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EFFECT OF SPRAYING BIOLOGICAL ADDITIVES FOR REDUCTION OF DUST AND BIOAEROSOL IN A CONFINEMENT SWINE HOUSE

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Abstract: The aim of this on-site experiment is to evaluate and compare efficiencies of currently utilized biological additives to reduce emissions of dust and bioaeorsol in a confinement swine house. The mean reduction rate of total dust only after spray ranged was approximately 30% for all the treatments, compared to initial level before spraying additives which was found to reduce the initial level of total dust significantly ($p<0.05$). The mean reduction rate of all the treatments at 1hr after spraying was about 24% which was 6% lower than only after spray. Since 3 hr after spraying, however, total dust level fluctuated inconstantly for all the treatments, besides application of soybean oil. The mean reduction rates of all the treatments only after spraying as compared to initial level before spraying were about 53% for total airborne bacteria ($p<0.01$) and 51% for total airborne fungi ($p<0.01$), respectively. At 1 hr after spraying, the reduction rate of total airborne fungi averaged to about 35% for all the treatments ($p<0.05$), while insignificant reductions of total airborne bacteria were found only in the treatments with salt water, soybean oil, artificial spice, and essential oil ($p>0.05$). The fluctuations of total airborne bacteria and fungi, which were similar to total dust, were observed for all the treatments 3 hr after spray.

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Key words: spray, biological additive, dust, bioaerosol, confinement swine house.

INTRODUCTION

Particulates suspended in the air of a swine house include dust and airborne microorganisms [3, 20]. Airborne microorganisms are adsorbed on dust particle smaller than 5 µm in diameter, inhaled by respiration, and deposited in the respiratory tract or lung of humans, which induce respiratory disorders, such as pneumonia, asthma, bronchitis, and rhinitis [1, 6, 7, 18]. The incidence of these respiratory symptoms and diseases are commonly widespread among farmers working in confinement swine houses that are managed almost in an enclosed condition to keep the pertinent thermal environment constant [13, 15, 21, 29]. Thus, to alleviate the potential for farmers to be exposed to dust and bioaerosol, it is essentially important to pertinently control and manage the air quality in the confinement swine house.

Of many techniques devised to reduce emission of dust and bioaerosol in the confinement swine house, spraying with biological additives has been available because they are non-toxic to farmers and swine, more inexpensive and easier to handle compared to other techniques, such as filtration and chemical agents [17]. However, there is little information for their removal efficiencies on dust

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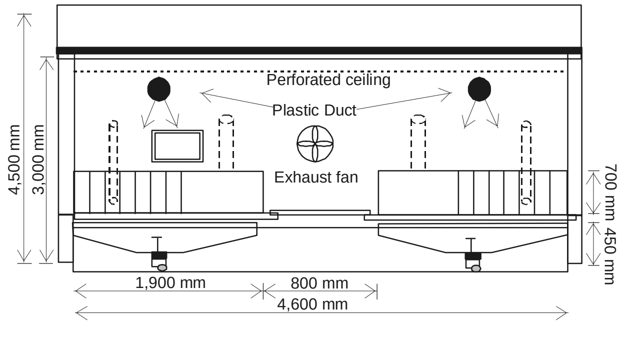
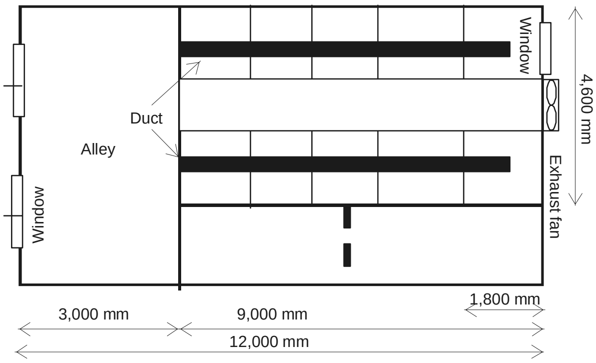


Vertical cross-section



Horizontal cross-section

Figure 1. Layout of experimental housing.

and bioaerosol because until now they have been applied mainly to reduce odorous compounds in swine houses [11, 14, 22, 27, 31]. Furthermore, most previous researches related to evaluation of biological additives were not conducted with on-site scale but on a pilot scale and focused on application of individual additive, although a comparative case study should be developed to objectively elucidate the effectiveness of these additives.

Therefore, the purpose of the study is to compare removal efficiency of dust and bioaerosol of newly devised additives, as well as existing biological additives simultaneously by spraying them in an on-site confinement swine house and observing the reduction level as a function of time.

MATERIALS AND METHODS

Housing and pigs. The confinement pig building (4.6 m × 12.0 m × 3.0 m) used for the experiment was located at the stock farm in college of agriculture, Seoul National University in Korea. It had a 0.45 m deep manure pit under a fully slatted floor with a pit surface area of 22.8 m^2. There were 5 pens (1.9 m × 2.4 m × 0.7 m), installed with open partitions and constructed from galvanized steel spindles 3.7 cm apart, on either side of a 0.8 m wide central alley. The floor consisted of slats. The inside of the house was insulated with 0.8 mm steel plate and 50 mm styrofoam in the side walls and ceiling. The layout of the experimental housing is well shown in the Figure 1.

Table 1. Compositions and treatments of additive application.

Treatment	Composition
Tap water	100% : 10 l tap water
Salt water	5% : 500 g salt in 10 l water
Treated manure	100% : 10 l digested manure
Microbial additive (randomly selected commercial product)	1% : 100 ml in 10 l water (recommended by the manufacture)
Soybean oil	5% : 500 ml in 10 l water
Artificial spice	0.2% : 20 ml in 10 l water
Essential oil	0.185% : 10 ml herb and 8.5 g ravenda in 10 l water

At the beginning of experiment the slurry pit was empty and clean. Every 2 weeks during experimental periods the slurry was removed incompletely from the pit by a typical gravity drain waste system. Ventilation mode in the confinement swine house is a negative pressure system installed in the wall. The air entered the compartment via 2 perforated ducts (Φ 25 cm) located below the ceiling and discharged through perforations 12 (Φ 5 cm); 80 cm apart; directed downwards into the pigs in the pens. The 70 cm-diameter wall exhaust fan in the compartment removed the stale air. Fundamentally, an automatic controller adjusted the wall ventilation rate, based on the inside room temperature.

Four crossbred (Landrace × Yorkshire × Duroc) growing pigs with an approximately average weight of 50 kg were randomly housed in each pen. All pigs were feeder-fed at 16% curd protein corn-soybean meal-based diet that satisfied the NRC nutrient requirements. The feeders were filled by hand once per 2 days. Pigs were given ad libitum access to feed and water supplied by a nipple.

Selection of additives. The composition and list of additives which were evaluated in this study are shown in Table 1. Additives were sprayed in the room uniformly by a manual sprayer for 15 minutes. Total volume of a mixture of water and additive sprayed once was 10 l and repeated 3 times per each treatment. Also, mean value of 3 measurements per treatment was referred to as the representative value. The dilution ratio of water and additive was created based on the economical criteria. The treated manure used in this experiment was digested under autothermal aerobic condition, and its characteristics presented in Table 2.

Measurements. Experimental data presented in this paper were collected during June–August in 2003. Air was sampled at 2 locations which were 0.3 m and 0.15 m above the floor in the middle of the central alley. The samplers were protected by mesh cages having a porosity of 91%. All the samples were taken 6 times: before spray, after spray, 1 hr, 3 hr, 5 hr, and 24 hr after spray.

Total dust levels were measured with an portable direct recorder (M8000-01, Sibata, Japan) which ranged from

Table 2. Characteristics of the auto-thermal aerobic digested manure

Odorous compounds					Odor			Pathogen - log (cfu/m^3) -	
NH_3	H_2S	CH_3SH	DMS	DMDS	concentration index	intensity	offensiveness	*E. coli*	*Salmonella*
0.14 (±0.05)	5.15 (±2.14)	0.97 (±0.25)	0.80 (±0.27)	0.56 (±0.19)	23 (±8)	1.2 (±0.3)	1.0 (±0.4)	1.16 (±0.28)	0.75 (0.21)

Table 3. Initial level of dust and bioaerosol in pig building before spraying additives

	Total dust (µg m^{-3}, GM ± GSD)	Bioaerosol (cfu m^{-3}, GM ± GSD)	
		Total airborne bacteria	Total airborne fungi
Tap water	691 ± 236	$1.02 \times 10^6 \pm 4.45 \times 10^5$	$2.57 \times 10^4 \pm 1.32 \times 10^4$
Salt water	1359 ± 402	$9.26 \times 10^5 \pm 3.27 \times 10^5$	$7.85 \times 10^4 \pm 1.18 \times 10^4$
Digested manure	1165 ± 35	$9.42 \times 10^5 \pm 5.13 \times 10^5$	$3.43 \times 10^4 \pm 1.60 \times 10^4$
Microbial additive	820 ± 71	$5.83 \times 10^5 \pm 2.61 \times 10^5$	$1.95 \times 10^4 \pm 0.83 \times 10^4$
Soybean oil	875 ± 172	$1.13 \times 10^6 \pm 6.28 \times 10^5$	$2.79 \times 10^5 \pm 8.91 \times 10^4$
Artificial spice	1220 ± 527	$1.44 \times 10^6 \pm 5.73 \times 10^5$	$2.35 \times 10^5 \pm 8.16 \times 10^4$
Essential oil	709 ± 90	$1.23 \times 10^6 \pm 4.63 \times 10^5$	$1.66 \times 10^5 \pm 6.07 \times 10^4$
Total average	977 ± 267	$1.04 \times 10^6 \pm 3.08 \times 10^5$	$1.19 \times 10^5 \pm 8.87 \times 10^4$

0.001–9.999 mg m^{-3}. One-stage viable particulate cascade impactor (Model 10-800, Andersen Inc., USA), set at flow rate of 28.3 l min^{-1}, was used for sampling airborne bacteria and fungi. Before sampling, the inside of the sampler was disinfected with 70% alcohol and then was inserted with the agar plate according to collection stage. Trypticase soy agar (Lot 2087730, Becton Dickinson and Company, USA), where cycloheximide 500 mg was added to suppress the growth of fungi, was used as bacterial culture medium. 2% Malt extract agar (Lot 3111376, Becton Dickinson and Company, USA) where cycloheximide 100 mg was applied to suppress the growth of bacteria was used for airborne fungal culture. The culture media for which sample collection were finished were immediately taken to the microbe laboratory and cultured in the incubator for 1–2 days under a 37ºC condition for bacteria, and for 3~5 days under a 20~25ºC condition for fungi, respectively. After incubating was finished, colony counting was made on plates including between 30–300 colonies. Concentrations of airborne microbes were then calculated from the number of colonies, the volume of air sampled, and the dilution factor.

Air temperature and relative humidity were monitored at each sampling location by thermometers (NK201, Carlis, Korea) connected to a computer-based data logging system. The thermometers were calibrated in air prior to the tests, and measurement accuracies of temperature and relative humidity were within ± 0.1ºC and ± 3.5%, respectively.

Data analysis. Differences of dust and bioaerosol between initial concentration before spray and concentration at sampling time after spray for each additive were determined by T-test utilizing SAS software package [23].

RESULTS AND DISCUSSION

Initial level of dust, bioaerosol and environmental factors in confinement pig building before spraying additives. During the experimental period, the initial concentrations of total dust before spray were averaged to 977 (± 267) mg m^{-3}. Initial level of total dust observed in the study was generally lower than values reported by some researchers who investigated the type of confinement swine houses [6, 8, 9, 26]. This result would probably be due to supplying feedstuff manufactured in pellet type, and whole slatted floor of the confinement pig building which were also in accordance with findings by previous studies [2, 16].

The geometric means for total airborne bacteria and fungi before spraying additives were 1.04×10^6 (± 3.08×10^5) cfu m^{-3} and 1.19×10^5 (± 8.87×10^4) cfu m^{-3}, respectively. These initial levels of total airborne bacteria fungi was slightly higher than the range of 1×10^3–7×10^5 cfu m^{-3} demonstrated by previous studies [6, 21, 24], whereas the initial level of total airborne fungi was included in the range of 2×10^3–1×10^5 cfu m^{-3} reported by some researchers [6, 9]. It is considered, unreasonable however to objectively compare the values obtained with this study with previous data because the various technologies for quantifying total airborne bacteria and fungi have been adopted respectively, due to there being no standard method.

The ranges of initial temperature and relative humidity in the confinement pig building during the experimental period, were 22~28ºC and 59~65%, respectively. Little difference of temperature between initial time before spray and sampling time of 24 hr after spray was not found, whereas relative humidity increased 10~20%

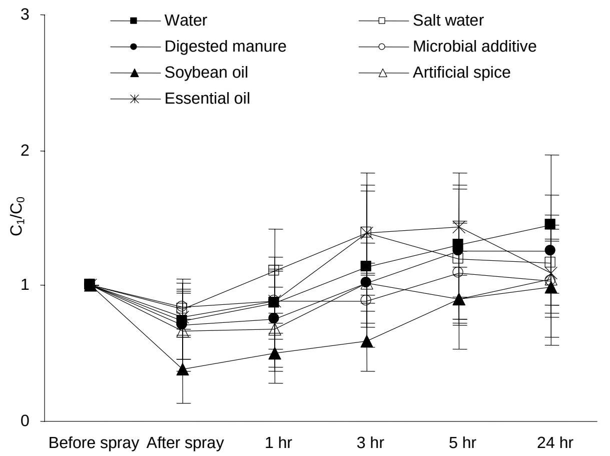


Figure 2. Time-based reduction rate of total dust after spraying additives.

higher than initial level until 1 hr after spray, and then decreased to the level similar to initial time before spray.

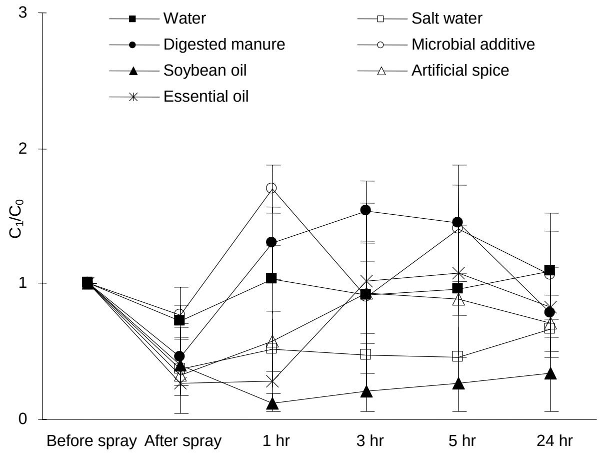
Time-based reduction rate of total dust after spraying additives. To represent reduction rate of total dust after spraying each additive, the ratio of the level at sampling time (C_t) and the initial level before spray (C_0) was applied based on the change rate of concentration as a function of time (dC/dt). The mean reduction rate of total dust only after spray ranged was approximately 30% for all the treatments compared to initial level before spraying additives which was found to reduce the initial level of total dust significantly ($p<0.05$). The mean reduction rate of all the treatments at 1 hr after spray was about 24% which was 6% lower than only after spray. However, 3 hr after spray, total dust level fluctuated inconstantly for all the treatments, apart from application of soybean oil (Fig. 2).

It was observed that an appreciable duration effect to lower the dust level reached only 1 hr for all the treatments, except for soybean oil. This would probably occur due to 2 factors: inner relative humidity and animal activity. As a result of the experiment, the inner relative humidity house increased to about 10-20% after spraying all the additives, as mentioned above, when compared with the initial relative humidity before spray and this humid condition in confinement swine was continuously maintained for 1 hr. However, 1 hr after spray, the inside relative humidity decreased or fluctuated which may induce a temporal variation of dust level. This hypothesis is also supported by the fact that relative humidity is inversely related to the total dust concentration in confinement swine houses [12]. In addition to relative humidity, this would perhaps be caused by the fact that temporal change of the unpredicted pig activity strongly affects the total dust level in the air [10]. On the other hand, reduction of the dust level after spraying soybean oil continued significantly for 24 hours in comparison with initial dust level before spray ($p<0.05$). Excellent efficiency of soybean oil application for reducing dust in the confinement swine house has been demonstrated beforehand by some researchers [25, 30]. A possible explanation for the process of dust reduction by application of soybean oil is that the droplets of sprayed soybean oil would presumably cause airborne dust particles to coagulate, settle and adhere to surfaces in confinement swine house [25]. Pearson and Sharples [19] reported that spraying of some oils might provoke an adverse health effect on farmers and swine because of carcinogenicity of some oils and increase the survival of microorganisms in the air by high humidity. However, vegetable oils such as soybean oil have been demonstrated to be physiologically safe, even though farmers were exposed to and then inhaled its suspended particles [25, 30]. Therefore, the utilization of soybean oil to lessen the dust level in the confinement pig house is considered to be most effective additive of other biological additives evaluated in the study.

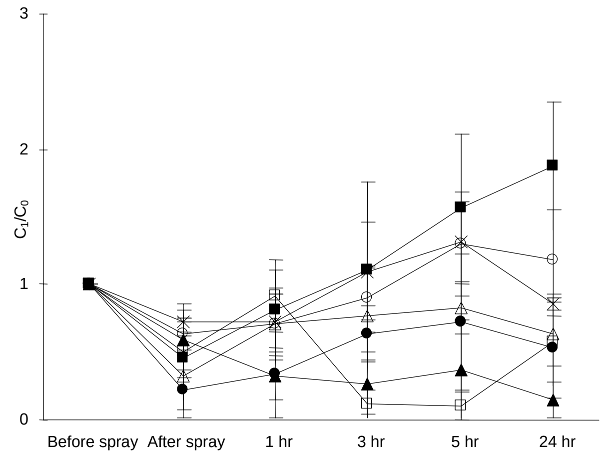
Time-based reduction rate of total airborne bacteria and fungi after spraying additives. The mean reduction rates of all the treatments only after spray as compared to initial level before spray, were about 53% for total airborne bacteria ($p<0.01$) and 51% for total airborne fungi ($p<0.01$), respectively. At 1 hr after spray, the reduction rate of total airborne fungi was averaged to about 35% for all the treatments ($p<0.05$), while insignificant reductions of total airborne bacteria were found only in the treatments with salt water, soybean oil, artificial spice, and essential oil ($p>0.05$). The fluctuations of total airborne bacteria and fungi, 3 hr after spray, which were similar to total dust, were observed for all the treatments (Fig. 3).

Time-based change pattern of total airborne bacteria and fungi after spray was somewhat identical to total dust. This phenomenon can perhaps be explained in terms of the following 2 notions. One is that the survival of airborne microorganisms is determined primarily by thermal environment factors: temperature and relative humidity [28]. Especially fluctuation of relative humidity causes the movement of water molecules in and out of the cell in an equilibrium system and sequentially a collapse of the natural structure of cellular system, resulting in the death of the airborne microorganisms [5]. The other is that dust is the carrier of airborne microorganisms [7]. In case of the former, however, the relationship between survival of airborne microorganisms and temperature and relative humidity has not been elucidated apparently until now. Furthermore, the extreme inside temperature and relative humidity which can remarkably influence the survival of airborne microorganisms were seldom measured; the significant differences between before and after spray were also not observed during the experimental period. It was presumed, therefore, that survival of total airborne bacteria and fungi in the air would be determined by the latter rather than the former.

Another unique observation is that the level of total airborne bacteria after spraying digested manure and



Total airborne bacteria



Total airborne fungi

Figure 3. Time-based reduction rate of bioaerosol after spraying additives.

microbial additive increased sharply in comparison with the initial level before spray. This results perhaps from bacterial aerosolized droplets emanated from sprayed digested manure and microbial additive which are liable to contain relatively more microbes than the other biological additives.

CONCLUSIONS

Soybean oil showed a significant reduction effect on total dust, airborne bacteria and fungi until 24 hr after spray, whereas a significant duration effect of other biological additives on reducing them continued until 1 hr after spray. In the application of digested manure and microbial additive, however, the level of total airborne bacteria was rather higher than the initial level before spray, which probably results from bacterial aerosolized droplets emanated from the sprayed digested manure and microbial additive. Time-based change pattern of total airborne bacteria and fungi after spray was similar to total dust because dust particles adsorb airborne microorganisms and moves together in the air. In conclusion, soybean oil was the most effective additive of biological additives evaluated in the study in lowering the level of dust and bioaerosol in the confinement swine house.

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