Journal of Civil & Environmental Engineering

Lovanh et al., J Civil Environ Eng 2012, 2:4
DOI: 10.4172/2165-784X.1000114

Research Article Open Access

Volatile Fatty Acids in Suspended Particulate Matter from a Poultry House Using Rice Hulls as Bedding Materials-A Profile of First Flock after Total Cleanout

Lovanh N*, Loughrin J and Sistani K

USDA-ARS, Animal Waste Management Research Unit, Bowling Green, KY 42104, USA

Abstract

Livestock operations have long been associated with unpleasant odors whether it is a swine, poultry, or dairy operation. Unpleasant odorous smell has been generally accepted as part of livestock operations in the past. However, as more and more animal production continues to evolve into major concentrated operations, odor emissions from these confined animal feeding operations (CAFOs) have caused persistent public concern and complaints. In addition, particulate matters and other gas emissions have also been a cause for environmental and health concerns. Therefore, a thorough understanding of air emissions from CAFOs is a first necessary step in formulating effective management strategies for dealing with these odor and air quality issues. In this study, the examination and characterization of volatile fatty acids (VFA), major components of odors from poultry operations, in suspended particulate matter (SPM) from a broiler house were carried out using particle trap impactors. The inhalable fractions (IH) of SPM from the particle trap impactors were extracted and analyzed for its VFA contents using High Performance Liquid Chromatography (HPLC). The results showed that proprionic and butyric acid are the major VFA found in the IH collected from the broiler house after a total cleanout. Their concentrations ranged from 80 to 382 μg/m³ for propanoic acid and 143 to 405 μg/m³ for butanoic acid. Trace amounts of other VFA (i.e., acetic acid, pentanoic acid, and hexanoic acid) were also observed from particulate matter (PM) analyses. The concentration profile of VFA appeared to reach a maximum at the middle of the flock age (e.g., when the birds reach about four to five-week old) and tapering off toward the end of the flock age. The mass fractions of VFA were also observed to be inversely proportional to PM concentrations.

Keywords: Volatile fatty acids; Suspended particulate matters; Air quality; Broiler poultry house; Rice hull bedding

Introduction

The increase in human population has created a parallel increase in demand for agricultural commodities. Satisfying the demand for food has already altered the way we raised crops and carried out livestock productions that had confound effect on the environment. For instance, the increase consumption of animal protein in developed and developing countries has resulted in concentrated production of poultry and other livestock, which has led to concentrated emissions of odorous pollutants and fugitive dust from these production facilities and has created few concerns regarding health and welfare of animals as well as humans in or near these facilities. Odor from animal feeding operations is not caused by a single compound, but rather a large number of compounds which includes ammonia, volatile organic compounds, and sulfur compounds [1]. Recently the WHO had concluded that there is a causal relationship between suspended particulate matter exposure and health effects [2]. Studies to date show that particulates (especially from industrial sources) are strongly associated with mortality and other endpoints such as hospitalization for cardio-pulmonary diseases [3-5]. Suspended particulate matters in livestock buildings may carry biochemical agents such bacteria, viruses, and odors [6-9].

In the US, the Environmental Protection Agency (USEPA) regulates SPM or total suspended particles (TSP) in the ambient air. The primary and secondary National Ambient Air Quality Standards (NAAQS) for PM10 is 150 μg/m³ for a 24-hr average. The primary and secondary standard for PM2.5 is 65 μg/m³, calculated as a 3-yr average of the ninety-eighth percentile. The annual standard is 15 μg/m³ as the 3-yr average of annual arithmetic means [10].

For poultry operations, the emission of these particulate matters has similar effect on animal and human health. The negative impacts of air contaminants on animal health and performance have been well documented [11-22]. The main concern at the local level, however, is the persistent odorous smell from poultry operations. The persistent and long life expectancy of odors and toxic pollutants from poultry houses may be due to the ability of suspended particulate matters (SPM) to serve as carriers for odorous compounds such as volatile fatty acids (VFA). SPM is generated from the feed, animal manure, and the birds themselves. A large portion of odor associated with exhaust air from poultry houses is SPM that have absorbed odors from within the houses. The air in a commercial broiler production house contains all of the materials emitted to the atmosphere, some of which are potential contaminants such as VFA in SPM. The emission rate of any specific contaminant from these poultry houses is the rate at which pollutants are expelled into the surrounding atmosphere and is the product of the concentration of the contaminant inside the houses and the rate of ventilation.

Although there are some data on odors and dust [9,6] to our knowledge there are no studies on the correlation between dust and odors, especially temporal data on the profile of odors in particulate matters. Data involving odorous compounds such as VFA and SPM are scarce and incomplete. Therefore, the objective of this study was to examine and characterize the profile of various VFA in the inhalable

***Corresponding author:** Lovanh N, USDA-ARS, AWMRU, 230 Bennett Lane, Bowling Green, KY 42104, USA, Tel: 270-781-2632; Fax: 270-781-7994; E-mail: nanh.lovanh@ars.usda.gov

Received May 09, 2012; **Accepted** May 26, 2012; **Published** May 28, 2012

Citation: Lovanh N, Loughrin J, Sistani K (2012) Volatile Fatty Acids in Suspended Particulate Matter from a Poultry House Using Rice Hulls as Bedding Materials-A Profile of First Flock after Total Cleanout. J Civil Environ Eng 2:114. doi:10.4172/2165-784X.1000114

Citation: Lovanh N, Loughrin J, Sistani K (2012) Volatile Fatty Acids in Suspended Particulate Matter from a Poultry House Using Rice Hulls as Bedding Materials-A Profile of First Flock after Total Cleanout. J Civil Environ Eng 2:114. doi:10.4172/2165-784X.1000114

fractions of SPM from a poultry house that used rice hulls as bedding materials over a period of one flock. Understanding the association of odors (VFA) with SPM from poultry houses will serve as the stepping stone in applying the correct and necessary abatement technologies in reducing these odors and their associated impact on the environment and human health.

Materials and Methods

Suspended particulate matter sampling

Air samples were taken inside a broiler poultry house at 1.0 m above the floor using particle trap impactors in triplicate. Air samples (total n=50) were taken for the inhalable fractions (IH), PM2.5, and PM10. However, only the VFA in the IH (n=21) are reported here. Due to logistical difficulty between the lab and the sampling site, air samplings were carried out once a week for duration of one flock after total cleanout. These sampling events were carried out during the winter months of February and March of 2008. The sampling location was at the midpoint of the poultry house which has dimensions of 13 m by 145 m. The poultry houses were located in the northwest area of Kentucky. Rice hulls were used as bedding materials for these poultry houses. The air temperature inside the house during brooding ranged from 29 to 32°C and 18 to 22°C for other period. During the brooding period (0-15 days), approximately 27,000 birds were placed in each house and were confined to the front half of the house. Aircheck 2000 pumps (SKC, Inc., California) were used to pull air (3 liters per minute) through quartz filters (1.2 µm; SKC, Inc.) for 2 hours during the late morning to the early afternoon for each sampling event. The filters were housed in round cassettes (37 mm ID; Omega, MA) with inlet orifice of 4 mm in diameter. Quartz filters were chosen due to its durability (temperature up to 275°C) and resistant to acids, bases, and solvents. These filters meet OSHA and NIOSH specifications. The filters were oven dried to remove any moisture before use. After collection, each filter was placed in an air-tight container for transport and stored in a refrigerator (4°C) overnight. The filters were then extracted and analyzed within a day of sampling. The collected TSP were quantified and analyzed for VFA using High Performance Liquid Chromatography (HPLC) as soon as possible, usually a day after sampling. From here on in, TSP and SPM will be used interchangeably.

Suspended particulate matter analysis

Total suspended particulate samples were extracted in deionized water and analyzed using HPLC. The amount of water used for each extraction was the same. Volatile fatty acids (acetic, propionic, butyric, pentanoic, and hexanoic acids) were determined by high pressure liquid chromatography (Ultimate 3000 HPLC, Dionex Corporation, San Francisco, CA). Small amounts of extracted samples were centrifuged at 10,000 rpm for 5 minutes. The supernatants were then filtered through a 0.2 µm-pore-size filter (Whatman). The filtered sample (10 µL) was injected into HPLC via an autosampler (Model WPS-3000SL Micro, Dionex Corporation). Sulfuric acid (5 mM; RICCA Chemical Co., Arlington, TX) was filtered and used as mobile phase for an isocratic run. The mobile phase was pumped at 0.5 mL/min through a 300 mm x 7.8 mm (8 µm particle size) RHM Monosaccharide column (Phenomenex, Torrence, CA) held at a temperature of 65°C to a photodiode array detector (Model PDA-3000, Dionex Corporation) with wavelength set at 210 nm. An example of VFA chromatogram is shown in Figure 1. The chromatogram consists of seven different volatile fatty acids ranging from 2 to 6-carbon fatty acids. Retention times for heavier fatty acids are longer than the lighter ones. All fatty acids shown were analyzed for in real samples.

Results and Discussion

Suspended particulate matter

Total suspended particulate (TSP) concentrations were measured and calculated for a flock of broilers on rice hull beddings after a total cleanout. Figure 2 shows the TSP concentrations over the age of the birds, except week 7 (PH) samples were taken one day after birds were harvested. Air samples were not taken during the first week of brooding. The overall range of the TSP was 0.347 to 8.889 mg/m^3. It appears that the TSP concentrations increased with bird age. This is as expected since birds would produce more feces and develop a larger area of skin and feathers as they grew. Since the orifice of the particle trap samplers was large enough, most of the coarse TSP from the air inside the broiler house except large debris (i.e., feathers, feed, and etc. bigger than 4 mm) was able to be captured. These are the potential inhalable fractions that a human worker could aspirate while working inside the broiler house. As more birds became larger, they consumed more and were more active which would contribute to the increase in TSP concentrations.

The concentrations of TSP in this study corroborated well with other studies. For instance, Takai et al. (1998) [23] had reported TSP concentrations in the range of 0.45 to 4.5 mg/m^3 for inhalable dust concentrations from poultry houses across Europe. Redwine et al. (2002) [24] had reported a higher concentration range of total

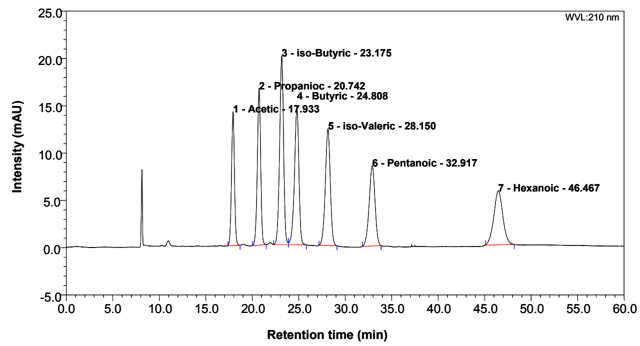

Figure 1: High performance liquid chromatogram of various volatile fatty acids ranging from 2 to 6-carbon fatty acids. Lighter fatty acids have shorter retention times. mAU = milli absorbance unit.

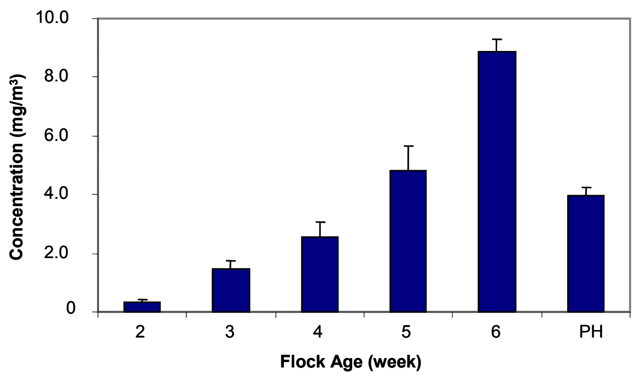

Figure 2: Profile of suspended particulate matter (SPM) concentrations in air samples from the first flock of broilers after a total cleanout. PH represents post-harvest sample which was taken a day after the birds were harvested or removed. SPM concentrations increase with bird age. The error bars represent the standard deviations of triplicate samples.

suspended particulate (7 to 11 mg/m^3) from tunnel-ventilated broiler houses in Texas during summer time. However, the concentrations of TSP from our experiment are still within this reported range. Other studies [25-27] found similar concentrations of TSP from laying hen houses and broiler houses.

Volatile fatty acids

Volatile fatty acids (VFA) were extracted from the TSP and analyzed on an HPLC. The concentrations of VFA were normalized to the amount of air sampled. The profile of VFA as a function of flock age is shown on Figure 3. Only propionic and butyric acids are represented here since there were only small amounts of other VFA such as acetic, pentanoic, and hexanoic acids found in the dust samples. Figure 3 shows that VFA concentrations increased with flock age and decreased at the end of the flock. These results corroborated well with other results [28,29] from broiler digestive track studies of VFA where VFA tend to increase with bird age and tapering off at the end. The concentrations of butyric acid were always higher than those of propionic acid except during the fifth week of growth. Concentrations of propionic acid ranged from 80 to 382 μg/m^3. The highest concentration of propionic acid was found during the fifth week of growout. Concentration profile of butyric acid followed the same trend as that of propionic acid. Concentrations of butyric acid ranged from 143 to 405 μg/m^3. However, the highest concentration of butyric acid was observed during the fourth week of grow out. The increases in the VFA concentrations up to their peak concentrations may be due to the increase in consumption and excretion as the birds aged. The decrease in VFA concentrations during the last week of growth may be due to physiological changes in the birds or the physicochemical alteration of VFA on the poultry litter. It is not due to the lack of activity by the birds and the crowding of the larger-size birds as indicated by the increase in SPM concentrations (Figure 2).

The mass fraction profiles of VFA showed a decrease with bird age (Figure 4). Mass fraction is the ratio of VFA to the mass of collected TSP. It appears that the mass fraction of VFA was highest at the beginning of flock and then decreased toward the end of flock. This is as expected since a larger amount of TSP was produced as birds aged compared to the amount of VFA being excreted. The mass fractions of propionic and butyric acids reached maxima at around 35% and 70%, respectively. These maxima were observed at the beginning of bird flock. Butyric acid, with higher molecular weight, showed higher mass fractions throughout the growth periods except during the fifth week of growout. Further examination of VFA with respect to the concentrations of TSP showed that mass fraction of VFA is inversely proportional to the TSP concentrations-- the higher the TSP concentrations, the smaller the VFA mass fractions (Figure 5). It is logical that as more TSP being formed from feather, feed, excreta, and other materials as the birds aged; the proportions of VFA (mostly from excreta) became smaller which was observed in Figure 5.

Other factors such as high ammonia concentrations and temperature may have affected the reduction in VFA concentrations. [30,31] had reported that small amount of VFAs was produced when high concentrations of ammonia were observed in anaerobic digestion systems. Abouelenien and colleagues (2009) [32] had found a similar result from high ammonia concentrations and temperature in a dry anaerobic methane production system from poultry litter. In our experiment, ammonium concentrations (data not shown) were observed to increase as the flock aged which could have explained the decrease in VFA concentrations. Biological factors such as the increase in VFA degraders, *Lactobacillales* and others, may also have played a

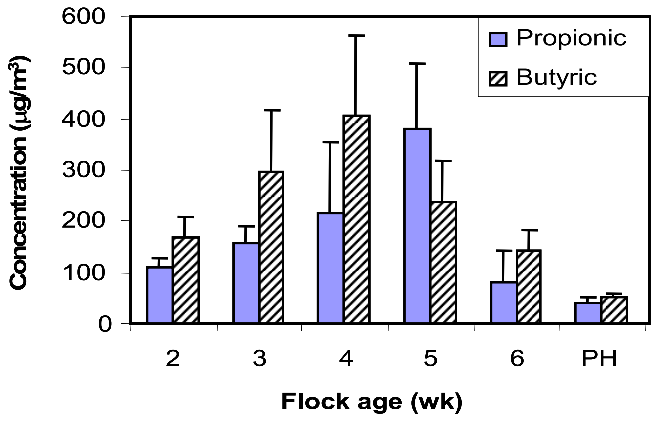

Figure 3: Profile of volatile fatty acid (VFA) concentrations in the SPM extraction normalized to total volume of air sampled. The error bars represent the standard deviations of triplicate samples.

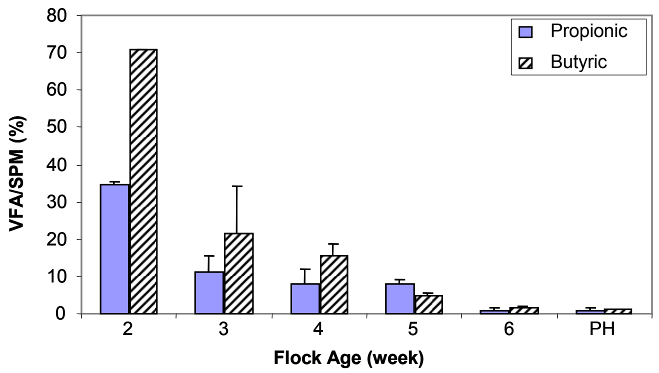

Figure 4: Mass fractions (in percent) of volatile fatty acids as function of flock age. Fractions of VFAs in SPM decrease with bird age. The error bars represent the standard deviations of triplicate samples.

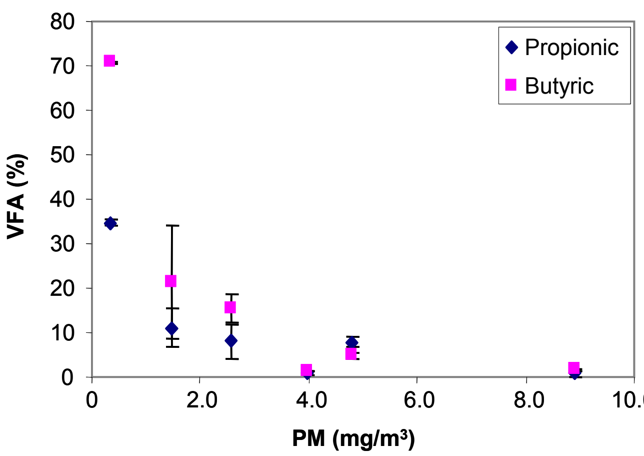

Figure 5: Percent mass fraction of volatile fatty acids as function of suspended particulate matter concentrations. Mass fractions of VFA are inversely proportional to the concentrations of SPM. The error bars represent the standard deviations of triplicate samples.

role in VFA reduction [33,28] as these microbes increased over time in the poultry litter.

Conclusions

An experiment was carried out to examine the profile of volatile fatty acids (the major odor causing agents in poultry litter) in suspended particulate matters from a broiler house using rice hull bedding materials after a total cleanout. Particle trap samplers were used to collect the suspended particulate matters over a period of one flock. Volatile fatty acids were extracted from TSP and analyzed. Based on these analyses, concentrations of suspended particulate matter appeared to be increasing with flock age. Concentrations of VFA appeared to increase or reach a maximum during the fourth or fifth week of growth and then tapering off. Mass fractions of volatile fatty acids appeared to be decreasing with flock age. This was as expected since the concentrations of SPM increased over time which would reduce the proportion of VFA. Furthermore, other factor such as biochemical factors may affect the concentrations of VFA in the broiler house as well. Concentrations of VFA appeared to be inversely proportional to the SPM concentrations. Clearly, particulate matters could serve as potential carriers for short and long-range transport of odorous compounds such as VFAs. Therefore, mitigation strategies for odor reduction will need to include some sort of particulate matter abatement strategies as well to be more effective.

Acknowledgements

We would like to thank Mike Bryant for his technical assistance. This research was part of USDA-ARS National Program 206: Manure and By-product Utilization. Mention of a trademark or product anywhere in this paper is to describe experimental procedures and does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

References

1. National Academy of Sciences (2003) Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. National Academies Press. Washington, D.C., USA
2. WHO (2003) Health aspects of air pollution with particulate matter, ozone and nitrogen dioxide. WHO, Bonn.
3. Pope CA 3rd, Burnett RT, Thun MJ, Calle EE, Krewski D, et al. (2002) Lung cancer, cardio-pulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA 287: 1132-1141
4. Hoek G, Brunekreef B, Goldbohm S, Fischer P, van den Brandt PA (2002) Association between mortality and indicators of traffic-related air pollution in the Netherlands: a cohort study. Lancet 360: 1203-1209.
5. Zanobetti A, Schwartz J, Samoli E, Gryparis A, Touloumi G, et al. (2002) The temporal pattern of mortality responses to air pollution: a multicity assessment of mortality displacement. Epidemiology 13: 87-93.
6. Hartung J (1985) Gas chromatographic analysis of volatile fatty acids and phenolic/indolic compounds in pig house dust after ethanolic extraction. Environmental technology letters 6: 21-30.
7. Baekbo P (1989) Air quality and pig herd health. Institute for intern medicine, The Royal Veterinary and Agricultural University, Copenhagen, Denmark.
8. Homes MJ, Heber AJ, Wu CC, Clark LK, Grant RH, et al. (1996) Viability of bioaerosols produced from a swine facility. Proceedings of International Conference on Air Pollution from Agricultural Operations. Kansas City, MO, USA.
9. Williams AG (1989) Dust and odour relationships in broiler house air. Journal of Agricultural Engineering Research 44: 175-190.
10. USEPA (2008) 40 CFR Part 50.6, 50.7, and Appendices K and N. National Ambient Air Quality Standards for Particulate Matter.
11. Donham KJ, Gustafason KE (1982) Human occupational hazards from swine confinement. Ann Am Conf Gov Hyg 2: 137-142.
12. Donham KJ, Zavala DC, Merchant J (1984) Acute effects of the work environment on pulmonary functions of swine confinement workers. Am J Ind Med 5: 367-375.
13. Iversen M, Dahl R, Korsgaard J, Hallas T, Jensen EJ (1988) Respiratory symptoms in Danish farmers: an epidemiological study of risk factors. Thorax 43: 872-877.
14. Donham KJ (1990) Relationships of air quality and productivity in intensive swine housing. J Agric Practice 10: 15-18.
15. Iversen M, Pedersen B (1990) The relationship between respiratory symptoms, type of farming and lung function disorders in farmers. Thorax 45: 919-923.
16. Whyte RT, Williamson PAM (1993) Aerial pollutant burdens and respiratory impairment of poultry house stockmen. Proceedings of International Livestock Environment Symposium IV. ASAE. Warwick, England.
17. Donham KJ, Rubino M, Thedell TD, Kammermeyer J (1977) Potential health hazards to agricultural workers in swine confinement buildings. J Occup Med 19: 383-387.
18. Miles DM, Branton SL, Lott BD (2004) Atmospheric ammonia is detrimental to the performance of modern commercial broilers. Poult Sci 83: 1650-1654.
19. Reece FN, Lott BD (1980) Effect of carbon dioxide on broiler chicken performance. Poult Sci 59: 2400-2402.
20. Reece FN, Lott BD, Deaton JW (1980) Ammonia in the atmosphere during brooding affects performance of broiler chickens. Poult Sci 59: 486-488.
21. Ritz CW, Fairchild BD, Lacy MP (2004) Implications of ammonia production and emissions from commercial poultry facilities: A Review. J Applied Poult Res 13: 684-692.
22. Olanrewaju HA, Dozier III WA, Purswell JL, Branton SL, Miles DM, et al. (2008) Growth performance and physiological variables for broiler chickens subjected to short-term elevated carbon dioxide concentrations. Int J oult Sci 7: 738-742.
23. Takai H, Pedersen S, Johnsen JO, Metz JHM, Koerkamp P, Uenk, et al. (1998) Concentrations and emissions of airborne dust in livestock buildings in northern Europe. J Agric Eng Res 70: 59-77.
24. Redwine JS, Lacey RE, Mukhtar S, Carey JB (2002) Concentration and emissions of ammonia and particulate matter in tunnel-ventilated broiler houses under summer conditions in Texas. Trans ASAE 45: 1101-1109.
25. Lacey RE, Redwine JS, Parnell Jr CB(2003) Particulate matter and ammonia emission factors for tunnel-ventilated broiler production houses in the southern U.S. Trans ASAE 46: 1203-1214.
26. Lim TT, Heber AJ, Ni JQ, Gallien JX, Xin H (2003) Air quality measurements at a laying hen house: Particulate matter concentrations and emissions. American Society of Agricultural and Biological Engineers.
27. Roumeliotis TS, Van Heyst BJ (2007) Size fractionated particulate matter emissions from a broiler house in southern Ontario, Canada. Sci Total Environ 383: 174-182.
28. van Der Wielen PW, Biesterveld S, Notermans S, Hofstra H, Urlings BA, et al. (2000) Role of volatile fatty acids in development of the cecal microflora in broiler chickens during growth. Appl Environ Microbiol 66: 2536-2540.
29. Wang ZR, Qiao SY, Lu WQ, Li DF (2005) Effects of enzyme supplementation on performance, nutrient digestibility, gastrointestinal morphology, and volatile fatty acid profiles in the hindgut of broilers fed wheat-based diets. Poult Sci 84: 875-881.
30. Angelidaki I, Ahring BK (1993) Thermophilic anaerobic digestion of livestock waste: the effect of ammonia. Appl Microbiol Biotechnol 38: 560-564.
31. Angelidaki I, Ahring BK (1994) Anaerobic thermophilic digestion of manure at different ammonia loads: effect of temperature. Water Res 28: 727-731.
32. Abouelenien F, Kitamura Y, Nishio N, Nakashimada Y (2009) Dry anaerobic ammonia methane production from chicken manure. Appl Microbiol Biotechnol 82: 757-764.
33. Lovanh N, Cook KL, Rothrock MJ, Miles DM, Sistani K (2007) Spatial shifts in microbial population structure within poultry litter associated with physicochemical properties. Poult Sci 86: 1840-1849.