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Effect of Bedding Materials on Ammonia Release from Manure

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ABSTRACT Experiments were conducted to assess the effectiveness of bedding materials in reducing ammonia release from manure. Three new and six commonly used bedding materials were tested and compared. In the first set of experiments, a layer of bedding material was placed in a test chamber for each material, and cow manure was then added to the bedding material. Ammonia concentration in the chambers was measured daily for five consecutive days. In the second experiment, ammonia gas was introduced into the chambers filled with bedding materials to quantify the ammonia adsorption by the bedding materials. The results showed that all tested materials were effective in reducing ammonia release from manure, but higher density materials seemed to perform better than bulky materials when the same volume of material was used. Reduction in ammonia by bedding materials was mostly attributed to gas adsorption.

Keywords: animal bedding, manure, ammonia, adsorption

INTRODUCTION

Bedding is commonly used in animal facilities to provide better welfare and environment to the animals. Two important requirements for a material to be used for bedding are moisture adsorption and odour reduction. Bedding may reduce odour from animal manure through three modes of action: (a) adsorbing moisture to keep manure dry to reduce the microbial activities; (b) preventing urine from mixing with feces; and (c) adsorbing odorous gases directly. Keeping manure moisture below 40% generally halts the anaerobic biological decompression of manure (Miner and Barth, 1988). Bedding adsorbs moisture from manure and keep it relatively dry (<40% moisture), thus stopping or reducing odour generation (Mode 1). Conversion of urinary urea to ammonia is by urease, an enzyme produced by microorganisms in feces, which reacts with urinary urea to form ammonia. If urine is absorbed by bedding before it contacts feces, manure will produce little ammonia (Mode 2). Bedding materials are porous with large surface (pore) areas, which are capable of adsorbing odorous gases directly (Mode 3). The objective of this project was to assess the effectiveness of a new bedding material, SuperStraw, and determine its mode of action in reducing ammonia release from animal manure. Some commonly used bedding materials were also tested for comparison.

MATERIALS AND METHOD

Two sets of experiments were performed to assess the effectiveness of three SuperStraw products and investigate their mode of action in reducing ammonia release from manure. In the first set of experiments, manure was mixed in the bedding material to evaluate the effectiveness of Modes 1 and 2 (moisture reduction) in reducing ammonia release. In the second set of experiments, ammonia gas was injected into a chamber (container) partially filled with the bedding material to assess Mode 3 (gas adsorption).

Materials

SuperStraw samples were received from Biovalco Inc., Winnipeg, Manitoba. SuperStraw products were produced by subjecting wheat straw to high pressure and temperature to achieve a highly porous and absorptive end product. Three SuperStraw products were selected for testing: SuperStraw (SS), SuperStraw Flakes (SSF), and SuperStraw Pelleted (SSP) (fig. 1). The performance of these three products was compared with six other bedding materials currently available in the market, including Bentonite Clay (BC) (traditional cat litter), Hemp (H), Spruce Wood Shavings (WS), Wood Pellets (WP), Chopped Wheat Straw (CWS), and Flax Shive (FS) (fig. 1).

(a) SuperStraw (b) SuperStraw Flakes (c) SuperStraw Pelleted

(d) Bentonite Clay (e) Hemp (f) Spruce Wood Shavings

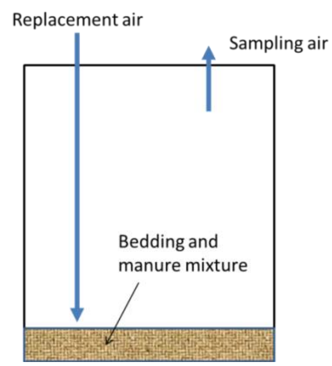
(g) Wood Pellets (h) Chopped Wheat Straw (i) Flax Shive

Figure 1. Photographs of nine bedding materials tested

Test setup

Ten airtight stainless steel containers (Simplehuman®) were used to conduct tests. The container was 493 mm high and had a cross section approximately of 461 × 266 mm (fig. 2a). When the lid was clamped shut, a silicone gasket ensured an airtight seal. Two holes were drilled on the lid for air sampling (fig. 2b), one for taking air samples and the other for replacement air to flow into the container. A 3-mm (1/8”) inner diameter Teflon tube was installed as the sampling port and another Teflon tube was inserted through the lid to bring the replacement air close to the bedding material tested. Each container was filled with a 25.4 mm (1”) thick layer of one of the bedding materials to be tested. The volume of material in each chamber was about 3 L. One chamber (container) was left empty as the control.

(a)



(b)

Figure 2. Photograph of test container (Simplehuman®) and illustration of sampling air flow

Manure test

The first set of tests was conducted to study SuperStraw products as a bedding material in reducing odour produced by manure. Fresh cow manure and urine was collected from a local farm and refrigerated until use. For each test, 1/2 tbs of manure mixed with urine was added to the bedding material in each chamber per day to simulate manure accumulation in actual barns.

Manure and urine were added by using a measuring spoon and syringe, with the aid of a template for even and consistent locations of manure placement. The resulted manure to bedding ratios (MBR) (grams of manure per grams of bedding material) are summarized in Table 1. It should be noted that the volume of bedding material was the same for all nine materials in each chamber although the MBRs (mass based) were different among the materials.

Table 1. Manure to bedding ratios for the materials tested

	SuperStraw	SuperStraw Flakes	SuperStraw Pelleted	Bentonite Clay	Hemp	Spruce Wood Shavings	Wood Pellets	Chopped Wheat Straw	Flax Shive
MBR	22%	14%	6%	2%	23%	31%	4%	71%	16%
Bedding (g)	167	262	600	2000	157	116	877	51	230
Manure (g)	10	10	10	10	10	10	10	10	10
Urine (g)	26	26	26	26	26	26	26	26	26
Moisture content	13.6%	12.6%	12.6%	6.8%	14.0%	12.2%	6.8%	19.6%	15.6%

The test chambers were kept in a room at 18°C and the lids were left open to allow free air movement over the surface of bedding material during testing, except when taking air sample. The lid was closed for 30 minutes to allow the gases to build up in the chamber right before an air sample was taken. This required gas-build-up time was determined from preliminary tests, which showed that 30 minutes was sufficient for ammonia to reach a steady level in the test chambers. Samples were taken from each chamber daily for five consecutive days (Day 1 – Day 5). The ammonia level varied little in most chambers (except the control) after five days.

Two manure gases are commonly used as odour indicators - ammonia and hydrogen sulfide. This study was focused on ammonia. Hydrogen sulfide level was very low and measured as a reference. A single gas photoacoustic analyzer (Chillgard RT, MSA, Cranberry, PA), was used to measure ammonia concentration. The instrument had a sensitivity of 1 ppm and accuracy of 2 ppm and was checked frequently by using 50 ppm ammonia calibration gas. A portable analyzer (Jerome 631, Arizona Instrument LLC, Chandler, AZ) was used to measure hydrogen sulfide concentration. The instrument offers an analysis range of 0.003-50 ppm, with a resolution of 0.001 ppm.

Ammonia gas adsorption test

The same test chambers (containers) were used for adsorption tests. Instead of using manure as the odour source, ammonia gas was introduced into each chamber directly by placing a cup with 1/8 tsp of ammonia solution (ammonium hydroxide) inside each chamber. The chambers were closed for 2 hours before measuring the ammonia concentration in the headspace. The adsorption capacity was estimated as follows:

$$A = (C_t - C_c) \times 10^{-6} \times V \times \rho \div m \tag{1}$$

where

- A = ammonia adsorption capacity (mg/g)
- C_t = measured ammonia concentration in treatment (ppm)
- C_c = measured ammonia concentration in control (ppm)
- V = volume of test container (m^3)
- ρ = density of ammonia (mg/m^3)
- m = mass of bedding material (g)

RESULTS AND DISCUSSION

Manure gases

SuperStraw products significantly reduced ammonia release compared with the control (fig. 3). Without any bedding in the test chamber (control), ammonia level increased gradually to about 50 ppm in 5 days, whereas, the ammonia level increased only slightly to 7 ppm for SuperStraw. This meant that the reduction of ammonia release by SuperStaw was about 7 times. The similar observation was made for the other two SuperStraw products (SSF and SSP).

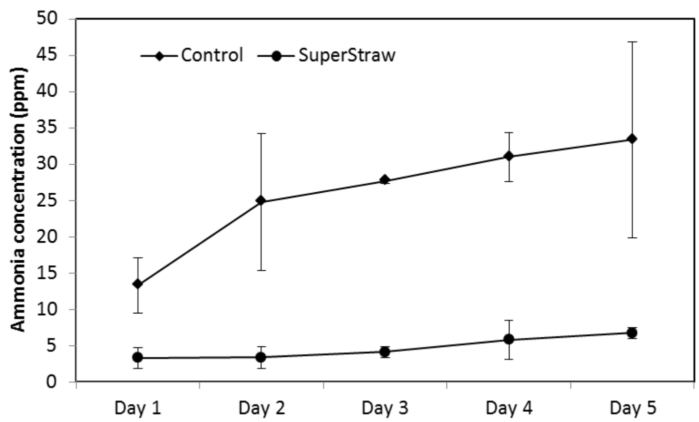


Figure 3. Comparison of ammonia levels in test chambers between control (no bedding) and SuperStraw bedding

A general observed trend was that ammonia increased slightly with time, except for wood pellets (fig. 4). The day-1 ammonia levels ranged from 2.5 ppm (for most materials) to 6.3 ppm (wood pellets), with no specific patterns observed. The ammonia level for the control was significantly ($P<0.05$) higher than all nine materials. The differences in ammonia level among the nine materials on day 5 were greater than that on day 1, with the lowest ammonia level observed for Bentonite Clay (3.7 ppm) and the highest for Flax Shive (12.7 ppm) (fig. 5). The nine materials were ranked as follows based on their measured ammonia levels on day 5 (from the lowest to the highest): Bentonite Clay, SuperStraw Pelleted, SuperStraw Flakes, Wood Pellets, SuperStraw, Spruce Wood Shavings, Hemp, Chopped Wheat Straw, and Flax Shive. Fisher pairwise comparisons showed that ammonia levels for all nine materials were significantly ($P<0.05$) lower than the control (Table 2).

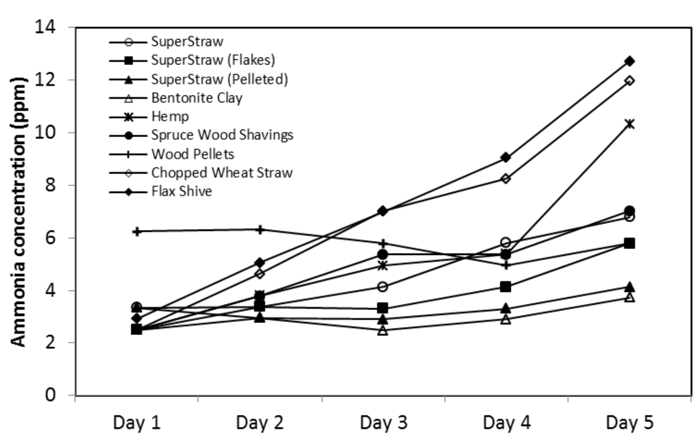


Figure 4. Comparison of ammonia levels among different bedding materials

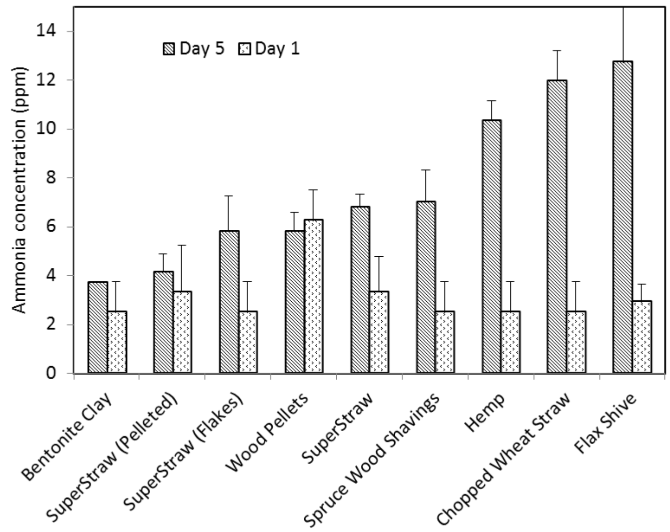


Fig. 5. Ammonia levels ranked from the lowest to the highest based on Day 5 ammonia levels.

Table 2. Fisher pairwise comparisons of day-5 ammonia levels (including control)

Material	Mean (ppm)	Grouping
Control	33.3	A
Flax Shive	12.7	B
Chopped Wheat Straw	12.0	B C
Hemp	10.3	B C
Spruce Wood Shavings	7.0	B C
SuperStraw	6.8	B C
Wood Pellets	5.8	B C
SuperStraw Flakes)	5.8	B C
SuperStraw Pelleted)	4.1	B C
Bentonite Clay	3.7	C

To evaluate the overall performance of bedding materials for the entire 5-day test period, paired t-tests were selected to compare the nine bedding materials against each other, as well as with the control (Table 3). It could be seen that the ammonia levels for all bedding materials were significantly different from (lower than) the control. In other words, all nine materials tested were effective in reducing ammonia release. The difference between SuperStraw and SuperStraw Flakes was statistically significant (P = 0.031), whereas the difference between SuperStraw and SuperStraw Pelleted was not significant (P = 0.063). The difference between SuperStraw Flakes and SuperStraw Pelleted was not significantly different (P = 0.285). Although Bentonite Clay was ranked number one based on the day-5 ammonia level, the overall difference between SuperStraw Flakes and Bentonite Clay was not statistically significant (P=0.062).

Table 3. Summary of P-values obtained from paired t-tests to compare nine bedding materials in pairs

	SuperStraw	SuperStraw Flakes	SuperStraw Pelleted	Bentonite Clay	Hemp	Spruce Wood Shavings	Wood Pellets	Chopped Wheat Straw	Flax Shive	Control
SuperStraw	--	0.031	0.063	0.029	0.410	0.759	0.262	0.092	0.063	0.0020
SuperStraw Flakes			0.285	0.062	0.120	0.052	0.045	0.049	0.038	0.0019
SuperStraw Pelleted				0.034	0.150	0.092	0.002	0.074	0.059	0.0027
Bentonite Clay					0.095	0.040	0.001	0.051	0.042	0.0023
Hemp						0.440	0.780	0.040	0.023	0.0013
Spruce Wood Shavings							0.334	0.075	0.056	0.0016
Wood Pellets								0.582	0.452	0.0052
Chopped Wheat Straw									0.031	0.0008
Flax shive										0.0009
Control										--

The above analysis showed clearly that all nine materials were effective in reducing ammonia release, but it was difficult to precisely determine which material performed better. The nine materials could be roughly grouped into four groups: Group 1 - Bentonite Clay and SuperStraw Pelleted; Group 2 - SuperStraw Flakes, Wood Pellets; Group 3 – SuperStraw and Spruce Wood Shavings; and Group 4 - Hemp, Chopped Wheat Straw, and Flax Shive. This grouping generally agreed with the Fisher pairwise comparisons of day-5 ammonia levels among the nine materials (Table 4).

Table 4. Fisher pairwise comparisons of day-5 ammonia levels (excluding control)

Material	Mean (ppm)	Grouping
Flax Shive	12.7	A
Chopped Wheat Straw	12.0	A B
Hemp	10.3	A B C
Spruce Wood Shavings	7.0	B C D
SuperStraw	6.8	B C D
Wood Pellets	5.8	C D
SuperStraw Flakes	5.8	C D
SuperStraw Pelleted	4.1	D
Bentonite Clay	3.7	D

The measured hydrogen sulfide levels followed the similar trends as ammonia (figs. 6 & 7). The hydrogen sulfide level for SuperStraw bedding was significantly ($P<0.05$) lower than the control (fig. 6). The hydrogen sulfide level generally increased with time for all nine materials (fig. 7). However, it should be noted that the measured hydrogen levels were relatively low (<3.5 ppb) for all test conditions (treatments and control), therefore, it should be considered only as a reference in assessing and comparing the material performance.

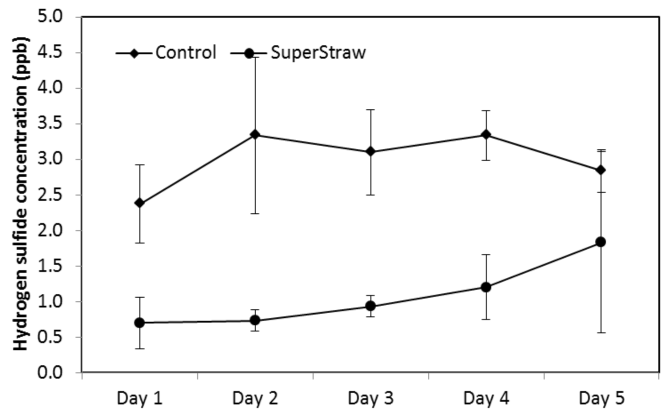


Figure 6. Comparison of hydrogen sulfide levels in test chambers between control (no bedding) and SuperStraw bedding

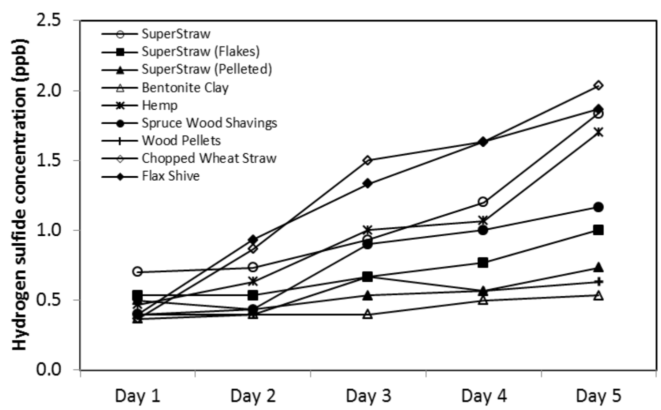


Figure 7. Comparison of hydrogen sulfide levels among different bedding materials

Ammonia adsorption

All nine materials were very effective in adsorbing ammonia when compared with the control. The ammonia level in the treatment chamber (without bedding) reached 609 ppm, while the ammonia level stayed below 38 ppm in all treatments (fig. 8). Reduction in ammonia concentration was 95%, 96%, and 98% for SuperStraw, SuperStraw Flakes, and SuperStraw Pelleted, respectively. The nine materials could be grouped into three groups based on their measured ammonia concentrations: Group 1 – SuperStraw Pelleted, Bentonite Clay, and Flax Shive; Group 2 – Hemp, SuperStraw Flakes, and SuperStraw; and Group 3 - Wood Pellets, Spruce Wood Shavings, and Chopped Wheat Straw (Table 5).

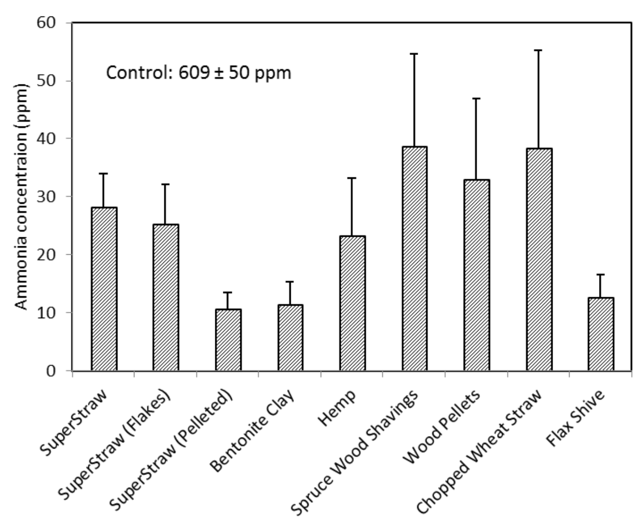


Figure 8. Comparison of ammonia levels among different bedding materials in adsorption tests

Table 5. Fisher pairwise comparisons of ammonia levels in adsorption

Material	Mean (ppm)	Grouping
Spruce Wood Shavings	38.6	A
Chopped Wheat Straw	38.2	A
Wood Pellets	32.9	A
SuperStraw	28.1	A B
SuperStraw Flakes	25.2	A B
Hemp	23.1	A B
Flax Shive	12.6	B
Bentonite Clay	11.4	B
SuperStraw Pelleted	10.6	B

It should be noted that the above comparison was based on the same volume of material used. The estimated amount of ammonia adsorbed by 3 L of materials were not statistically significant ($P>0.05$) among the nine materials (fig. 9). However, the adsorption capacity of materials is commonly expressed on mass basis. The large differences in bulk density among the materials led to significant ($P<0.05$) differences in adsorption capacity when expressed as per unit mass (fig. 10). Lighter materials had higher adsorption capacity per unit mass.

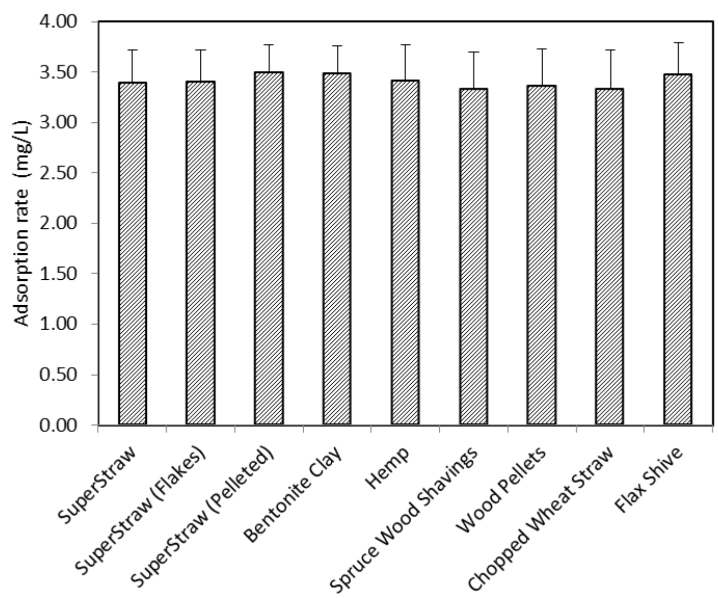


Figure 9. Estimated amount of ammonia adsorbed per unit volume of material

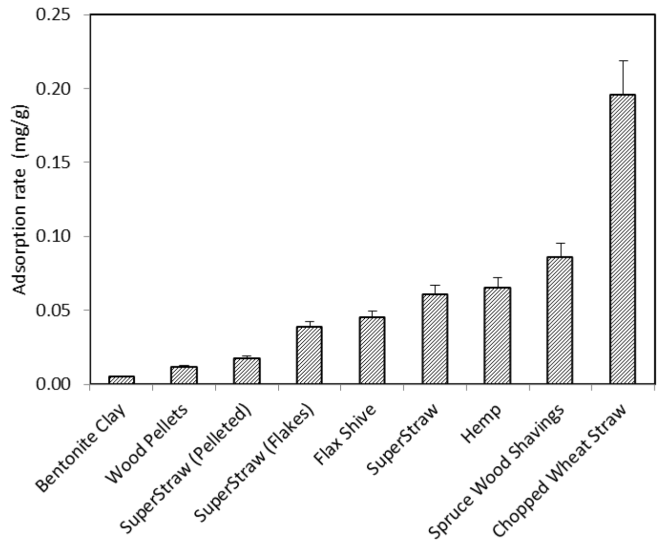


Figure 10. Estimated amount of ammonia adsorbed per unit mass of material

CONCLUSIONS

1. All nice bedding materials tested, including SuperStraw in all three forms, were effective in reducing ammonia released from manure. SuperStraw Pelleted performed slightly better than the other two forms SuperStraw.
2. SuperStraw performed slightly better than some other materials such as hemp, chopped wheat straw, and flax shive, but the differences were not significant in reducing ammonia released from manure.
3. For the three SuperStraw products, reduction in ammonia concentration by adsorption was greater than 95%.
4. On unit volume basis, the ammonia adsorption capacity was not significantly different among the nine bedding materials. However, the differences in adsorption capacity expressed as per unit mass were significant among the nine materials: lighter materials had higher adsorption capacity.

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