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Original Research

Characteristics of Gas Generation (NH_3, CH_4, N_2O, CO_2, H_2O) From Horse Manure Added to Different Bedding Materials Used in Deep Litter Bedding Systems

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ABSTRACT

The aim of this study was to analyze the influence of horse manure added to different bedding materials on the generation of gases (ammonia (NH_3), nitrous oxide, carbon dioxide, methane, water vapor) from deep litter bedding under standardized laboratory conditions. Two different types of straw (wheat and rye) and wood shavings were analyzed. The deep litter (substrate) was made of 25 kg of the respective bedding material, 60 kg horse feces, and 60 L ammonium chloride solution (urea), and spread out in identical chambers over 19 days (n = 3). On days 1, 8, 15, and 19, total nitrogen, total carbon, and dry matter content of the substrate, as well as the pH in 500-g samples, were measured along with. At the end of each test period, the nitrite nitrogen, nitrate nitrogen, and ammonium nitrogen contents of the leachate were analyzed. The wheat straw substrate emitted the highest concentration of NH_3 (4.31 mg/m^3; $P < .0001$) and the wood shavings substrate emitted the lowest (1.73 mg/m^3; $P < .0001$); the rye straw substrate generated 3.05 mg/m^3. In addition, significant differences occurred during days 1 to 3 with respect to the generation of the gases NH_3, methane, nitrous oxide, carbon dioxide, and water vapor, and after the opening of the chamber on day 15. The nitrogen losses through the leachate occurred mainly in the form of nitrate, where the leachate from the wheat straw substrate had a significantly higher amount of nitrate nitrogen (44.56 mg) as compared with the leachates of the rye straw (14.49 mg; $P \leq .0001$) and the wood shaving substrates (22.62 mg; $P = .0010$).

1. Introduction

It has been proven in numerous scientific studies that the type of bedding and the removal of manure are decisive criteria for air quality and hygiene in stalls [1-3]. In addition to good absorption of ammonia (NH_3) and a low generation of airborne particles, a high-quality bedding material is also characterized by a rapid compostability when mixed with horse feces and its general availability [4-7]. Despite the supply of numerous types of alternative bedding materials (such as wood shavings, flax, or hemp), different types of straw (eg, wheat or rye) are the most frequently used forms of bedding material in the world [8]. Furthermore, in comparison with the alternative materials, straw bedding has the advantage that horses can continually ingest coarse feed material (an additional source of roughage) and at the same time be occupied, whereby the risk for behavioral disorders is reduced [9]. Hunter and Houpt [10] as well as Ninomiya et al. [11] found a lower duration of standing on straw than on sawdust or wood shavings. Regarding animal welfare, Werhahn et al. [12] could verify that horses spent significantly more time lying on straw bedding than on straw pellets.

In practice, to minimize the production of noxious gases and smells, horse feces are often completely removed each

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Table 1
Course and experimental set-up of the investigation (between October 01 and November 29, 2009)

Trial	Date	Bedding Materials		
		Chamber 1	Chamber 2	Chamber 3
1	October 01 to October 19, 2009	Rye	Wood shavings	Wheat
2	October 21 to November 08, 2009	Wood shavings	Wheat	Rye
3	November 11 to November 29, 2009	Wheat	Rye	Wood shavings

day from the stall. Fleming et al. [13] reported that when horses are kept in individual boxes, a 14-day deep litter (horse feces are not removed; new bedding material is added each day) generated significantly lower NH_3 concentrations (1.93 mg/m^3) as compared with a complete daily mucking-out regime (2.17 mg/m^3). Only the daily collection of the horse feces (1.62 mg/m^3) led to a significantly lower NH_3 production as compared with the 14-day deep litter system. In addition, this method (deep litter) is associated with a lower amount of work and a lower straw usage than with the other methods of removing manure [14].

The organic compounds (easily degradable proteins and sugars) found in deep litter are degraded by a multitude of highly variable microorganisms using nitrification and denitrification processes, among others [15]. The course of microbial degradation processes (eg, nitrification, denitrification) depends essentially on the carbon (C)/ nitrogen (N) ratio, the C availability, the water content, pH, the oxygen (O_2) concentration, and the temperature in the substrate [16]. Microbial degradation can lead to the production of gases such as NH_3, methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O), which then end up in the stall air and the environment [17-19]. The generation of NH_3 andN_2O depends on the ammonium and total nitrogen (N_t) content of the substrate as well as the temperature, pH, and O_2 supply of the substrate. In contrast, the generation of CH_4 is closely connected with a lack of O_2 in the substrate [20]. High concentrations of noxious gases (NH_3, CO_2) in the area where horses are housed can increase the risk of respiratory diseases [21].

In Germany, about 8 million tonnes of horse manure are produced each year [22]. This is mainly spread as a fertilizer on agricultural land, where environmentally relevant substances, such as nitrate, nitrite, and ammonium in the leachate can damage the surrounding ecosystems (acidification of the soil, water pollution; eutrophisation) [23,24].

The aim of this study was to analyze the effect of horse manure added to different bedding materials on the generation of gases (NH_3, N_2O, CO_2, CH_4, and water vapor [H_2O]) from deep litter bedding under standardized laboratory conditions. An additional aim was to determine the amount of environmentally relevant substances (nitrate, nitrite, and ammonium) that were carried out of the substrates by the leachate, because the seepage into the soil (fertilization) of those substances can damage the surrounding ecosystems.

2. Materials and Methods

2.1. Experimental Setup

The investigation took place between October 1, 2009 and November 29, 2009. The gas generation in three different bedding materials used as deep litter bedding was analyzed. Three replications (parallel analysis of the three materials) were undertaken; each trial lasted 19 days. Table 1 shows the time course and experimental set up of the investigation.

2.1.1. Bedding Materials

The following bedding materials were analyzed under standardized laboratory conditions (temperature 18°C, relative humidity 45%): (1) wheat straw (not chaffed, blade length 20-35 cm, harvested in August 2009, Krone Big Pack, Germany; square bales 90 × 120 cm), (2) rye straw (not chaffed, blade length 25-40 cm, harvested in July 2009, Krone Big Pack, Germany; square bales 90 × 120 cm^2), and (3) wood shavings (spruce wood, length 0.5-4.0 cm, 25 kg packs; Brandenburg Com., Germany). All of the materials were stored under the same conditions in a dry room for 8 weeks before the investigation.

2.1.2. Substrate

To simulate the conditions found in practice, the composition of the bedding (substrate) used in the experiments was oriented on a horse box (dimensions: 3 × 3 m) and a 6-week-old deep litter bed. Accordingly, to produce the substrate, 25 kg of the respective bedding material was mixed with 60 kg horse feces and 60 L of artificially produced urea solution (3 mg/L ammonium chloride). To make the urea solution, urine samples from four different horses were collected before the investigation was undertaken and their mean ammonium content was determined (3 mg/L ammonium nitrogen [NH_4-N]). Subsequently, an ammonium chloride solution was produced as a urine equivalent on the basis of this mean NH_4-N content.

Pure horse feces were collected over 7 days before the start of the experiment from a riding stable housing 50 horses (Vechta, Germany). The feces were stored at 4°C in closed containers until required. Before every trial, 180 kg of the horse feces (3 chambers × 60 kg) were homogenized in a bath in a separate room. Each of the substrates was then mixed in a separate bath. First, 60 kg of the homogenized horse feces was placed in a 1,500-L plastic bath and mixed with 60 L of the manufactured urea solution. The two components were mixed using an electrical hand mixer (Type B6; Firma. beba-Mischtechnik GmbH, Essen, Germany). Later, 25 kg of the particular bedding material was mixed into the urea–feces mixture using the electrical hand mixer.

2.1.3. Chambers

Three separate chambers with identical proportions and construction (substrate and gas chamber, seepage sump with drainage system) were available for the trials (Fig. 1). The internal dimensions were 1.0 × 1.8 × 0.9 m. For heat