Nanoparticles for Controlling Disease-Causing Microorganisms in Pig Barns

B.Z. Predicala, and A.C. Alvarado

Bernardo Predicala

Alvin Alvarado

SUMMARY

Laboratory-scale tests were conducted to evaluate the effectiveness of various types of commercially-available nanoparticles on the levels of microorganisms commonly encountered in swine barns. Results indicate Zinc oxide (ZnO) nanoparticles had the highest antimicrobial efficacy among all the nanoparticles tested. Further experiments carried out in the barn indicated that partial filtration of barn air with a filter loaded with ZnO nanoparticles in the ventilation recirculation system achieved reduction in bioaerosol levels at the animal- and human-occupied zones. During sanitation, 10 mg/mL of ZnO nanoparticle solution sprayed on concrete pen floor surfaces showed significant decrease in total bacterial counts on surfaces four hours after application. Microbial population, however, started to increase after new nursery pigs were brought into the room.

"Zinc oxide (ZnO) nanoparticles had the highest antimicrobial efficacy among all the nanoparticles."

INTRODUCTION

Previous research has shown that selected nanoparticles can effectively reduce the levels of specific hazardous gases (hydrogen sulphide and ammonia) in swine barns (Alvarado et al., 2014). Since nanoparticles are also known to have antimicrobial properties (Sunada et al., 1998), it is interesting to evaluate if nanoparticles can be used in controlling the growth and airborne transmission of microorganisms in swine barns. If proven effective, then with a single treatment application, this technology could simultaneously address concerns with hazardous gas emissions as well as the spread of diseases, both of which have great impact on the overall profitability and sustainability.

Control of diseases in swine production is generally conducted on two fronts: biosecurity measures are put in place to prevent entry of infectious agents into the herd, and sanitation measures are conducted to prevent exposure of pigs to high levels of potentially disease-causing microorganisms within the production facilities. Conventional sanitation procedures involve high-pressure washing of pens and room surfaces followed by application of a disinfectant to kill remaining pathogens.

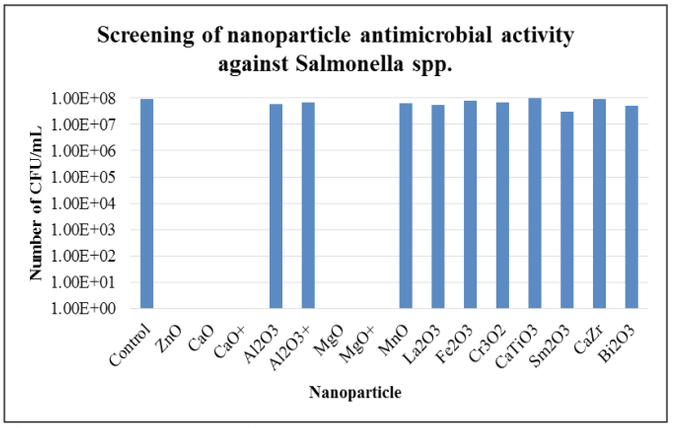

Figure 1. Results of exposing Salmonella cultures to 11 types of nanoparticles separately and then monitoring the number of colony-forming units (CFUs) after incubation for 16 hr at room temperature.

This project set out to control the growth and spread of disease-causing microorganisms in production facilities using commercially-available nanoparticles. Specifically, this study aimed to investigate application alternatives that can be implemented in barns for effective use of nanoparticles to control the spread and transmission of disease-causing microorganisms, assess the effectiveness of nanoparticles as an alternative method for sanitation, and conduct a technical and economic feasibility study of applying nanoparticle treatment technology in a commercial swine production operation.

RESULTS AND DISCUSSION

The inhibitory effect of eleven different types of nanoparticles was tested against representative Gram-positive (*Listeria monocytogenes, Streptococcus suis*) and Gram-negative organisms (*Pseudomonas fluorescence and Salmonella spp.*). As shown in Figure 1, this screening indicated that ZnO, CaO, CaO+, MgO and MgO+ had the greatest impact on the survival of microorganisms (i.e., with Zn and Mg basically completely eliminated all the surviving cells within 16 hr) whereas some of the other agents had no effect on cell number. Thus, ZnO, CaO and MgO agents were used in subsequent tests.

Barn evaluation of ZnO nanoparticles

Effect of treatment on airborne bioaerosols

The total CFU concentrations in the ventilation inlet stream as well as in the animal- and human-occupied zones of the pig-rearing chambers are shown in Figure 2.

Among the three sampling locations, the total CFU concentrations in the animal-occupied zones (about 0.5 m from pen floor) were the highest; on average, bioaerosol levels in the animal-occupied zones of the treated chamber were 3.4 times higher than the inlet concentrations, while the control chamber values were 5.1 times higher than the corresponding inlet concentrations. Additionally, while the CFU levels in the control room showed increasing trends as the trial progressed, a slight reduction (5%) was observed in the treated chamber 10 days after the filter with ZnO nanoparticles was installed. On day 10, mean CFU concentration in the animal-occupied zone of the treated chamber was 926 ± 207 CFU/m3 while the control chamber had 1583 ± 1458 CFU/m3. The control chamber, however, showed increasing trends until day 10.

Microbial loads on surfaces

Surfaces in the treated chamber exhibited a reduction in microbial levels 10 days after the filter with ZnO nanoparticles was installed. About 1.7, 1.3 and 1.4 log reduction was achieved in the concrete, metal and plastic surfaces, respectively. This reduction, however, could not be solely attributed to the application of nanoparticles in the treated chamber since the control chamber also followed the same trend. Concrete, metal and plastic surfaces in the control chamber showed about 1.5, 1.4 and 1.7 log reduction, respectively, 10 days after the filter with no nanoparticles was installed.

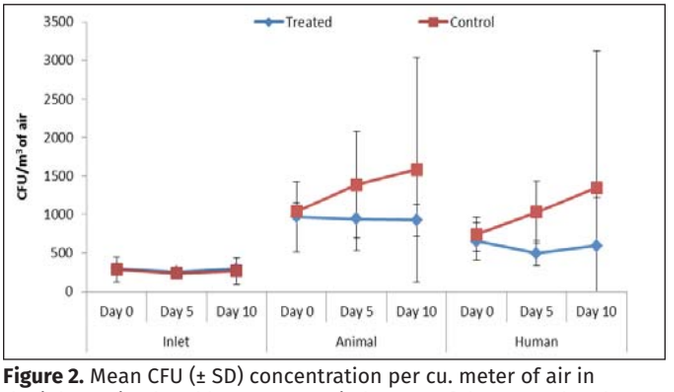

Figure 2. Mean CFU (± SD) concentration per cu. meter of air in the inlet, animal and human-occupied zones of the treated and untreated (control) chambers, n=4

Effect of treatment during sanitation

The effect of ZnO nanoparticles as a disinfectant applied as part of sanitation procedures between batches of animals in the room is shown in Figure 3. Before high-pressure washing (S1), microbial loads on surfaces were high and extremely variable, and statistical tests revealed that the total bacterial counts in all sampling locations were not significantly different ($p>0.05$) from each other. On average, CFU levels during this period ranged from 2.5×10^9 CFU/mL to 4.7×10^9 CFU/mL. These levels dropped to 6.0×10^8 CFU/mL to 1.0×10^9 CFU/mL after high-pressure washing (S2) which could be attributed to the fact that manure and other materials deposited on the floor were removed and cleaned during the high-pressure washing. However, the trends significantly ($p<0.05$) changed 4 hours after the application of disinfectants and drying. The total bacterial counts on surfaces applied with the conventional chemical disinfectant (Control) started to increase while the surfaces applied with ZnO nanoparticles solution continued to decrease. The treatment with the higher concentration of ZnO nanoparticles (10 mg/mL) achieved about 97% significant reduction ($p<0.05$) relative to its initial concentration before high-pressure washing (S1). This reduction can be attributed to the effect of ZnO nanoparticles solution applied on those concrete floor surfaces. However, after nursery pigs were brought into the room, the total bacterial counts on all treated surfaces started to increase, with the most apparent increase observed 24 hours after pigs were moved into the room (S5).

In assessing the feasibility of the use of ZnO nanoparticles as part of sanitation procedures between batches of animals, the total cost associated with the application of ZnO nanoparticles was compared to the cost incurred when using the conventional chemical disinfectant. Using the application rate identified from the room-scale trials (10 mg/mL), the total amount of ZnO nanoparticles required to disinfect a 100-head grow-finish room at the end of each room cycle was estimated to be about 0.7 kg. The duration to prepare and apply the treatment would be about 3 hours per cycle. In addition, the total cost for the required materials included the cost of mixing containers, weighing scale and funnels. Summing up all these estimates, the total cost associated with ZnO nanoparticles as a disinfectant in a grow-finish stage of operation was around CAD$1.14 per finished pig. This was just CAD$0.12 per pig higher than the use of the conventional disinfectant (CAD$1.02 per finished pig). The unit price per kilogram of the conventional disinfectant was slightly higher than ZnO nanoparticles but because of its higher water solubility, the time to prepare and apply the treatment was lower than with ZnO nanoparticles. Nevertheless, the slim margin of the total cost associated with ZnO nanoparticle solution compared to the conventional chemical disinfectant can be compensated by its effectiveness to reduce further the levels of microorganisms on surfaces when preparing the room for next growth cycle.

CONCLUSION

1. Specific type of commercially-available nanoparticles such as Zinc Oxide (ZnO) nanoparticles were found to be effective in controlling growth of selected pathogens that can be encountered in swine production environments.
2. Deploying the nanoparticles in filter systems through which barn air is passed can effectively reduce the levels of airborne bioaerosols in a pig barn. The set-up can be made more effective with better capture of air in the room to pass through the filter system.
3. Sanitation procedures involving the application of nanoparticles in solution on pig barn surfaces can effectively inhibit the growth of microorganisms and can be an alternative to conventional chemical disinfectants.
4. Using current cost estimates and application parameters, the use of ZnO nanoparticle solution during sanitation was only about 12 cents higher than the use of the conventional disinfectant.

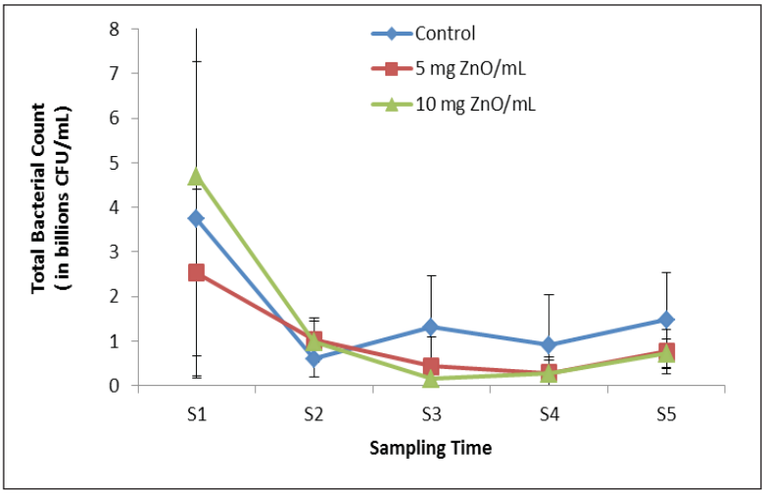

Figure 3. Mean (± SD) bacterial counts from surfaces treated with the conventional chemical disinfectant (Control) and the surface treated with ZnO nanoparticles at varying application rates, n=3. S1 = before high-pressure washing; S2 = right after washing and drying (disinfectants applied right after taking samples); S3 = 4 hr after sanitation and drying; S4 = 1 hr after pigs moved into the room; S5 = 24 hr after pigs moved into the room

ACKNOWLEDGEMENTS

We would like to acknowledge the financial support for this research project from the Saskatchewan Agriculture Development Fund, the Agriculture and Food Council of Alberta, and the Saskatchewan Pork Development Board. The authors would also like to acknowledge the strategic program funding provided by Sask Pork, Alberta Pork, Ontario Pork, the Manitoba Pork Council and the Saskatchewan Agriculture Development Fund. In addition, we also wish to acknowledge the support of the production and research technicians at Prairie Swine Centre that make it possible to conduct this research.