Can Surface-Applied Zeolite Reduce Ammonia Losses from Feedyard Manure?

Heidi M. Waldrip, Richard W. Todd, and N. Andy Cole

USDA-Agricultural Research Service (USDA-ARS)

Conservation and Production Research Laboratory, Bushland, Texas

INTRODUCTION

Volatilized ammonia (NH_3) from livestock manure results in losses of nitrogen (N), which may negatively affect air, soil, and water quality. The magnitude and rate of beef cattle feedyard NH_3 loss partially depends on urinary urea excreted by cattle, urea hydrolysis rate ($NH_2(CO)OH \rightarrow 2NH_4^+ + CO_2$), and dissociation of ammonium (NH_4^+; $NH_4^+ + OH^- \leftrightarrow NH_3 + H_2O$) following urea hydrolysis. Zeolite clinoptilolite (***Fig. 1a***) is a naturally occurring, porous aluminosilicate that can sorb and sequester cations, such as NH_4^+, within its negatively charged framework structure. Zeolite has been used to mitigate NH_3 losses from compost, sewage sludge, and manure in livestock barns; however, few studies have evaluated its effectiveness in open-lot systems. Zeolite application to feedyard pen surfaces could be a practical and cost-effective means to reduce the environmental impact of beef cattle production and improve manure fertilizer value.

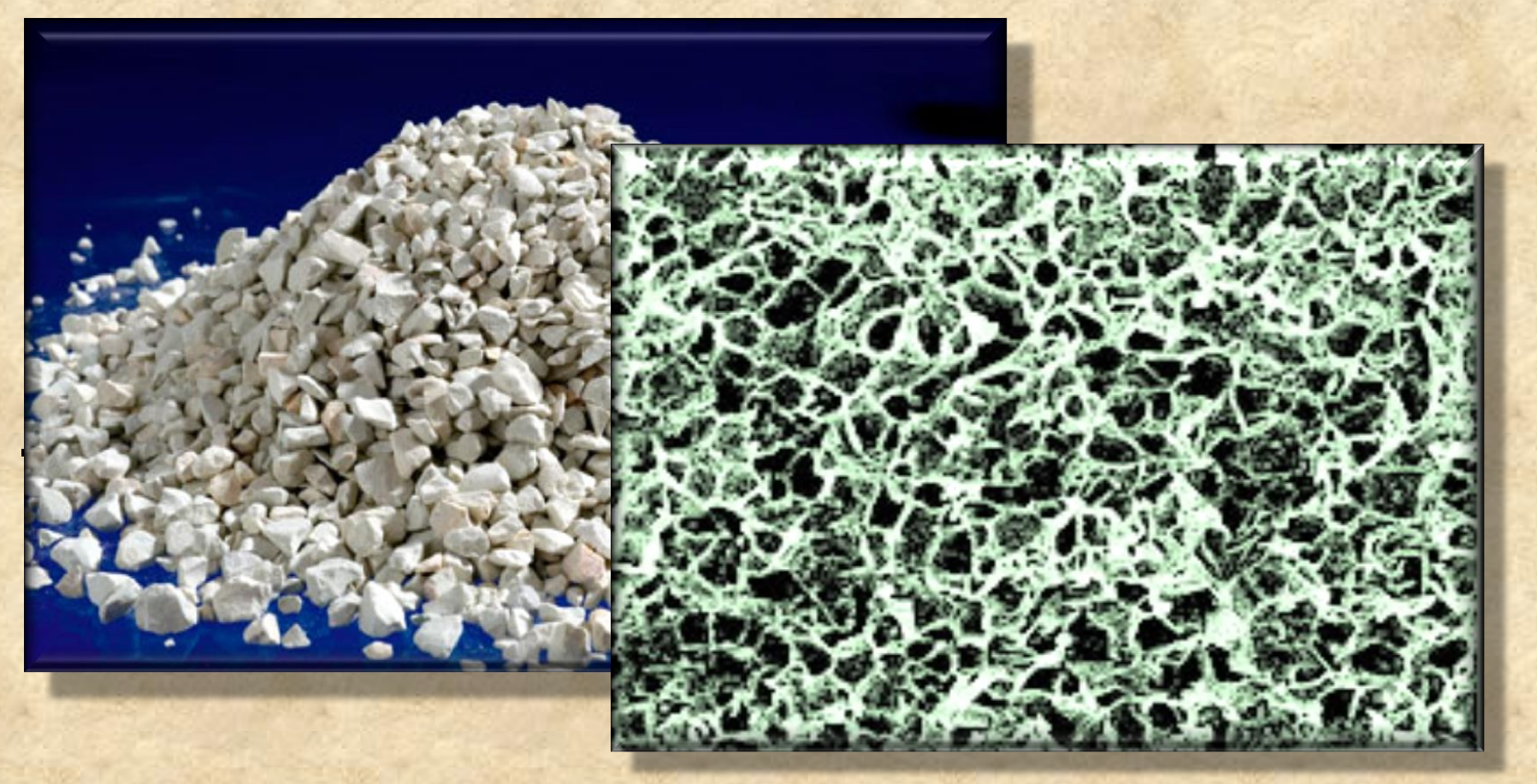

Fig. 1. Zeolite clinoptilolite in its commercial form and magnified to show detail of internal framework structure

OBJECTIVES:

- Characterize NH_4^+ sorption by commercially-available zeolites with differing physicochemical properties
- Evaluate *in vitro* effects of zeolite on cumulative losses of NH_3 following urine application to feedyard manure

MATERIALS AND METHODS

- Four zeolites (Zeolites A-D) were obtained from commercial vendors and physicochemical properties determined (***Table 1***).
- Zeolite NH_4^+ sorption characteristics were determined by equilibrating zeolites (2.0 g) with 0 to 28 cmol N L^{-1} as $(NH_4)_2/SO_4/0.01$ M $CaCl_2$ (20 mL). Concentrations of NH_4^+-N were determined colorimetrically using a flow injection analyzer (***Fig. 2a and b***).
- Recovery of sorbed NH_4^+ from zeolite in a manure matrix was determined by adding different rates of zeolite (0 to 10% of manure dry matter) to unconsolidated surface manure (2.0 g) from a commercial feedyard in the Texas Panhandle. Manure/zeolite mixtures were equilibrated for 4 h with 14 cmol L^{-1} NH_4^+-N as $(NH_4)_2/SO_4/0.01$ M $CaCl_2$ (20 mL), then subjected to a series of five 30 min extractions with 2.0 M KCl (***Fig. 3***).
- Effect of zeolite application rate on cumulative NH_3 emission from simulated feedyard urine spots was determined in a four-day flow-through chamber study with a setup similar to that depicted in ***Figure 4*** (Shi et al., 2001). Zeolites (0 to 5.0%) were added to sealed plastic containers containing 200 g manure and 80 mL of 9.0 g N L^{-1} artificial urine (Kool et al., 2006). Air (3.2 L min^{-1} per container) was passed through containers via a vacuum pump connected to a large manifold. Emitted NH_3 was collected in traps containing 100 mL of 0.5 M H_2SO_4 (***Fig. 5a, b; Table 2***).
- All analyses were conducted in triplicate and significance determined by repeated measures ANOVA.

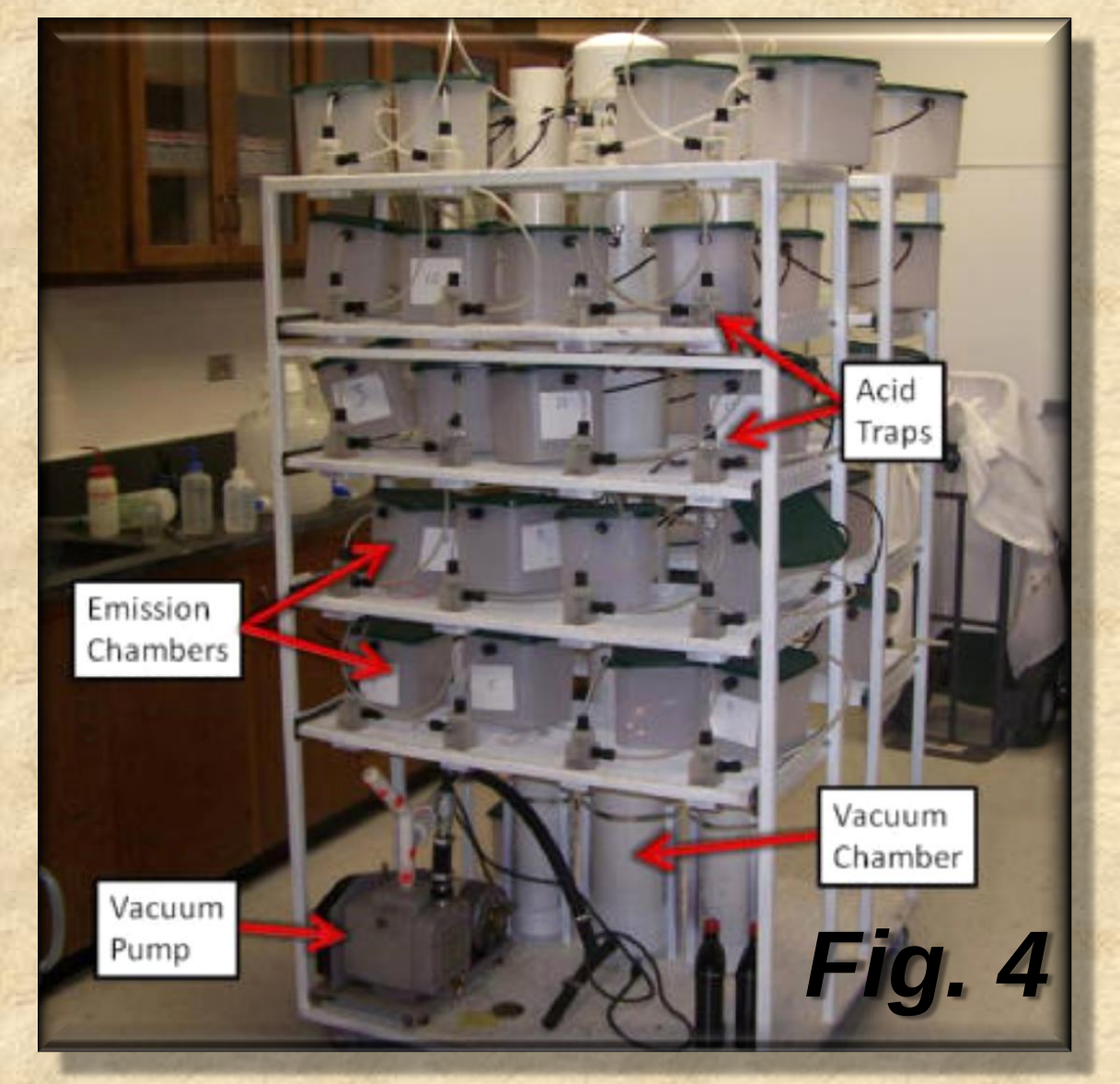

Fig. 4

References:
Kool, DM, Hoffman, E, Abrahamse, PA, Groeniigen, JW. 2006. Soil Biol. Biochem. 38:1757-1763.
Shi, Y., Parker, D.B., Cole, N.A., Auvermann, B.W., Mehlhorn, J.E. 2001. Trans ASABE 44:677-682.

TABLE 1. Selected properties of the four zeolites used in this study.

	Zeolite			
Parameter	**A**	**B**	**C**	**D**
pH[a]	8.5	9.0	8.2	8.0
CEC[b], $cmol_c$ kg^{-1}	61	62	51	60
EC, mmho cm^{-1}	0.12	0.73	1.09	<0.05
Exchangeable cations, mg kg^{-1}				
Ca^{2+}	1639	398	3376	4166
Mg^{2+}	181	55	99	110
K^+	1891	4627	4559	5309
Zn^+	0.2	0.8	0.5	0.5
Na^+	618	11,080	4976	5570
Total N, mg kg^{-1}	62	58	51	79
Total ammoniacal N, mg kg^{-1}	6	6	1	ND
Phosphorus[c], mg kg^{-1}	7	4	3	4
Organic matter, %	1.4	1.0	0.7	0.7
Clinoptilolite content, %	65	65	NA	95
Total surface area, mg g^{-1}	40 to 65	40 to 65	NA	<800
Pore size (diameter), angstroms	4 to 7	4 to 7	NA	4 to 7

[a] 1:1 ratio of zeolite to water.
[b] CEC, cation exchange capacity; EC, electrical conductivity; Ca^{2+}, calcium; Mg^{2+}, magnesium; K^+, potassium; Zn^+, zinc; Na^+, sodium; N, nitrogen; ND, not detected; NA, not available.
[c] Mehlich-3 phosphorus.

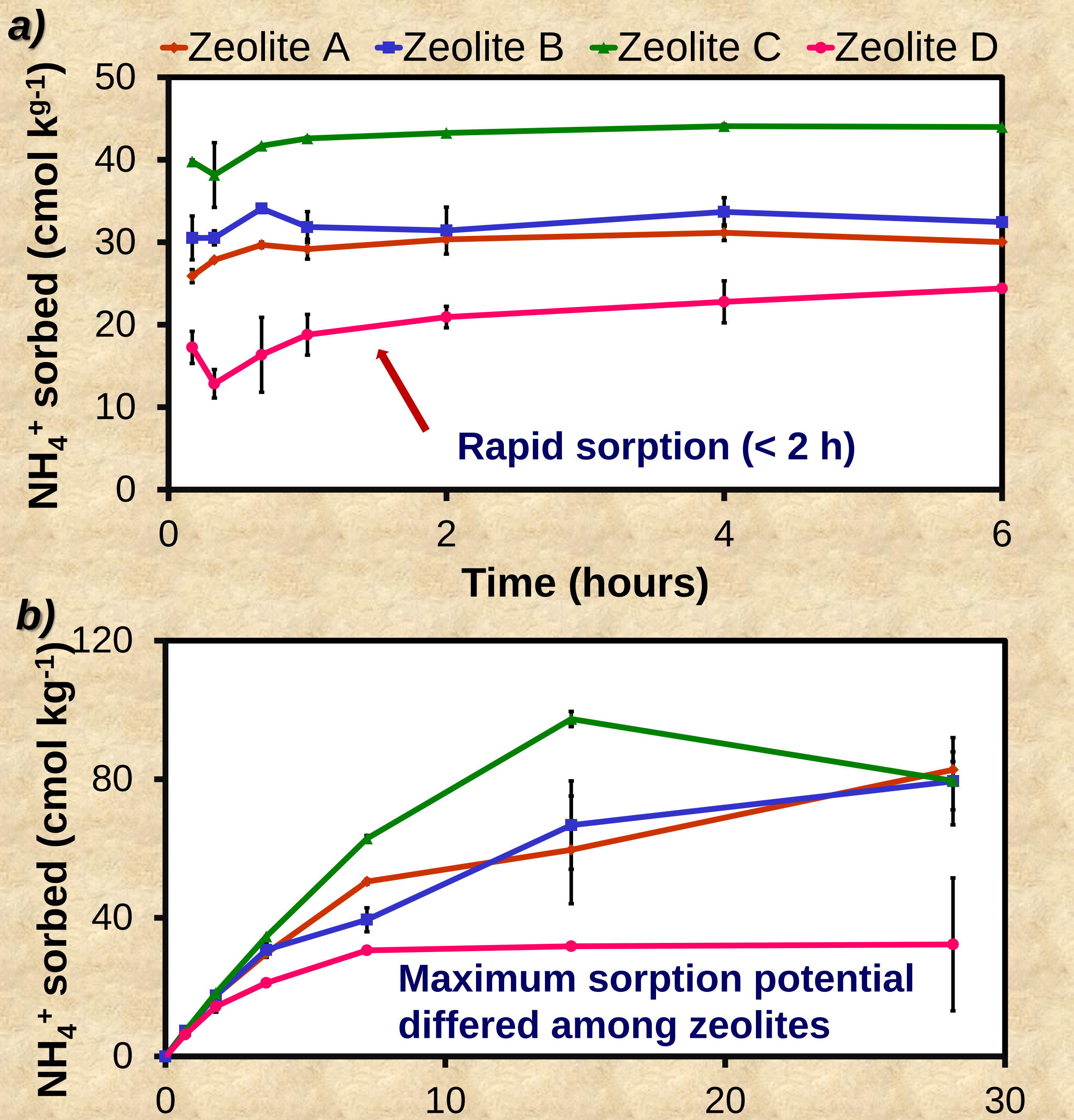

Fig. 2. (a) kinetics and ***(b)*** sorption of NH_4^+ by zeolites equilibrated with NH_4^+ at 22ºC. Error bars represent average ± standard deviation.

	Cumulative NH_3-N emission			
Treatment	Mean (mg)	Standard deviation (mg)	% of urine N added	% of Control
Control	73.6[a]	18.9	10.5[a]	100
0.5% Zeolite	59.4[b]	12.7	8.5[b]	80.7
1.0% Zeolite	42.9[c]	6.1	6.1[c]	58.3
5.0% Zeolite	60.2[b]	5.7	8.6[b]	81.8

TABLE 2. Effect of zeolite application rate on cumulative emission of NH_3 from simulated feedyard urine spots.

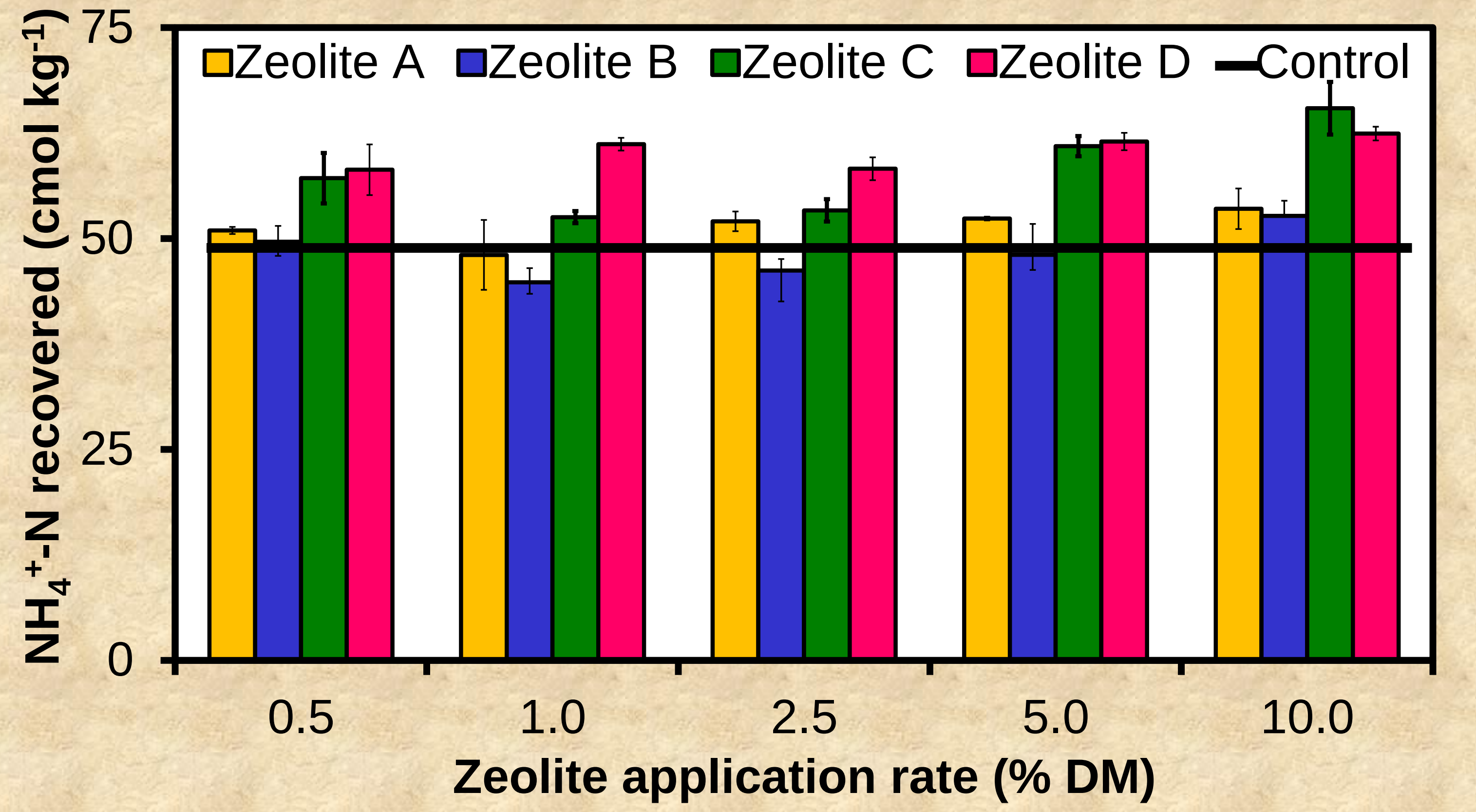

Fig. 3. Effect of zeolite application rate on recovery of NH_4^+-N in a manure/urine matrix. Error bars represent average ± standard deviation.

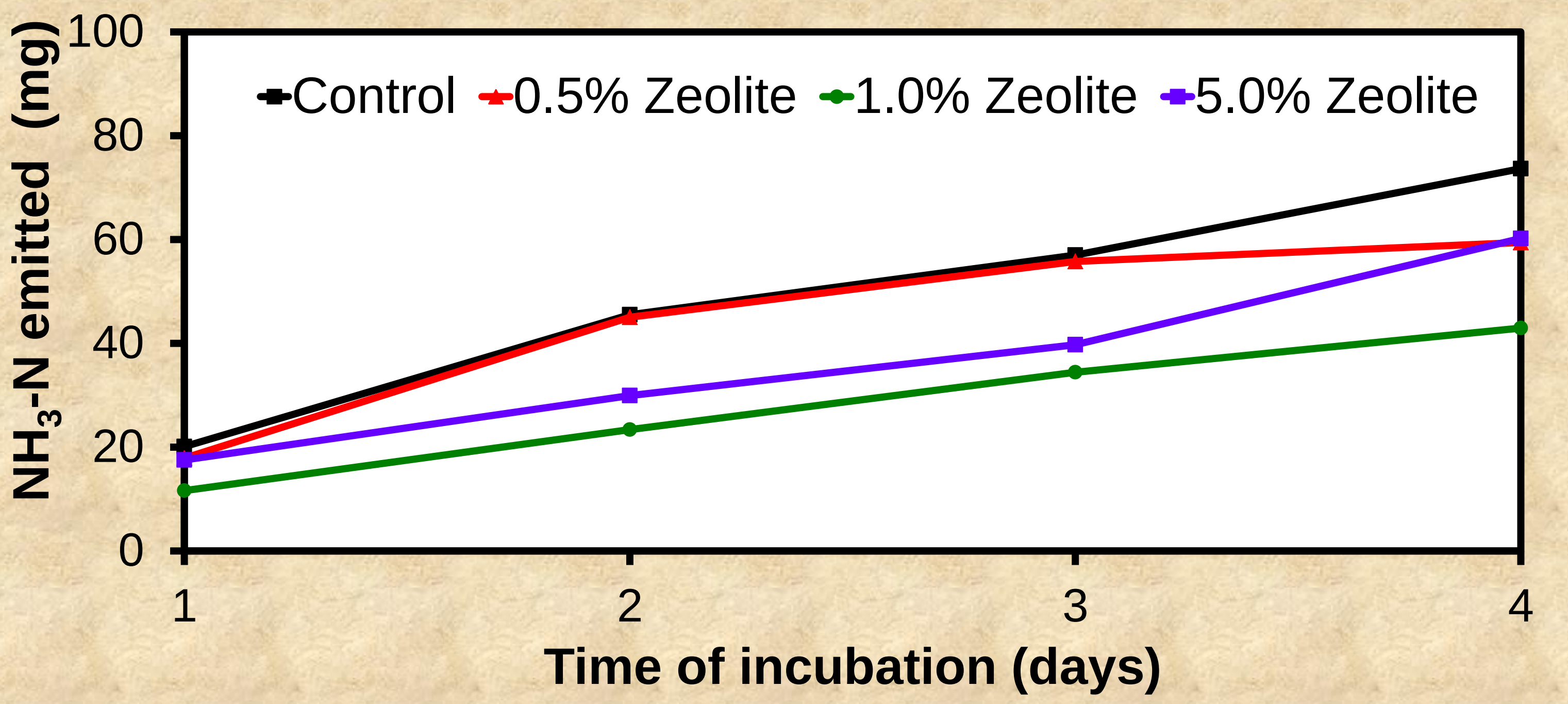

Fig. 5. Effect of zeolite application rate on cumulative (four-days) emission of NH_3 from simulated feedyard urine spots.

CONCLUSIONS

- In batch-incubation studies, NH_4^+ sorption by zeolite was rapid (1 to 2 h; ***Fig. 2a***) with large differences in sorption potential (***Fig. 2b***). Maximum sorption ranged from 28 to 97 cmol NH_4^+-N kg^{-1} zeolite.
- Effects of zeolite application rate on sorption and recovery of NH_4^+ were highly variable but tended to be proportional to zeolite application rate: as little as 0.5% zeolite increased NH_4^+-N recovery by up to 19% (***Fig. 3***).
- In flow-through chamber studies, higher rates of zeolite did not reduce cumulative NH_3 emissions, as 1.0% zeolite reduced cumulative NH_3 emission by 42% and 5.0% zeolite reduced N losses by only 18% compared to unamended manure (***Table 2***, ***Fig. 5***).
- Surface application of zeolite has potential for mitigating feedyard NH_3 losses, but specific zeolite properties influenced its effectiveness.
- Further studies are warranted to evaluate effects of repeated zeolite application, co-application of zeolite and urease inhibitors, and cost:benefit of zeolite application at commercial feedyards.

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TEXAS CATTLE FEEDERS ASSOCIATION

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