Microporous and Mesoporous Materials 118 (2009) 93–99

Contents lists available at ScienceDirect

Microporous and Mesoporous Materials

journal homepage: www.elsevier.com/locate/micromeso

Effect on manure characteristics of supplementing grower hog ration with clinoptilolite

J. Tiwari [a], S. Barrington [a,*], X. Zhao [b]

[a] Department of Bioresource Engineering, Macdonald Campus of McGill University, 21111 Lakeshore Road, Ste-Anne-de-Bellevue, Quebec, Canada H9X 3V9
[b] Department of Animal Science, Macdonald Campus of McGill University, 21111 Lakeshore Road, Ste-Anne-de-Bellevue, Quebec, Canada H9X 3V9

ARTICLE INFO

Article history:
Received 26 June 2008
Received in revised form 8 August 2008
Accepted 11 August 2008
Available online 30 August 2008

Keywords:
Clinoptilolite
Grower hogs
Viscosity
Odour
Manure physical characteristics

ABSTRACT

Diet manipulation, such as zeolite (clinoptilolite) supplementation, can reduce manure nutrient content but may negatively affect manure handling properties. The objective of the study was to measure the impact on manure physico–chemical properties of supplementing grower hog rations with 4% zeolite (90% + clinoptilolite). The manure was produced by feeding each one of four experimental rations to three hogs for four weeks. During the last week, the hogs were placed in metabolic cages to individually collect, measure and analyze their manure for nutrient content. The four rations consisted of a control with 100% crude protein (CP) and energy requirements (R1), and three 4% zeolite (90% + clinoptilolite) supplemented rations with a CP and energy of 100%, 100%; 90%, 90% and; 90% and 85% of requirements (R2, R3 and R4), respectively. The manures were aged at 25 °C for 67 days and then analyzed for nitrogen and carbon, and tested for flow characteristics and odour emissions. Ration R2 resulted in the lowest fresh manure total carbon (TC), but was significantly more diluted by urines. Ration R2 also produced fresh manure with the lowest total nitrogen (TN), while ration R3 produced that with the lowest total phosphorous (TP) and total potassium (TK), but not significantly different from that of the control ration, R1, because of a large coefficient of variation among hogs. Ration zeolite supplementation improved aged manure flow characteristics, especially for rations R3 and R4 with a lower fat formulation. Zeolite added to manure once excreted had no effect on its viscosity even if its total solids were increased. Rations R3 and R4 produced an aged manure which emitted less odours, as compared to ration R1; ration R2 produced less odours than ration R1, although not statistically significant ($P > 0.05$). Thus, swine diets supplemented with a zeolite (clinoptilolite) can lower the manure nutrient content without altering its physico–chemical properties. The results require repeating with more hogs and rations containing a better nutrient balance.

1. Introduction

In many regions of North America and Europe, the intensification of livestock operations resulted in the land application of manure nutrients in excess of that required by crops [1,2]. As a result, agricultural soils have become overloaded with nutrients, especially nitrogen (N) and phosphorous (P), and their respective drainage and erosion has enriched downstream lakes and rivers. The resulting aquatic plant growth and rapid algae bloom have increased the incidents of oxygen depletion in water bodies leading to fish kills and drinking water deterioration [3].

Because livestock manures are generally rich in N, especially in the form of ammonium, its management contributes over 50% of the total atmospheric ammonia (NH_3) emissions in Europe [4]. In Canada, livestock manure produced 70% of all atmospheric NH_3, and the application of chemical fertilizer increases this percentage to 90% [5]. As a result, N is being deposited on land and water surfaces at rates exceeding 20 kg/ha, and affecting sensitive ecosystems such as wetlands and the Mediterranean Sea [6,7].

Reducing the nutrient load of livestock manures can help to mitigate the problems associated with soil, water and air contamination. Only 30–35% of minerals such as N and P are absorbed by the digestive track of hogs, as opposed to 70% for carbohydrates [8]. Therefore, feed additives improving mineral digestion can reduce manure nutrient load and soil enrichment in high livestock density areas.

Clinoptilolite is a specific type of zeolite, which when used as swine feed additive, can potentially improve nutrient digestion and lower odour emissions from urine to feces [9]. Furthermore, a reduction in manure NH_3 emissions of 28–79% is reported as a result of zeolite diet supplementation. The primary odour-producing compound in swine manure evolves from the poor digestion of specific carbohydrates to the excessive feeding of proteins. Zeolite supplementation in a grower hog ration resulted in lower manure N and P levels [8–11]. Zeolite improved the digestibility of crude

* Corresponding author. Tel.: +1 514 398 7776; fax: +1 514 398 8387.
E-mail address: suzelle.barrington@mcgill.ca (S. Barrington).

1387-1811/$ - see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.micromeso.2008.08.041

protein (CP) and nitrogen-free extracts [12], and reduced the dietary CP requirements while minimizing manure NH_3 emissions [13]. These positive effects of clinoptilolite in animal diets results from its adsorption of excess ammonium ions in the digestive track to their release with lower concentrations, thus lowering the inhibitory effect of ammonium on the microbial population of the digestive track [11]. Furthermore, clinoptilolite is said to adsorb water, thus slowing down the passage of feed through the digestive track of the animal and improving nutrient ingestion [11].

If zeolite supplementation at levels of 2–10% can reduce manure nutrient content, it can also change the properties of manure, a topic which has not been intensively researched. Because zeolite is not degraded by the digestive track of livestock [14], it can potentially increase the total solids (TS) content of manures. For example, when included in a ration at a rate of 4% by weight, zeolite can increase the manure TS from 5% to 6%, assuming that 70% of the feed carbohydrates are digested. Accordingly, the supplementation of zeolite in livestock rations can increase the kinematic viscosity of manure which in turn, can require more handling energy.

The kinematic viscosity of manure was found to increase with TS [15,16]. There was a 10- to 80-fold increase in kinematic viscosity for a TS increased from 0% to 5% and 10%, respectively [17]. Manure slurries are known to be Newtonian fluids for TS under 5% [18] and non-Newtonian pseudoplastic fluids above 5% [16]. A rheological consistency coefficient (K) and a rheological behaviour index (n) were used to express the variation in manure viscosity with its TS [19]. For a shear rate of $10\ s^{-1}$, a similar expression was used to predict the apparent viscosity of swine manure as a function of TS ranging from 10% to 20% [16]

$$\eta_{\text{app}} = 4 \times 10^{-6}\,\text{TS}^{4.6432} \tag{1}$$

where TS is total solids of the manure, %; and η_{app} is the apparent viscosity, Pa s.

Therefore, the objective of this paper was to observe the effect of zeolite (90% + clinoptilolite), as grower hog feed additive, on the characteristics of manure produced, namely mass, TS, mineral content, total carbon (TC), loss of N during storage, flow characteristics and odour emissions. The evolution of TS, TN and TC was measured during an aging period of 67 days at a 25 °C, whereas the flow characteristics, viscosity and odour emissions were measured at the end of this period. To observe the effect of zeolite on manure viscosity, without the effect of fat in the ration, zeolite was added to freshly excreted manure at a level of 0%, 2% and 4% and manure viscosity was then measured.

2. Methodology

2.1. Experimental materials

The experimental manures were produced by grower hogs housed at the swine unit of the Macdonald Campus Experimental Farm, of McGill University, Montreal, Canada. All hogs were cross-bred (½ Duroque, ¼ Landrace and ¼ Yorkshire).

These hogs were raised in a grower room measuring 14.75 × 7.20 m and 3.05 m in height, with two rows of eight pens each measuring 3.00 × 1.84 m and offering 0.92 m^2/hog. All pens had a fully slatted floor. The feeders were placed against the central alleyway and offered feed ad libitum. The grower room was ventilated at a rate ranging from 5 to 48 L/s/hog, using a central air inlet with baffles pivoting against weights and a fan bank in one corner of the end wall.

The 12 stainless steel metabolic cages used in this experiment were housed in a laboratory measuring 16.25 × 7.6 m and 3.05 m in height, ventilated at a rate of 5 to 48 L/s/hog and maintained at 24 °C. The metabolic cages measured 0.60 m in width by 1.8 m in length and bars inside the cage were adjusted to restrain the hog in a position close to the feeder, while still allowing the animal to lie down and get up. Under the plastic mesh flooring of each metabolic cage, two trays were used to collect the urine and feces; the top tray was perforated to allow the urine to drain into the second non-perforated tray. Females were used for this experiment to facilitate the collection of feces and urines in the trays at the back of the cages.

The four experimental rations (control or R1, and the 4% zeolite supplemented rations, R2, R3 and R4) were prepared from corn and soybeans, by Agri-brands Purina Canada Inc., St-Hubert, Quebec (Table 1). Rations R1 and R2 were formulated to meet 100% of the nutrient requirements of finishing grower hogs [20] while rations R3 and R4 offered 90% of the crude protein (CP) and 90% or 85% of the energy requirements, respectively.

Supplied by KMI mines of Nevada, USA, zeolite (90% + clinoptilolite) at a rate of 4% was incorporated into rations R2, R3 and R4. Zeolite characterization was conducted by Core Laboratories Inc., of Calgary, Alberta, Canada, using XR diffraction and its clinoptilolite content was obtained by comparing the fingerprint to that of an almost pure sample (Table 2). Under acidic conditions and temperatures similar to that of the digestive track of a hog, the ammonia adsorption capacity of this zeolite was demonstrated to vary with particle size. In this experiment, a mixed particle size ranging but less than 0.5 mm was used [14].

Table 1
Composition of feed supplied to hogs during the test

Property	R1	R2	R3	R4
Crude protein (%)	15.5	15.5	14.0	14.0
Crude fat (%)	7	7	2	2
Crude fiber (%)	5	5	5	5
Na (%)	0.2	0.2	0.2	0.2
Ca (%)	0.75	0.75	0.75	0.75
P (%)	0.65	0.65	0.65	0.65
Cu (mg/kg)	125	125	125	125
Zn (mg/kg)	100	100	100	100
Vitamin A (IU/kg[a])	5400	5400	5400	5400
Vitamin D3 (IU/kg)	1200	1200	1200	1200
Vitamin E (IU/kg)	40	40	40	40
Selenium (mg/kg)	0.3	0.3	0.3	0.3
Zeolite (%)	0	4	4	4
Energy (Kcal)	3250	3250	2925	2760
Crude Protein (%)	100	100	90	90
Energy (%)	100	100	90	85

Note: R1, control ration with 100% CP and 100% energy; R2, 4% zeolite ration with 100% CP and 100% energy; R3, 4% zeolite ration with 90% CP and 90% energy; R4, 4% zeolite ration with 90% CP and 85% energy in diets.
[a] International units per kilogram.

Table 2
Bulk composition of experimental zeolite by percent weight

Elements	Chemical symbol	Weight (%)[a]
Quartz	SiO_2	Trace to 1
Plagioclase	$NaAlSi_3O_8$–$CaAl_2Si_2O_8$	Trace to 1
Calcite	$CaCO_3$	1
Dolomite	$[CaMg]CO_3$	Trace to 1
Clinoptilolite	$KNa_2Ca_2(Si_{28}Al_7)O_{72}{\cdot}24H_2O$	97–98
Opal	$SiO_2{\cdot}nH_20$	0
Muscovite/Illite	$KAl_2[AlSi_3O_{10}][OH]_2$	0
NH_4^+–N adsorption capacity at pH 2 and T = 39 °C (C mol$^+$/kg of zeolite) [14]		123

[a] Bulk composition analysis of the experimental zeolite by Core Laboratories Inc., Calgary, Alberta, Canada.