003
3	MEO	2	3 Mar. 2003	5 Mar. – 10 April 2003
4	MEOW	3	3 Mar. 2003	12 June – 21July 2003

3. Results

3.1 Odor concentration and emission rates

Geometric mean odor concentrations and emission rates are presented in Figures 1 and 2. Table 2 presents the means, which were calculated arithmetically unless otherwise indicated. The geometric mean (± c.i) of the odor detection concentration of n-butanol (ODC_b) was 39±4 ppb as compared with the target of 40 ppb specified by the EN13725 standard (CEN, 2002).

During trial 1 with SOS in B8, the barns were fully occupied with pigs during four of five odor sampling events. Data was not used when the barns were not fully occupied. In B7 and B8, the mean odor concentrations were 292±129 and 206±145 OU/m^3, and the means of odor intensity were 3.41±0.39 and 3.37±0.38 log ppm BIW. The mean odor emission rates were 19.0±18.4 and 9.1±9.1 OU/s-AU from B7 and B8, respectively. The differences in odor concentrations, intensities, and emissions were not significant ($p>0.05$).

In trial 2 with SOS+, mean odor concentrations (n=6) were 990±406 and 698±328 OU/m^3 and mean odor intensities were 3.42±0.08 and 3.42±0.15 log ppm BIW in B7 and B8, respectively. The mean odor emission rates were 20.8±7.4 and 14.4±7.3 OU/s-AU. Odor concentrations and emission rates were significantly different ($p<0.05$) while odor intensity and hedonic tone were not different ($p>0.05$).

During trial 3, the mean odor concentrations (n=4) were 615±289 and 556±281 OU/m^3 while the mean odor intensities were 3.26±0.30 and 3.19±0.33 log ppm BIW in B7 and B8, respectively. The mean odor emission rates were 25.1±41.4 and 22.5±24.7 OU/s-AU in B7 and B8. The differences were not significant ($p>0.05$).

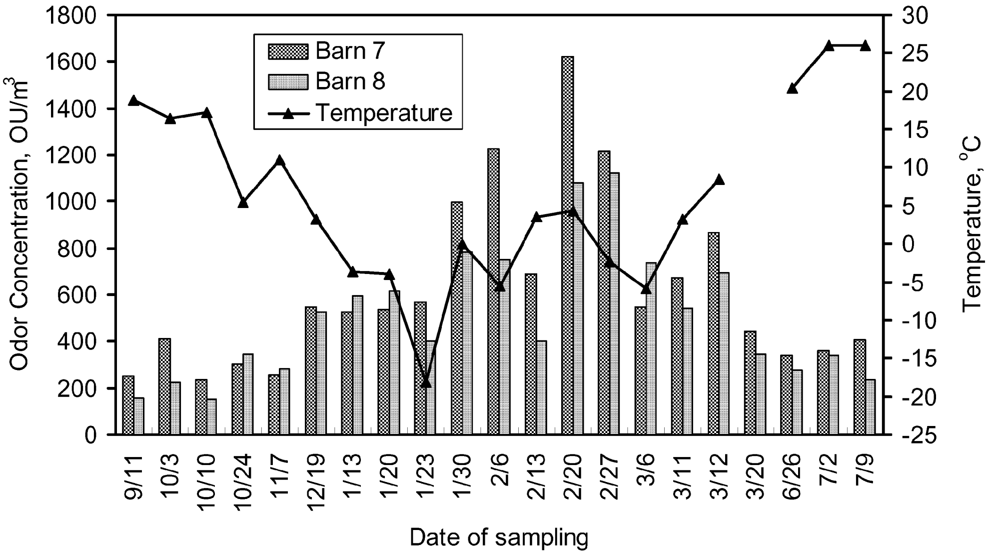

Figure 1. Mean odor concentrations and outdoor temperatures.

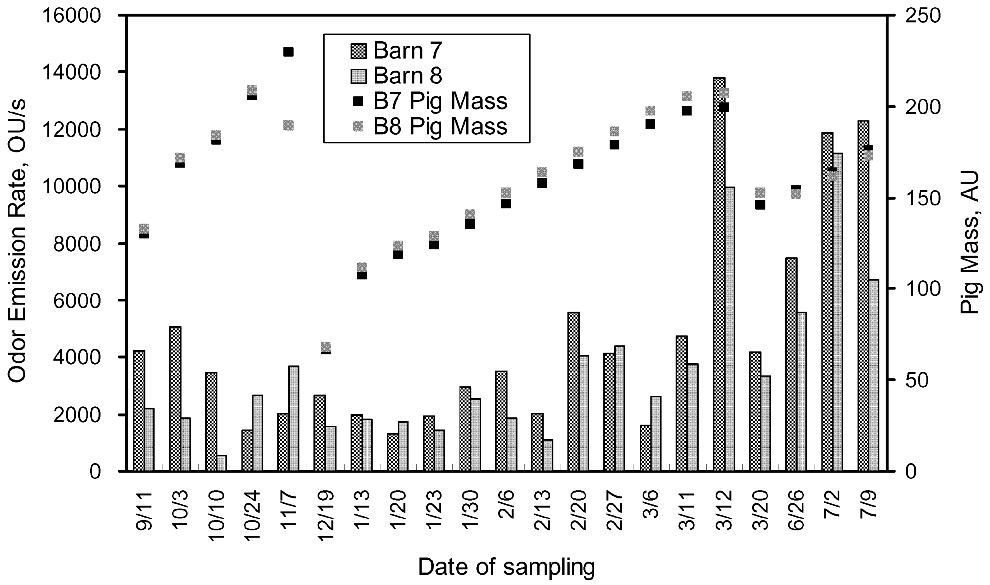

Figure 2. Geometric mean odor emission rates for each odor sampling day.

During trial 4, the mean odor concentrations (n=4) were 332±109 and 254±100 OU/m^3. The means of odor intensity were 3.28±0.13 and 3.15±0.17 log ppm BIW, and the mean odor emission rates were 62.6±24.1 and 46.1±33.1 OU/s-AU in B7 and B8, respectively (Table 2). The differences were not significant (p>0.05).

Throughout testing among all trials, the mean odor concentration in B7 (n=21) was 519±162 OU/m^3 and ranged from 233 to 1620 OU/ m^3. The geometric mean odor intensity was 2478 ppm BIW. The mean odor emission rate was 23.5±9.07 OU/s-AU and ranged from 6.97 to 72.3 OU/s-AU. The live mass specific odor emission rates for each sampling event are presented in Figure 3.

Table 2. Means (±95% c.i.) of odor and other variables, trials 1, 2, 3 and 4.

	Overall	Trial 1		Trial 2		Trial 3		Trial 4	
	B7	B7	B8	B7	B8	B7	B8	B7	B8
Inventory of pigs	1112	1059	1070	1132	1127	1047	1036	1129	1115
Mean pig mass, kg	73.2	81.1	81.5	67.1	70.0	87.3	92.0	76.9	76.8
Exhaust temp., ^oC	21.7	23.5	22.9	19.5	17.5	19.8	21.2	26.8	26.1
Ambient air	n=21	n=4		n=6		n=4		n=4	
OC, OU_E/m^3	105	127		134		60.8		62	
log int., ppm BIW	1.01	3.08		3.05		2.89		2.89	
Hedonic tone	-3.02	-2.49		-3.28		-2.65		-2.06	
Barn exhaust air	n=21	n=4		n=6		n=4		n=4	
OC, OU_E/m^3	508	352	248	984	694	525	475	320	246
log OC, OU_E/m^3	2.71	2.55±0.24	2.39±0.19	2.99±0.21	2.84±0.22	2.72±0.15	2.68±0.18	2.51±0.18	2.39±0.17
log int., ppm BIW	1.18	3.41±0.39	3.37±0.38	3.42±0.08	3.42±0.15	3.26±0.30	3.19±0.33	-	3.15±0.17
Hedonic tone	-4.83	-4.33	-4.04	-5.40	-5.37	-4.73	-3.82	-4.24	-3.64
Emission rates	n=20	n=4		n=6		n=4		n=3	
log E, OU_E /s-AU	1.37	1.36±0.61	1.04±0.48	1.32±0.19	1.15±0.23	1.33±0.59	1.28±0.36	1.81±0.22	1.68±0.24

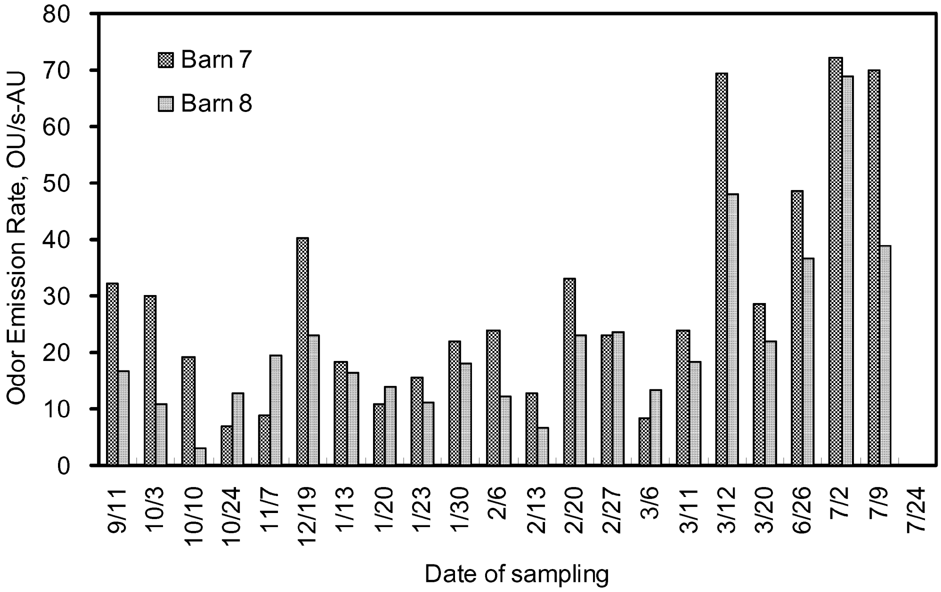

Figure 3. Live mass specific odor emission rates.

4. Discussion

4.1 Effect of SOS

The soybean oil test was conducted in two sequential trials. The number of nozzles was more than doubled in the second trial to give more floor coverage since only 1/3 of the floor was covered by the oil spraying during trial 1. A positive effect of oil sprinkling on odor emission was expected. However, a statistically significant difference was found for odor only in trial 2, with 30% lower emission rate in B8. The high variability and small number of odor samples may have caused an unfortunate lack of statistical power. Another possible problem was that some of the odorants may have reacted with the oil to produce more odorants. It was noted that strong odor was detected after the oil inside the barn had accumulated for several weeks.

4.2 Effect of MEO

Barn 8 showed lower ($p<0.05$) mean odor concentration, emission rate, and intensity; but the difference was not significant. Hedonic tone was significantly improved in B8. This may have been caused by the stronger scent of essential oils that masked barn odor, mitigating the nuisance.

4.3 Effect of MEOW

Barn 8 exhibited lower odor emission rates, but the difference was not significant. Odor intensity was significantly lower ($p<0.05$) and hedonic tone indicated that odor was less unpleasant in B8. Further research is needed to investigate the microbiological and chemical reactions between the odorant compounds and the essential oils.

4.4 Overall odor concentrations and emission rates

The overall geometric mean odor concentration and emission rate were 519 OU/m^3 (n=21) and 23.5 OU/s-AU or 4.51 OU/s-m^2 (n=20). Because the sampling collection period for the odor samples were only 2 or 3 min, the odor emission rates represented only short periods. Odor concentration was not significantly related to odor intensity and hedonic tone ($p<0.05$). Flushing manure pits increased odor concentration as illustrated in

Figure 4. During the flushing event, odor concentration increased from 694 to 1494 OU/m^3, which was about three times higher than the average odor concentration during non-flushing times. Odor emission rates were directly proportional to the hourly mean indoor and outdoor temperatures and ventilation rate (Table 2). These relationships were also observed by Heber et al. (1998).Hedonic tone was significantly correlated ($p<0.05$) with intensity ($r = -0.59$). Odor emission rate was directly correlated ($p<0.05$) with barn ventilation rate ($r=0.55$) and pig activity ($r=0.55$).

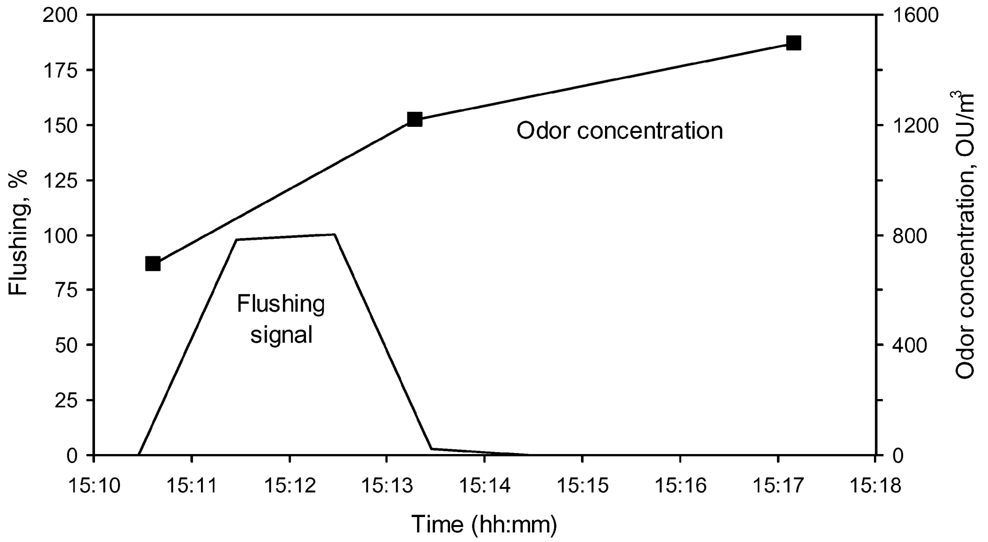

Figure 4. Odor concentration before, during and after flushing of manure on Feb. 20, 2003.

5. Conclusions

The effects of oil treatments on the overall average daily mean odor concentrations and emissions are summarized as follows:

1. Barn 7 ADM odor concentration and emission were 508 OU_E/m^3 and 23.5 OU/s-AU, respectively.
2. Odor intensity was reduced from 3.28 to 3.15 log ppm BIW by MEOW.
3. Hedonic tone was improved slightly from -4.7 to -3.8 by MEO and from -4.2 to -3.6 by MEOW.
4. Barn odor increased momentarily when flushing the manure pits with lagoon effluent.

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