JAST (Journal of Animal Science and Technology) TITLE PAGE

Upload this completed form to website with submission

ARTICLE INFORMATION	Fill in information in each box below
Article Type	Research article, Review article or Short Communcation
Article Title (within 20 words without abbreviations)	Odor generation pattern of swine manure according to the processing form of feed
Running Title (within 10 words)	Association of swine manure odor and feed type
Author	Won Choi[1], Wooje Lee[1], Kiyoun Kim[1, 2*]
Affiliation	1. Graduate School of Safety Engineering, Seoul National University of Science and Technology, Seoul, Korea 2. Department of Safety Engineering, Seoul National University of Science and Technology, Seoul, Korea
ORCID (for more information, please visit https://orcid.org)	Won Choi (https://orcid.org/0000-0003-4555-7913) Wooje lee (https://orcid.org/0000-0001-9981-4044) Kiyoun kim (https://orcid.org/0000-0001-6889-8548)
Competing interests	No potential conflict of interest relevant to this article was reported.
Funding sources State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available.	This study was supported by the Research Program funded by the Seoul Tech(Seoul National University of Science and Technology.
Acknowledgements	This study was supported by the Research Program funded by the Seoul Tech(Seoul National University of Science and Technology.
Availability of data and material	Upon reasonable request, the datasets of this study can be available from the corresponding author.
Authors' contributions Please specify the authors' role using this form.	Conceptualization: Choi W. Data curation: Choi W, Lee WJ. Formal analysis: Choi W. Methodology: Kim KY. Software: Kim KY, Choi W. Validation: Kim KY. Investigation: Choi W, Lee WJ. Writing - original draft: Choi W. Writing - review & editing: Kim KY, Lee WJ.
Ethics approval and consent to participate	This article requires IACUC approval because there are animal participants.

CORRESPONDING AUTHOR CONTACT INFORMATION

For the corresponding author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	Ki-Youn Kim
Email address – this is where your proofs will be sent	kky5@seoultech.ac.kr
Secondary Email address	kkysnu5@daum.net
Address	13 Gongneung-ro, Nowon-gu, Seoul 01811, Rep. of Korea
Cell phone number	+82-10-6312-9463
Office phone number	+82-2-970-6376
Fax number	+82-2-970-6377

Abstract

Feed has a great influence on the composition of swine manure, which is the principal cause of odor. Therefore, the purpose of this study is to simply change the shape of pig feed and control calories to find a suitable feed form for reducing the smell of swine manure. The experiment was conducted on 15 pigs from July to August 2021, and a total of three measurements were done. Three types of feed were evaluated in this study. The analysis items related to odor of swine manure are complex odor, ammonia, sulfur-based odors, and VOCs. In the case of complex odor, dilution multiples tended to decrease over time, except for type A feed. The concentration of ammonia in all types of feed decreased over time. Most sulfur-based odorous substances except hydrogen sulfide at the first measurement were not detected. Representatively, Decane, 2,6-Dimethylnonane, and 1-Methyl-3-propylcycolhexane were detected in VOCs generated from swine manure. The major odorous substansces in swine manure have changed from ammonia and sulfur compounds to VOCs. In order to reduce the odor caused by swine manure, it is ad-vantageous to use low-calorie feed consisting of pellet-type.

Keywords: Odor; Feed; Swine; Manure; Farm

Introduction

The odor emitted from swine farms is a serious problem for nearby residents and hinders the development of the swine industry [1]. Odor can also have a significant im-pact on human health and quality of life [2]. The operational conditions such as com-posting facility aeration process, sealing level, emission source identification, gas emission treatment and collection are considered as the form of basic swine odor management [3]. In addition, pertinent management of livestock manure composting can help minimizing the effects of odors, although odors cannot be completely avoided [4].

It is also very important to understand the chemical composition of the odor and the concentration of the odorous substances. Ammonia and sulfuric compounds are the representative livestock odor substances found in previous studies [5], but the composition of odor-forming substances is not simple [5,6]. Analyzing individual substances that make up complex compounds can greatly contribute to finding causes of odor and ways to reduce odor [7].

Until now, studies conducted to reduce the odor released from swine farms have focused on remodeling swine farm facilities, application of odor reducing substances such as deodorants, and identification of odor causing substances [8]. Although various techniques have been tried to reduce odor emitted from swine houses, there is no pertinent odor control method suggested to meet efficiency, economics and safety. Biofiltration methods such as biofilter, bioscrubber and biotrickling filter are proven efficient to reduce odor emission in pig building by many researchers [9]. However, they can be difficult to operate and more expensive than other odor reduction strategies in terms of construction cost. The chemical methods using many different oxidizing agents like ozone are also effective in reducing malodors in pig building, but these have relatively short periods' effectiveness and can be potentially toxic to farmers and pigs if applied excessively [10]. However, these methods can be suitable as countermeasures after the occurrence of odors.

The swine manure is the principal cause of odor derived from swine farms [11]. In addition, main factor affecting the composition of swine manure was reported to be the feed [12]. Previous research has shown that amino acid supplementation in feed affects odor intensity, ammonia release and swine manure properties such as PH, ammonia, nitrogen, sulfur, phenolic compounds and VFA. Their results showed that supplementing crystal-line S-containing AA(amino acid) in surplus of the requirement increased odor emission ($P < 0.001$) and odor intensity ($P < 0.05$) and reduced odor hedonic tone ($P < 0.05$) from the air above the manure pits. To reduce odor from pig manure, dietary S-containing AA should be minimized to just meet the recommended requirements [13]. However, there are little information on the generation pattern of swine odor substance according to feed processing form and composition.

Therefore, the purpose of this study is to find a form of feed suitable for reducing odors by changing the processing mode and caloric value of feed that directly affects swine manure composition.

Method

Subject

The experimental procedure was approved by the Institutional Animal Care and Use Committee at Seoul National University of Science & Technology (approval No. : 2021-0002). The experimental period was between July and August in 2022. Three types of feed (A type: powder & general calorie feed, B type: pellet & general calorie feed, C type: pellet & low calorie feed) were evaluated in this study. Table 1 shows the general ingredient information for feed.

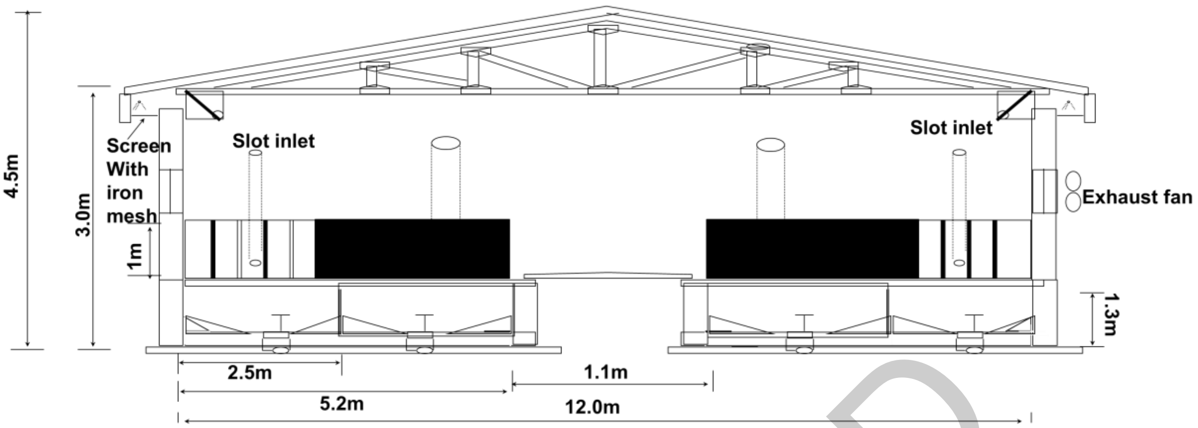
Table 1. General ingredient information on feed.

Item	Type A	Type B	Type C
Dry matter, %	87.82	87.64	87.37
Gross energy(GE), kcal/kg	3,907	3,844	3,820
Crude protein(CP), %	12.51	12.73	13.71
Ether extract(EE), %	5.20	4.26	4.29
Crude ash(Ash), %	3.72	3.86	3.82
Neutral detergent fiber(NDF), %	13.66	14.46	11.75
Acid detergent fiber (ADF), %	2.89	3.57	3.31

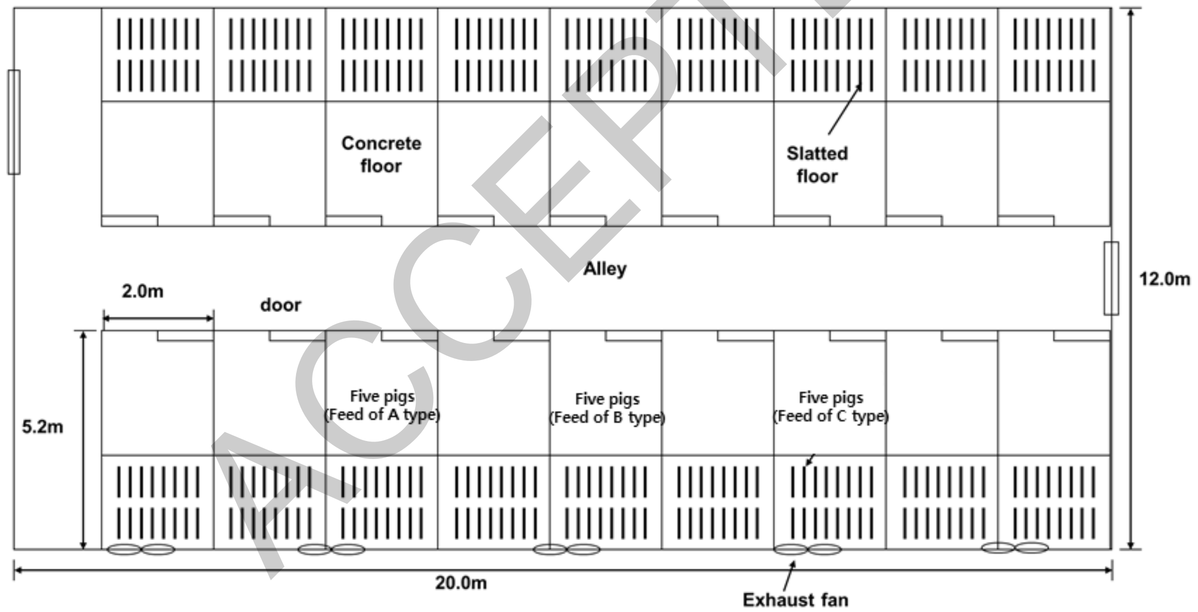
Experimental swine house (4.5m×12.0m×3.0m) selected in this study was located at the National Institute of Animal Science, Korea. It had two pig housing rooms and 10 pens (L:6.0m X W:5.2m X H:0.5m) in each room installed with open partitions and constructed from galvanized steel spindles 3.7cm apart, on either side of a 1.1m wide central alley. A 1.3m deep manure pit was under a partially slatted and concrete floor with a pit surface area of 22.8㎡. Inside, the building was insulated with 0.8mm steel plate and 50mm styrofoam in the side walls and ceiling. The ventilation mode in the pig building is a negative pressure system equipped in the wall. The 70cm-diameter wall exhaust fan in the compartment removed the stale air. Fundamentally, an automatic controller adjusted the wall ventilation rate based on the optimal room temperature (15-25℃) and relative humidity (40-70%) for growing pig well. The layout of the experimental swine house is well described in figure 1.

Total fifteen crossbred (Landrace×Yorkshire×Duroc) growing pigs with the approximate average weight of 50kg were housed and five pigs were placed shown in Figure 1 to investigate the odor generation pattern according to three types of feed with different processing form. All the pigs were feeder-fed at 16% protein corn-soybean meal-based diet that satisfied the NRC(National Research

Council) nutrient requirements. The feeders were manually filled once every two days. Pigs were given ad libitum access to feed and water supplied by a nipple.



(a) View of vertical cross-section



(b) View of horizontal cross-section

Figure 1. The layout of experimental swine house

Measurements

1kg of swine manure collected from pit of three treatment pens was placed in a glass bottle and maintained at 25℃ through a thermostat and air was sampled thrice every two weeks after the initial concentration measurement to evaluate the odor generation pattern during experimental period. The odorous air samples were collected in a 3L capacity Tedlar bag using portable air sampler (FIBOX, Odortech, South Korea). Complex odors were analyzed by using human sense of smell according to the standard test protocol presented by the Korean Ministry of Environment. The concentration of ammonia and the sulfur-based substance (Hydrogen sulfide, Methyl mercaptan, Dimethyl sulfide, Dimethyl disulfide), which are the main substances of swine odor, were measured using a direct recording measuring device (BL-002, Baseline, Korea) connected to the Tedlar bag. The operation mode of the direct recording measuring device was continuous monitoring in seconds for 1 minute using the periodic measurement mode and the average of values measured for 1 minute was used as a representative value.

For qualitative analysis of swine manure odor substances, air samples were collected in a solid adsorption tube (Tenax TA tube, Carbograph1, U.S.) at a flow rate of 100ml/min for 20 minutes. After condensing and adsorbing the collected air sample to 2L each, TD (APK, KNR, Korea)-GC (7820A, Agilent, USA)-MS (5977E, Agilent, USA) was used for detecting individual volatile organic compounds. Table 2 shows the detailed analysis conditions of TD-GC-MS.

Table 2. Analysis conditions of TD-GC-MS

TD-GC-MS			
Thermal desorption (APK720R)			
Valve oven temperature		150℃	
Transfer line temperature		180℃	
Concentration		1st Desorption temperature	300℃
		Focusing temperature	-20℃
		Focusing time	10 min
Desorption		Temperature	300℃
		Desorption time	3 min
GC-MS (Agilent7820A-5977E MSD)			
Inlet	Temperature	250℃	
	Flow rate	1 ml/min	
Oven temperature		35℃ (20min) 5℃/min to 50℃ (10min) 5℃/min to 100℃ (10min) 5℃/min to 130℃ (10min) 5℃/min to 185℃ (0min) (total 80 min)	
MS	Aux-1 Temperature	300℃	
	MS source	230℃	
	MS quad	150℃	

Results

Complex Odor

The results of sensory evaluation for complex odor are shown in Figure 2. In this data, a high air dilution ratio means a severe odor. In all types of feed, the highest air dilution ratio was found at the first sampling and it was very low at the second sampling. However, it tended to increase again at the third sampling.

In case of type A feed, the air dilution ratio was measured at an average of 2,481(±890) when first sampled, but at the last sampling, it was measured at 3,000(±0) higher than the first, indicating that the odor became worse. For type B feed, the air dilution ratio was determined to be the highest at 2,678(±719) at the first sampling, but the odor decreased the most at the second sampling over time. And it was found that the odor increased when the last sample was collected four weeks later. For type C feed, the air dilution ratio was 1,386(±451) at the first sampling and 486(±217) at the second sampling, and the odor level decreased as time passed. However, the type C feed also showed an air dilution ratio of 595(±165) in the sampling after 4 weeks (third sampling), indicating that the odor level increased again.

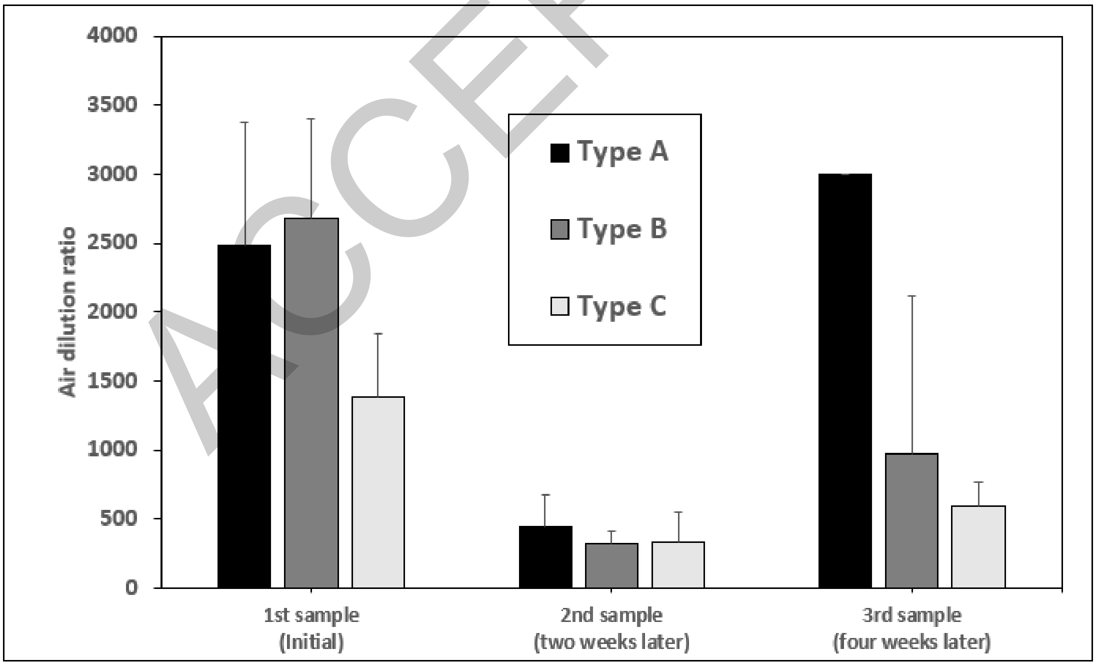


Figure 2. Temporal trend of the air dilution ratio(complex odor) by feed types

Ammonia

As shown in Figure 3, ammonia concentration decreased over time in all types of feed. The Type A feed reduced ammonia concentration from 1,452(±1,395) ppm at the first sampling to 234(±115) ppm at the second sampling and 111(±48.6) ppm at the third sampling continuously. The type B feed decreased from 646(±188) ppm at the first sampling to 96(±54.3) ppm at the second sampling, but slightly increased to 100(±89.5) ppm at the third sampling. The type C feed showed a stable decrease in concentration from 780(±413) ppm to the last 60(±21.7) ppm.

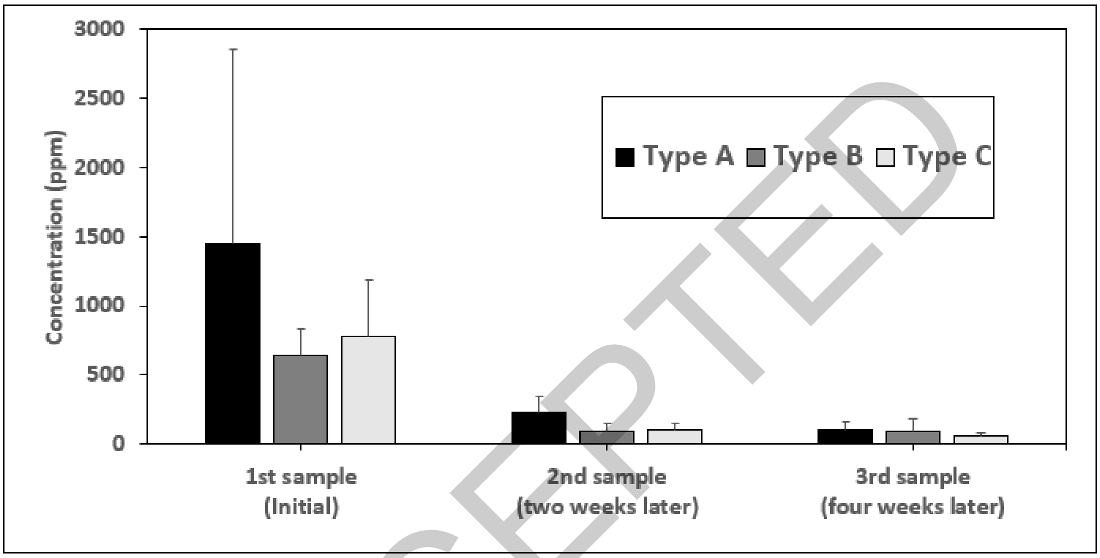


Figure 3. Temporal trend of ammonia concentration by feed type

Sulphur-based odorous substances

At the first sampling, all substances (MM, DMS, DMDS) except H2S were below the detection limit or the quantitative limit. Hydrogen sulfide was measured at a level of 3.26 to 3.72 ppm in all samples regardless of feed type. In the case of the second sampling, 1.29 ppm of DMDS was detected in swine manure sample No. 1 among Type A feeds, and 0.18 ppm of DMS was detected in swine manure sample No. 2. In addition, 0.22 ppm of MM and 0.70 ppm of DMS were detected in the manure sample No. 3. H2S was detected at 0.27 ppm in the 12th odor sample of Type C feed. And all the rest of swine manure samples were below the detection limit or below the quantitative limit. The third sampling was analyzed below the quantitative limit in all samples (refer to Table 3).

Table 3. Analysis results of sulphur-based odorous substances

Sampling	Feed type	No.	Concentration(ppm)			
			H_2S	MM	DMS	DMDS

1st sample (Initial)	A	1	**3.65**	n.d.	n.d.	n.d.
		2	**3.71**	n.d.	n.d.	n.d.
		3	**3.72**	n.d.	n.d.	n.d.
		4	**3.68**	n.d.	n.d.	n.d.
		5	**3.71**	n.d.	n.d.	n.d.
	B	6	**3.36**	n.d.	n.d.	**b.d.l**
		7	**3.26**	n.d.	n.d.	**b.d.l**
		8	**3.44**	n.d.	n.d.	n.d.
		9	**3.49**	n.d.	n.d.	n.d.
		10	**3.37**	n.d.	n.d.	n.d.
	C	11	**3.64**	n.d.	n.d.	n.d.
		12	**3.4**	n.d.	**b.d.l**	n.d.
		13	**3.43**	n.d.	**b.d.l**	n.d.
		14	**3.43**	n.d.	n.d.	n.d.
		15	**3.62**	n.d.	n.d.	n.d.
2nd sample (two weeks later)	A	1	n.d.	n.d.	n.d.	**1.29**
		2	n.d.	**b.d.l.**	**0.18**	**b.d.l.**
		3	n.d.	**0.22**	**0.7**	**b.d.l.**
		4	n.d.	n.d.	n.d.	n.d.
		5	n.d.	n.d.	n.d.	n.d.
	B	6	n.d.	n.d.	n.d.	**b.d.l.**
		7	n.d.	n.d.	n.d.	**b.d.l.**
		8	n.d.	n.d.	n.d.	n.d.
		9	n.d.	n.d.	n.d.	n.d.
		10	n.d.	n.d.	n.d.	n.d.
	C	11	n.d.	n.d.	n.d.	n.d.
		12	n.d.	n.d.	n.d.	n.d.
		13	n.d.	n.d.	**b.d.l.**	**b.d.l.**
		14	**0.27**	n.d.	n.d.	**b.d.l.**
		15	n.d.	n.d.	n.d.	**b.d.l.**
3rd sample (four weeks later)	A, B, C	1~15	n.d.	n.d.	n.d.	n.d.

- H_2S: hydrogen sulfide, MM: methyl mercaptan, DMS: dimethyl sulfide, DMDS: dimethyl disulfide
- n.d.: not detected
- b.d.l.: below detection limit

Qualitative analysis of VOCs (Volatile Organic Compounds)

Tables 4 to 12 show representative VOCs for each feed type detected through qualitative analysis. The major VOCs were analyzed by sorting the materials in the order of areas, and all chromatograms had the same abundance range for mutual comparison. At the first sample, Decane (n-Decane, 2-

Methylldecane, 3-Methylldecane, 4-Methylldecane, 5-Methylldecane, etc.), 2, 6-Dimethylnonane, and 1-Methyl-3-propylcyclohexane were commonly detected as shown in Table 4~6.

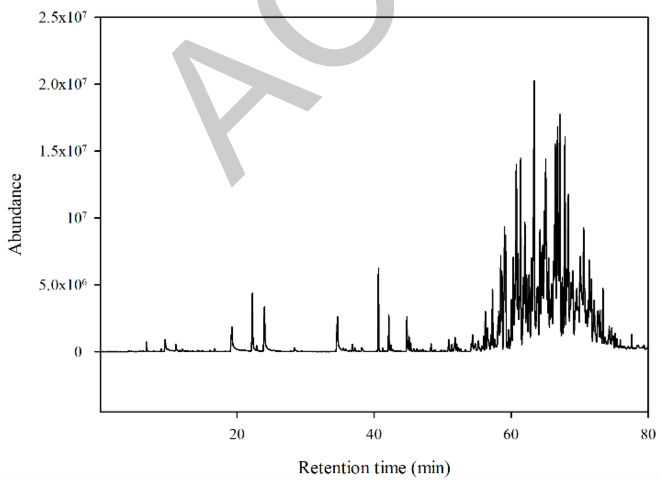
At the second sample of type A feed, Decane (n-Decane, 2-Methyldecane, 3-Methyldecane, 4-Methyldecane, 5-Methyldecane, etc.), and methyl disulfide were ana-lyzed as the main components of VOCs. Overall the Decane accounted for most of the top areas of type A feed as shown in Table 7.

In case of type B feed, components such as Decane (n-Decane, 2-Methyldecane, 3-Methyldecane, 4-Methyldecane, 5-Methyldecane, etc.), n-Undecane, methyl disulfide, and Dimethylsiloxane cyclic trimer were analyzed as major VOCs. Overall about half of the top areas were Decane and the other half were other substances as shown in Table 8.

In case of Type C feed, the top three materials in the area were composed of only the four substances listed above and the substances were the main VOCs as shown in Table 9.

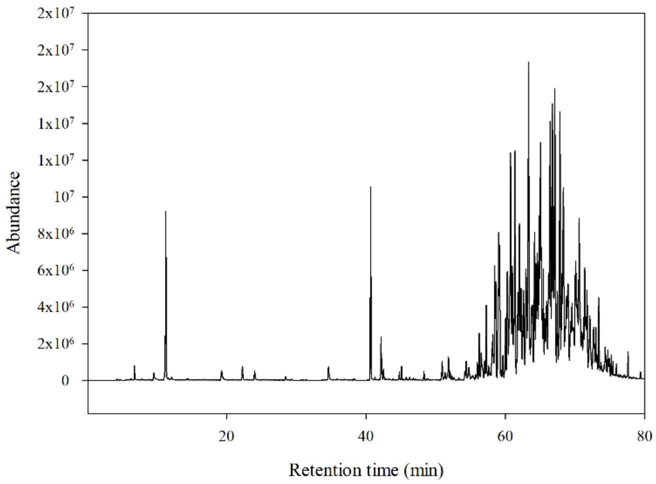
At the third sample, Butyl alcohol, Methyl disulfide, and n-Dodecane were analyzed as major VOCs in the case of type A. Many other substances were also detected besides major substances in case of type A feed as shown in Table 10. For type B and C feed, Dime-thylacetamide, Dimethylsiloxane cyclic trimer, 1,1,3,3,5,5-Hexamethyl-cyclohexasiloxane, and n-Dodecane were analyzed as the main VOCs. In both type B and C feed, Dimethyla-cetamide accounted for the largest number of areas and the area itself of all materials was also smaller than the first and second sampling days as shown in 11 and 12.

Table 4. Qualitative analysis of VOCs emitted from swine manure by type A feed (1st sample)



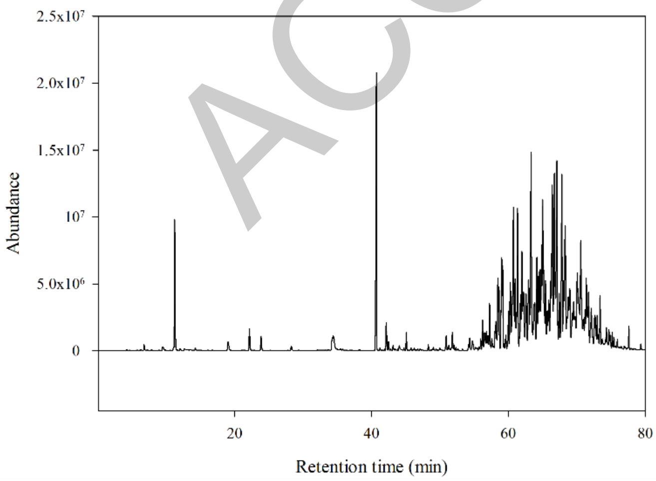
Material	AREA (%)
Decane, 4-methyl- $$ 4-Methyldecane	7.987212
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	6.679324
Decane $$ n-Decane $$ n-C10H22	5.7009
Cyclohexane, 1-methyl-3-propyl- $$ 1-Methyl-3-propylcyclohexane #	5.630505
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	5.588327
Cyclohexane, (1-methylpropyl)- $$ Cyclohexane, sec-butyl- $$ 2-Cyclohexylbutane	5.372896
Decane, 4-methyl- $$ 4-Methyldecane	5.272657
Naphthalene, decahydro-, trans- $$ trans-Bicyclo[4.4.0]Decane $$ trans-Decalin	4.277875
2-HEXENE, 4-ETHYL-2,3-DIMETHYL-	3.775411
Undecane $$ n-Undecane $$ Hendecane $$ n-C11H24	3.109701

Table 5. Qualitative analysis of VOCs emitted from swine manure by type B feed (1st sample)



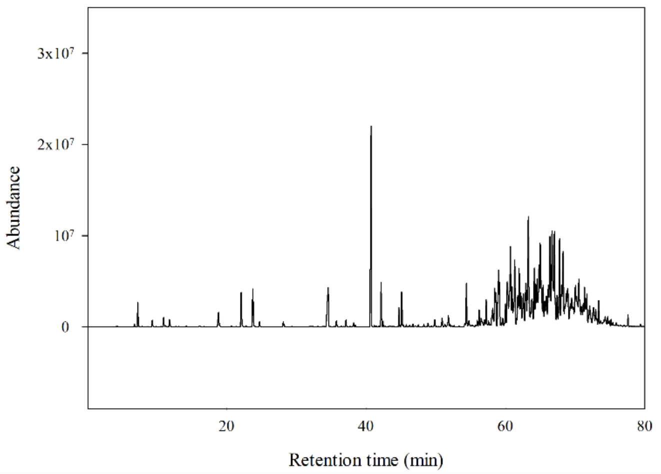
Material	AREA (%)
Nonane, 2,6-dimethyl- $$ 2,6-Dimethylnonane	7.88554
Decane, 4-methyl- $$ 4-Methyldecane	7.621157
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	6.852162
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	5.818283
Cyclohexane, 1-methyl-3-propyl- $$ 1-Methyl-3-propylcyclohexane #	5.712244
Decane (CAS) $$ n-Decane $$ Isodecane $$ n-C10H22 $$ DECAN $$ DECYL HYDRIDE	4.634188
Naphthalene, decahydro-, trans- $$ trans-Bicyclo[4.4.0]Decane $$ trans-Decalin	4.451261
Undecane $$ n-Undecane $$ Hendecane $$ n-C11H24	3.587239
2-HEXENE, 4-ETHYL-2,3-DIMETHYL-	3.491618
Disulfide, dimethyl $$ 2,3-Dithiabutane $$ Methyl disulfide $$ (CH3S)2 $$ DMDS	3.314788

Table 6. Qualitative analysis of VOCs emitted from swine manure by type C feed (1st sample)



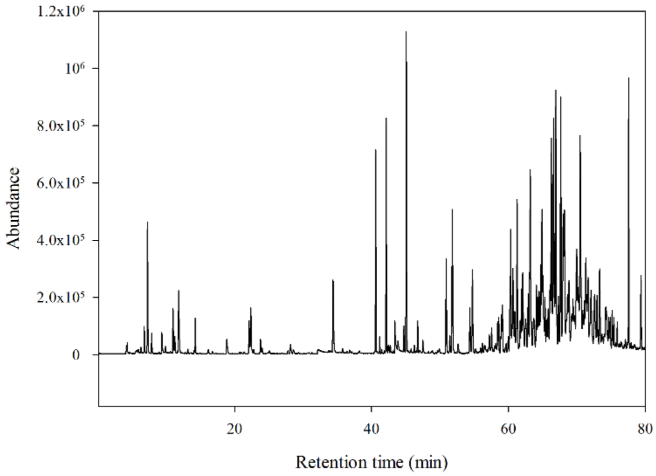
Material	AREA (%)
Disulfide, dimethyl $$ 2,3-Dithiabutane $$ Methyl disulfide $$ (CH3S)2 $$ DMDS	8.02678
Nonane, 2,6-dimethyl- $$ 2,6-Dimethylnonane	7.344922
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	6.503653
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	5.402275
Decane, 4-methyl- (CAS) $$ 4-Methyldecane	5.161768
Cyclohexane, 1-methyl-3-propyl- $$ 1-Methyl-3-propylcyclohexane #	5.03554
Decane (CAS) $$ n-Decane $$ Isodecane $$ n-C10H22 $$ DECAN $$ DECYL HYDRIDE	4.337969
Decane, 5-methyl- $$ 5-Methyldecane	4.329988
Naphthalene, decahydro-, trans-(CAS) $$ trans-Decalin	4.201495
Methane, thiobis- (CAS) $$ 2-Thiapropane $$ Methylthiomethane $$ Methyl sulfide	3.841082

Table 7. Qualitative analysis of VOCs emitted from swine manure by type A feed (2nd sample)



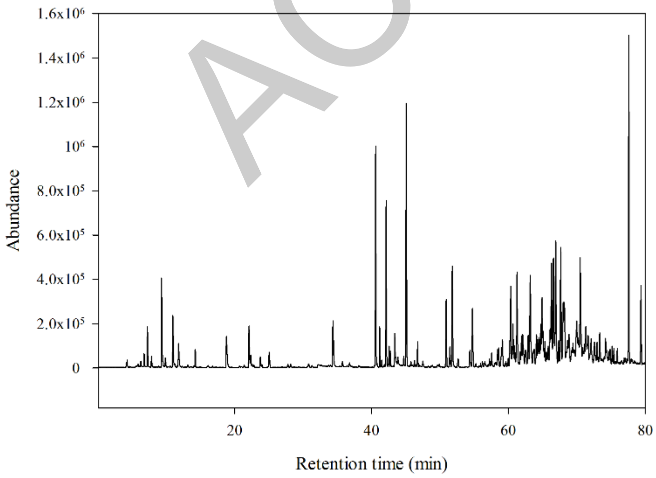
Material	AREA (%)
Disulfide, dimethyl $$ 2,3-Dithiabutane $$ Methyl disulfide $$ (CH3S)2 $$ DMDS	9.705413
Decane, 4-methyl- $$ 4-Methyldecane	6.542727
Decane, 4-methyl- (CAS) $$ 4-Methyldecane	6.315957
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	5.289905
Decane, 5-methyl- $$ 5-Methyldecane	4.818947
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	4.243003
Naphthalene, decahydro-, trans-(CAS) $$ trans-Decalin	4.017869
Decane $$ n-Decane $$ n-C10H22	3.51853
1-Butanol $$ Butyl alcohol $$ n-Butan-1-ol $$ n-Butanol $$ n-Butyl alcohol	3.343668
1,2-DIETHYLCYCLOHEXANE $$ CYCLOHEXANE, 1,2-DIETHYL-	3.187118

Table 8. Qualitative analysis of VOCs emitted from swine manure by type B feed (2nd sample)



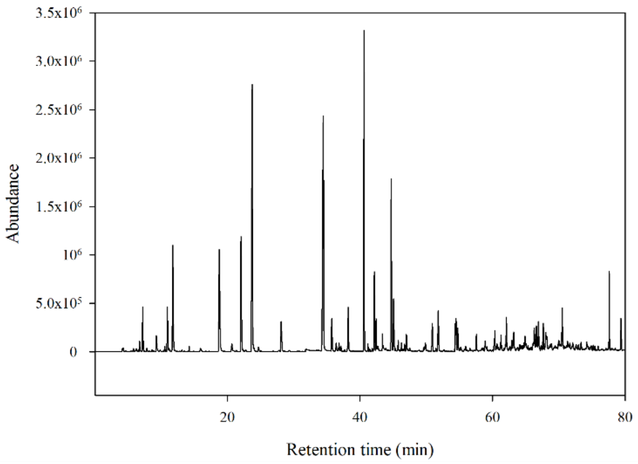
Material	AREA (%)
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	6.609496
Cyclotrisiloxane, hexamethyl- $$ Dimethylsiloxane cyclic trimer	6.304064
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	5.756465
Undecane $$ n-Undecane $$ Hendecane $$ n-C11H24	5.504505
Decane, 4-methyl- (CAS) $$ 4-Methyldecane	5.231404
Decane, 4-methyl- $$ 4-Methyldecane	4.597365
Toluene $$ Benzene, methyl $$ Methacide $$ Methylbenzene $$ Methylbenzol $$ Tol	4.041278
Dodecane (CAS) $$ n-Dodecane $$ Ba 51-090453 $$ Adakane 12 $$ Isododecane	3.779903
p-Xylene $$ Benzene, 1,4-dimethyl- $$ p-Dimethylbenzene $$ p-Xylol $$ Chromar	3.735315
Cyclotetrasiloxane, octamethyl- (CAS) $$ Octamethylcyclotetrasiloxane	3.555896

Table 9. Qualitative analysis of VOCs emitted from swine manure by type C feed (2nd sample)



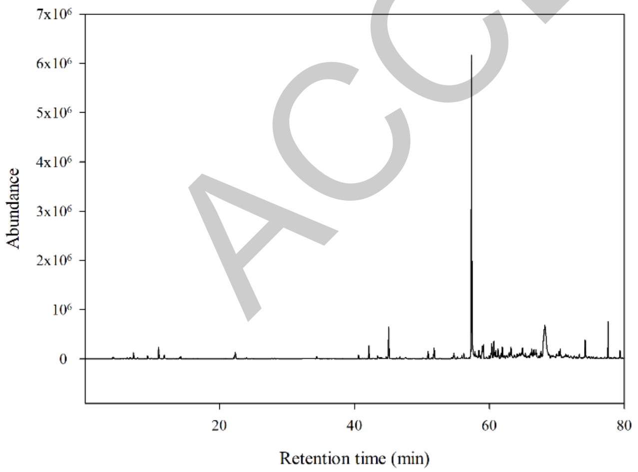
Material	AREA (%)
Cyclotrisiloxane, hexamethyl- $$ Dimethylsiloxane cyclic trimer	7.635677
Dodecane (CAS) $$ n-Dodecane $$ Ba 51-090453 $$ Adakane 12 $$ Isododecane	7.084222
Disulfide, dimethyl $$ 2,3-Dithiabutane $$ Methyl disulfide $$ (CH3S)2 $$ DMDS	5.757904
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	4.845701
Decane, 4-methyl- (CAS) $$ 4-Methyldecane	4.411717
Toluene $$ Benzene, methyl $$ Methacide $$ Methylbenzene $$ Methylbenzol $$ Tol	4.24771
Decane, 3-methyl- $$ 3-Methyldecane $$ 2-Ethylnonane	4.05272
Undecane $$ n-Undecane $$ Hendecane $$ n-C11H24	4.050104
Decane, 4-methyl- $$ 4-Methyldecane	3.950257
Benzene, 1,3-dimethyl- $$ m-Xylene $$ m-Dimethylbenzene $$ m-Xylol	3.904593

Table 10. Qualitative analysis of VOCs emitted from swine manure by type A feed (3rd sample)



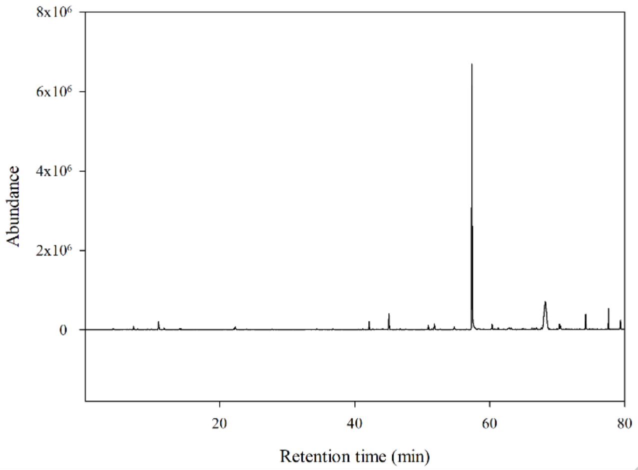
Material	AREA (%)
1-Butanol $$ Butyl alcohol $$ n-Butan-1-ol $$ n-Butanol $$ n-Butyl alcohol	14.77515
2-Butanol (CAS) $$ sec-Butanol $$ sec-Butyl alcohol $$ 2-Hydroxybutane	13.18913
Disulfide, dimethyl $$ 2,3-Dithiabutane $$ Methyl disulfide $$ (CH3S)2 $$ DMDS	10.50262
1-Propanol (CAS) $$ Propanol $$ n-Propanol $$ n-Propyl alcohol $$ Optal	6.10064
2-Butanone (CAS) $$ Methyl ethyl ketone $$ MEK al $$ Butanone $$ Butan-2-one	5.592962
1-Pentanol (CAS) $$ Amylol $$ n-Pentanol $$ Amyl alcohol $$ n-Pentan-1-ol	5.089471
2-Propanol (CAS) $$ Isopropyl alcohol (CAS) $$ Propan-2-ol $$ Isohol $$ Propol	4.86954
Dodecane (CAS) $$ n-Dodecane $$ Ba 51-090453 $$ Adakane 12 $$ Isododecane	2.005177
Cyclotrisiloxane, hexamethyl- (CAS) $$ 1,1,3,3,5,5-HEXAMETHYL-CYCLOHEXASILOXANE	1.932917
Benzene, 1,3-dimethyl- (CAS) $$ m-Xylene $$ m-Xylol $$ 1,3-Xylene $$ 2,4-Xylene	1.895775

Table 1. Qualitative analysis of VOCs emitted from swine manure by type B feed (3rd sample)



Material	AREA (%)
Acetamide, N,N-dimethyl- (CAS) $$ Dimethylacetamide $$ Acetdimethylamide	48.52994
Cyclotrisiloxane, hexamethyl- (CAS) $$ 1,1,3,3,5,5-HEXAMETHYL-CYCLOHEXASILOXANE	4.384024
Dodecane (CAS) $$ n-Dodecane $$ Ba 51-090453 $$ Adakane 12 $$ Isododecane	3.686652
Cyclotetrasiloxane, octamethyl- (CAS) $$ Octamethylcyclotetrasiloxane	2.871906
Decane, 4-methyl- (CAS) $$ 4-Methyldecane	2.635184
Cyclohexane, 1-methyl-3-propyl- $$ 1-Methyl-3-propylcyclohexane #	2.525301
p-Xylene $$ Benzene, 1,4-dimethyl- $$ p-Dimethylbenzene $$ p-Xylol $$ Chromar	1.956902
Decane $$ n-Decane $$ n-C10H22	1.85774
2-Propanone (CAS) $$ Acetone (CAS) $$ PROPAN-2-ONE $$ Propanone $$ (CH3)2CO	1.840257
Decane, 2-methyl- $$ 2-Methyldecane $$ n-C8H17CH(CH3)2	1.681695

Table 12. Qualitative analysis of VOCs emitted from swine manure by type C feed (3rd sample)



Material	AREA (%)
Acetamide, N,N-dimethyl- $$ Acetdimethylamide $$ Dimethylacetamide $$ DMAC	72.72181
Cyclotrisiloxane, hexamethyl- $$ Dimethylsiloxane cyclic trimer	3.73434
Dodecane (CAS) $$ n-Dodecane $$ Ba 51-090453 $$ Adakane 12 $$ Isododecane	3.615716
2-Propanone (CAS) $$ Acetone (CAS) $$ PROPAN-2-ONE $$ Propanone $$ (CH3)2CO	2.265999
Tetradecane $$ n-Tetradecane	2.242041
Benzene, 1,2-dimethyl- (CAS) $$ o-Xylene $$ o-Xylol $$ 3,4-Xylene $$ 1,2-Xylene	1.719144
Toluene $$ Benzene, methyl $$ Methacide $$ Methylbenzene $$ Methylbenzol $$ Tol	1.660869
Cyclotetrasiloxane, octamethyl- (CAS) $$ Octamethylcyclotetrasiloxane	1.48166
Phenol (CAS) $$ Izal $$ PhOH $$ Benzenol $$ Oxybenzene $$ Monophenol	1.427148
Ethylbenzene $$ Benzene, ethyl- $$ Ethylbenzol $$ Phenylethane $$ Aethylbenzol	1.089788

Discussion

The most important part of the odor evaluation is the evaluation as soon as possible after the odor sample is collected. It is usually recommended to evaluate within four to six hours because losses can occur during the transport and storage of odor samples, which can be underestimated compared to the actual degree of odor [14, 15]. In this experiment, the sampling site and the evaluation site are located about 2 hours away, and accordingly, the loss of odor samples occurred in the preparation process for transporting and evaluating the samples may be a limitation of this study.

As a result of the sensory evaluation of the complex odor, it was confirmed that the degree of odor significantly weakened after two weeks compared to the collection day (1st sample) of swine manure. However, after four weeks, the odor level increased again, which would be due to the decomposition of swine manure. Therefore, it is recommended to set the evaluation period within two weeks when evaluating the odor of swine manure.

There is a lack of information on feed in this study. However, information on the calories, mixing conditions, and nutritional content of feed varies widely from product to product. Additionally it is very difficult to manage all feed uniformly. In this study, we tried to propose a method that can reduce the odor of swine manure by simply controlling the shape of feed and calories. For example, most of pigs do not chew their food carefully like humans do. It can be seen from the fact that corn is not digested in pig manure and is discharged as it is.

Ammonia and sulfur-based odorous substances are the causative agents that account for the majority of swine manure odors [16]. Most previous studies have shown that ammonia and sulfur-based odor substances have a constant decrease in concentration over time [17]. In this study, it was also confirmed that the concentration of ammonia and sulfur-based odor substances decreased over time compared to the concentration on the collection day of swine manure.

Based on the results of qualitative analysis of VOCs, Decane substances accounted for most of the VOCs from the collection day of swine manure to two weeks later. Four weeks later, however, Butyl alcohol, Methyl disulfide, and n-Dodecane dimethylacetamide be-came the main VOCs. It was found that the composition of the major VOCs changed over time, which is also due to swine manure decay [18]. The simple adjustments such as the shape of feed and calories were made in this study. In addition, a qualitative analysis was conducted to investigate what odor substances were generated according to the digestive state. In the future, however, we feel the need to propose a plan to control the nutrients in the feed by matching the information on the blending conditions and nutritional components of the feed with the quantitative analysis results of GC-MS.

In case of a study conducted on animals as in this study, the health status and condition of pigs subject to the study may affect the results of the study. The fact that both the health and condition of the 15 pigs during the experiment period are not consistent can also be a limitation of this study [19]. In the future, thus, it is necessary to increase the number of pigs to be evaluated in order to obtain more reliable data than the current re-search results. In addition, there is limitation for evaluating complex odor concentration such as the small number (five persons), disproportionate gender ratio and the failure to completely control the olfactory state of panels who conducted a sensory evaluation [20]. It is expected that more reliable results can be obtained if further research, which is improved by reflecting these limitations, is conducted in the future.

Conclusion

According to the processing mode and calorific composition of the feed, which is a factor that greatly affects the odor of swine manure, 15 pigs were raised under different forms and calorific compositions of feeds and the occurrence pattern of swine manure odor generated according to each condition was analyzed simultaneously. On the collection day of swine manure, ammonia and sulfuric compounds were the main substances affecting the degree of odor. After 4 weeks, however, it was confirmed that the main odorous substances changed from ammonia and sulfuric compounds to VOCs. This finding would be conversion of main odorous compounds due to decay of swine manure from two weeks later. This phenomenon was more pronounced in pigs fed with powdered feedstuff and the higher the calories of feed, the worse the odor. Therefore, it is advantageous to use low-calorie feed consisting of pellet type to reduce the odor generated during the swine raising process. Furthermore, it is considered that manure in swine farms should be treated two weeks before its decay occurs to effectively prevent emission of odor derived from swine manure.

Acknowledgements

This study was supported by the Research Program funded by the Seoul Tech(Seoul National University of Science and Technology.

Reference

[1] Hansen, Michael J., et al. Multivariate prediction of odor from pig production based on in-situ

measurement of odorants. Atmospheric Environment, 2016, 135: 50-58.

[2] Aatamila, Marjaleena, et al. Odour annoyance and physical symptoms among residents living near waste treatment centres. Environmental Research, 2011, 111.1: 164-170.

[3] Schlegelmilch, M., et al. Odour control at biowaste composting facilities. Waste Management, 2005, 25.9: 917-927.

[4] Coker, Craig, et al. Managing odors in organics recycling. BioCycle, 2012, 53.4: 25-28.

[5] Zang, Bing, et al. Effects of mix ratio, moisture content and aeration rate on sulfur odor emissions during pig ma-nure composting. Waste Management, 2016, 56: 498-505.

[6] Zhu, Jun, et al. Reduction of odor and volatile substances in pig slurries by using pit additives. Journal of Environ-mental Science & Health Part A, 1997, 32.3: 605-619.

[7] Parker, David B., et al. Odor and odorous chemical emissions from animal buildings: Part 6. Odor activity value. Transactions of the ASABE, 2012, 55.6: 2357-2368.

[8] Blazy, Vincent, et al. Correlation of chemical composition and odor concentration for emissions from pig slaugh-terhouse sludge composting and storage. Chemical Engineering Journal, 2015, 276: 398-409.

[9] Melse RW and Ogink NWM. 2005. Air scrubbing techniques for ammonia and odor reduction at livestock operations: Review of on-farm research in the Netherlands. Transactions of the the ASABE, 2005, 48:2303-2313.

[10] Kim, Bernuth R.D., et al. Effect of ozonation on odor and the concentration of odorous organic compounds in air in a swine housing facility. Transactions of the ASABE, 2005, 48:2297-2302.

[11] Martel, Myra C., et al. Detailed study of odor from pig buildings to improve understanding of biotrickling filter performance. Transactions of the ASABE, 2017, 60.6: 2151-2162.

[12] Huong, Luu Quynh, et al. Hygienic aspects of livestock manure management and biogas systems operated by small-scale pig farmers in Vietnam. Science of the total environment, 2014, 470: 53-57.

[13] Le, P. D., et al. Effects of crystalline amino acid supplementation to the diet on odor from pig manure. Journal of Animal Science, 2007, 85.3: 791-801.

[14] Trabue, Steven L.; ANHALT, Jennifer C.; ZAHN, James A. Bias of Tedlar bags in the measurement of agricultural odorants. 2006.

[15] Groves, William A.; Zellers, Edward T. Investigation of organic vapor losses to condensed water vapor in Tedlar® bags used for exhaled-breath sampling. American Industrial Hygiene Association Journal, 1996, 57.3: 257-263.

[16] Banwart, W. L.; Bremner, J. M. Identification of sulfur gases evolved from animal manures. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, 1975.

[17] Gay, S. W., et al. Odor, total reduced sulfur, and ammonia emissions from animal housing facilities and manure storage units in Minnesota. Applied Engineering in Agriculture, 2003, 19.3: 347.

[18] Ni, Ji-Qin, et al. Volatile organic compounds at swine facilities: A critical review. Chemosphere, 2012, 89.7: 769-788.

[19] Kurth, Kathy T., et al. Use of a Mycoplasma hyopneumoniae nested polymerase chain reaction test to determine the optimal sampling sites in swine. Journal of Veterinary Diagnostic Investigation, 2002, 14.6: 463-469.

[20] Lundstrom, Johan N.; Olsson, Mats J. Subthreshold amounts of social odorant affect mood, but not behavior, in heterosexual women when tested by a male, but not a female, experimenter. Biological psychology, 2005, 70.3: 197-204.Author 1, A.B.; Author 2, C.D. Title of the article. Abbreviated Journal Name Year, Volume, page range.