Investigation of Enhanced Sanitization and Disinfection Measures Applicable for Antibiotic-Free Pig Production System

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Summary

This project aims to develop enhanced biosecurity measures that can eliminate or reduce the proliferation of disease-causing pathogens in antibiotic-free pig production as well as in conventional barns for all-inclusive disease prevention. Specifically, this will investigate alternative sanitization and disinfection measures that are effective for control of potentially antibiotic-resistant pathogens, and those measures that might prevent or reduce further development of antimicrobial resistance in the pig production environment.

A comprehensive literature review gathered information on existing and potential sanitization and disinfection technologies available in other jurisdictions, similar industries or applications requiring stringent pathogen control. Sanitization technologies identified from the initial literature search, including use of alternative chemical-based disinfectants, selected nanoparticles, thermal and irradiation technologies were subjected to screening to evaluate their potential applicability in Saskatchewan swine barns. Results will provide valuable tools for pathogen control not only to pig producers implementing antibiotic-free production but also for disease prevention in conventional livestock production in general.

Introduction

Overuse of antibiotics can contribute to the development of antimicrobial resistance to (medically important) antibiotics. In recent years, some pig producers have shifted to raising pigs without the use of any antibiotics, with processors offering premiums for pigs raised completely without antibiotics - as consumer demand for such products increased.

Producers developed strategies such as feeding prebiotics and enhanced vaccination programs to offset the reduced availability or the total absence of antibiotics in their operations. However past studies (Desrosiers, 2013) have shown high herd health also helps reduce the reliance on antibiotics. Therefore strong biosecurity and sanitization protocols are essential to ensure that exposure to pathogens is either eliminated or reduced significantly. Currently, the most commonly used method for controlling pathogens in pig production barns is the use of disinfectants such as quaternary ammonium compound (QAC) and peroxygen, which are more commonly known by their respective trade names. Repeated use of QAC-based disinfectants can lead to the disinfectant being no longer effective for gram-negative bacteria, especially to *Escherichia coli* (*E. coli*) and *Salmonella sp*. Therefore, there is a need for alternative sanitization and disinfection technologies that producers can reliably employ to control the growth and transmission of disease–causing microorganisms, particularly those that may have potentially acquired resistance to current conventional disinfectants and the antibiotics used in the farms.

Experimental Procedures

Phase 1: Evaluation of potential sanitization and disinfection techniques applicable to swine production in Saskatchewan

A comprehensive literature review was conducted compiling various sanitization and disinfection procedures and technologies that have been developed and applied in other industries and applications (such as water treatment facilities, hospitals, care home institutions, food processing and manufacturing facilities) to determine their possible application in swine barns. Potential measures include the application of technologies such as ultraviolet germicidal irradiation, non-thermal plasma, ozonation, thermo-assisted drying and decontamination, and the use of slightly acidic electrolyzed water, among others. Aside from the use of new technologies and equipment, the use of nanoparticles (zinc oxide, silver nanoparticle, and titanium dioxide) as potential antimicrobial agents was also considered, together with the use of various chemical-based disinfectants with different active ingredients (peracetic acid, hydrogen peroxide, chlorine dioxide, sodium hypochlorite).

Assessment criteria that considered cost, applicability, potential effectiveness against antimicrobial-resistant pathogenic strains, among others, was developed and then applied to identify the top three to four potential sanitization and disinfection alternatives for consideration in the next stage of evaluation.

Phase 2: In-barn testing of the selected most promising sanitization techniques

Efficacy of the top two potential sanitization and disinfection techniques identified in the previous phase for controlling the growth of disease-causing microorganisms will be evaluated in nursery and grower-finisher rooms at the Prairie Swine Centre (PSC) barn. After each room turn, selected rooms will be pressure-washed following standard cleaning practices, except the sanitizing/disinfecting step; this last step will be carried out as part of this experiment.

Phase 3: Feasibility analysis and development of recommendations and application guidelines

Following the in-barn experiments, a feasibility analysis will be conducted to determine the costs and requirements for the proper implementation of the top treatments in a typical swine production facility.

Results and Discussion

A preliminary evaluation of the various sanitization and disinfection measures can be seen in Table 1. To reinforce the screening process, an information survey is being conducted to supplement and verify the information gathered on each potential measure, by contacting additional information sources and experts such as swine veterinarians, animal scientists, health researchers, microbiologists, equipment and disinfectant suppliers, pig producers and livestock farmers with on-farm experience on the use of these measures, among others.

Initial results from the literature search also indicate that currently, the most common method for controlling pathogens in livestock facilities is the use of chemical disinfectants. The potential alternatives and experimental measures identified from the literature search included ultraviolet (UV) germicidal irradiation, ozonation, thermo-assisted drying, non-thermal plasma, and the use of slightly acidified water spray, among others, with varying degrees of efficacy in inactivating pathogens. The result of the preliminary assessment and ranking of the various potential measures shown in Table 2 allowed the initial identification of the most promising ones for the next phase of the study (testing under pig barn conditions).

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Table 1a. Evaluation of conventional disinfectants

Disinfectants	Cost	Applicability to Swine Barn	PROPERTIES				SAFETY	
			Antimicrobial Spectrum	Development of AMR	Effectiveness Against AMR	Reactivity	Health Aspect	Toxcity to Environment
A. LIQUID								
1. Alcohols	Moderate (requires high volume)	Applicable	Low	Low		Fast acting	Low	Low
2. Formaldehydes	Low	Applicable	High	Low	Low (selective)	Slow acting	Harmful	Intermediate
3. Glutaraldehyde	Moderate	Highly Applicable	High	Low	Low (selective)	Fast acting	Harmful	Intermediate
4. Iodine	Low	Applicable	Low	High risk (*S. suis, B. hyodysenteriae, ascaris suum* eggs)	Low (selective)	Fast acting	Low	Intermediate
5. Sodium hypochlorite	Low	Applicable	High	High Risk (Rotavirus and PCV virus) (*S. aureus*) (*S. enteritis*)	Moderate	Medium	Low	Low
6. Hydrogen peroxide	Moderate	Highly Applicable	High	Low (*S. suis, S. typhimurium* are resistant under high organic matter conditions)	Moderate	Fast acting	Low	Low
7. Peracetic acid	Moderate	Highly Applicable	High	Low (*S. suis, S. typhimurium* are resistant under high organic matter conditions)	High	Fast acting	Low	Low
8. Phenols and Phenolic derivatives	Low	Applicable	Low	Low Rish (rotavirus)	Moderate	Medium	Harmful	Harmful
9. Quaternary Ammonium Compound (QAC)	Moderate	Highly Applicable	Intermediate (Low)	High risk (*S. typhimurium, Salmonella* and *Bacillus sp.*)	High	Slow acting	Low	Low
B. POWDER								
1. Calcium Oxide	Low	Highly Applicable	Intermediate	Low	High	Slow acting	Intermediate	Intermediate
2. Sodium hydroxide	Low	Applicable	Intermediate	Low	Moderate	Slow acting	Harmful	Harmful
C. TECHNOLOGY								
1. Thermo-Assisted Drying and Decontamination	Extremely High	Applicable (material of construction should be considered)	High		Moderate	Slow acting	Harmful	Intermediate

Implications

Based on the initial screening and evaluation of identified sanitization and disinfection alternatives, the following measures i.e., use of peracetic acid, calcium oxide, slightly acidic electrolyzed water, and use of silver nanoparticles, were initially identified for consideration for testing and evaluation in subsequent phases of the project.

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Table 1b. Evaluation of non-conventional disinfectants.

DISINFECTANTS	COST	Applicability to Swine Barn	PROPERTIES				SAFETY	
			Antimicrobial Spectrum	Development of AMR	Effectiveness against AMR	Reactivity	Health Aspect	Toxicity to Environment
A. GAS								
1. Carbon dioxide contact cleaning	Extremely High	Not applicable (Inside access problematic)	Low		Low	Fast acting	Low	Intermediate
2. Chlorine dioxide	Extremely High	Applicable	High	High risk (*S. aureus*)	Moderate	Medium	Intermediate	Low
3. Slightly Acidic Electrolyzed Water	Extremely High	Highly applicable	Extremely high		High	Fast acting	Low	Low
4. Ozone	Extremely High	Highly applicable	Extremely high	Low risk	High	Fast acting	Harmful	Intermediate
B. NANOPARTICLES								
1. Silver Nanoparticles	High	Highly applicable	Extremely high	No risk	High	Fast acting	Low	Low
2. Titanium Oxide	Moderate	Applicable (limited, focuses on its photocatalytic property)	High		High	Medium	Intermediate	Low
3. Zinc Oxide	Moderate	Highly applicable	High	No risk	High	Medium	Low	Low
C. TECHNOLOGY								
1. HYDROVAC	Moderate	Not applicable (Not a sanitation procedure)	Low		Low	Slow acting	Low	Low
2. NON-THERMAL PLASMA	Extremely High	Applicable (mostly in vitro studies)	Extremely high	High Risk (*S. enterica, B. cereus, B.subtilis, G.* stearothermophilus, some yeast and molds)	High	Fast acting	Low	Low
3. Ultraviolet Germicidal Irradiation	Extremely High	Highly applicable	Extremely high	Low risk (for some fungi) (*E. coli* is resistant after 80 cycles)	High	Fast acting	Harmful	Intermediate
4. Steam wash	Moderate	Applicable (inside access problematic)	Low		Low	Slow acting	Low	Low
5. Soda Blast	Moderate	Not applicable (disinfection is still required)	Low		Low	Fast acting	Intermediate	Harmful (leaves high level of residue)

Table 2. Results of evaluated sanitation alternatives based on its efficiency.

Disinfectants	Applicability to Swine Barn (20%)	Properties (40%)			Safety (20%)			Total (low score; most preferred)	RANK
		Antimicrobial Spectrum (10%)	Development of *ARG (10%)	Effect on **ARB (10%)	Reactivity (10%)	Toxicity (20%)	Effect on Environment (20%)		
A. Conventional Disinfectants									
1. Alcohol	2	6	1	2	0	0	0	11	7
2. Formaldehyde	2	1	1	4	1	6	1	16	9.5
3. Glutaraldehyde	0	1	1	4	0	6	1	13	8
4. Iodine	2	6	4	4	0	0	1	17	11
5. Sodium hypochlorite	2	1	4	1	0.5	0	0	8.5	5
6. Hydrogen peroxide	0	1	1	1	0	0	0	3	2
7. Peracetic acid	0	1	1	0	0	0	0	2	1
8. Phenols and Phenolic derivatives	2	6	1	1	0.5	6	2	18.5	12
9. Quaternary Ammonium Compound	0	3	1	0	1	0	0	5	3
10. Calcium oxide	0	3	1	0	1	2	1	8	4
11. Sodium hydroxide	2	3	1	1	1	6	2	16	9.5
12. Thermo-assisted Drying and Decontamination	2	1	2	1	1	2	1	10	6
B. Non-conventional Disinfectants									
1. Carbon Dioxide contact cleaning	6	6	2	4	0	0	1	19	11
2. Chlorine dioxide	2	1	4	1	0.5	2	0	10.5	8
3. Slightly acidic electrolyzed water	0	0	2	0	0	0	0	2	3
4. Ozone	0	0	1	0	0	6	1	8	6.5
5. Silver Nanoparticles	0	0	0	0	0	0	0	0	1
6. Titanium dioxide	2	1	2	0	0.5	2	0	7.5	5
7. Zinc oxide	0	1	0	0	0.5	0	0	1.5	2
8. HYDROVAC	6	6	2	0	0	0	0	14	9
9. Non-thermal plasma	2	0	4	0	0	0	0	6	4
10. Ultraviolet germicidal irradiation	0	0	1	0	0	6	1	8	6.5
11. Steam wash	2	6	2	4	1	0	0	15	10
12. Soda Blast	12	4.8	0	3.6	0	1	1	22.4	12