FIVE-YEAR REVIEW SUMMARY REPORT CODE OF PRACTICE FOR THE CARE AND HANDLING OF PIGS

Code Technical Panel

August 2020

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

To ensure relevance, the National Farm Animal Care Council (NFACC) recommends that codes of practice be reviewed every five years and revised every ten. As the *Code of Practice for the Care and Handling of Pigs* was implemented in 2014, the Canadian Pork Council coordinated a review in 2019.

A code technical panel (CTP) was established and its membership reflected the composition of the NFACC's board of directors. The CTP began its deliberations on March 18, 2019. It met three times in person and four times by teleconference. The Canadian Pork Council, with funding support from Agriculture and Agri-Food Canada, defrayed most of the costs of the committee's work and provided a secretariat service. Where possible, CTP members covered their personal travel costs and their time.

The panel utilized the NFACC's questionnaire (Appendix A) to guide their discussion and have identified eight recommendations for consideration.

In implementing the program, pork producers identified two significant issues that required attention: the development of a workable definition of "periodic exercise" and the deadline to transition from gestation stalls to group housing.

> **Periodic exercise:** The CTP does not believe that periodic exercise offers much welfare value to sows maintained in gestation stalls. Research results have shown that neither walking sows around the barn at regular intervals, nor housing animals in stalls that enable them to turn around, are ideal solutions. Implementing periodic exercise in a commercial production environment at a level that may bring benefits to the sow would be very challenging. Periodic exercise does not provide an equivalent welfare benefit when compared to the freedom of choice, the amount of free movement and social interaction the sows receive in a group environment.
>
> **Group Housing:** The CTP members acknowledge that not all pork producers will be able to make the conversion to group housing by the 2024 deadline identified in the code without compromising the welfare of the animals, a risk that results from a rushed conversion to inadequate facilities, and/or causing significant financial burden for some producers.

The CTP did recognize the effort that individual producers have put into implementing the Code's recommendations over the past five years. This included not only the daily implementation of the requirements, but also the complete rebuild of the sector's on-farm animal care program.

The CTP accepts and endorses the Canadian Pork Council's commitment to provide an annual progress report on the implementation of the code of practice to NFACC and its members including the following:

1. Number and % of sows transitioned to group housing by province, and updated projections to 2029
2. Number and % of animal handlers trained in group housing management (by producer survey)
3. Number and % of herds enrolled in the PigCARE Program
4. Number of on-farm PigCARE assessments conducted
5. Data on overall compliance with the Code requirements from Pig Care assessments
6. Update on research conducted

2 BACKGROUND

2.1 THE CODE OF PRACTICE FOR THE CARE AND HANDLING OF PIGS

The codes of practice are nationally developed guidelines for the care and handling of farm animals. In 2014, the National Farm Animal Care Council (NFACC) published the *Code of practice for the Care and Handling of Pigs.* It replaced a previous version created in 1993 and published by Agriculture and Agri-Food Canada.

The code of practice plays an important role in the ongoing efforts of pork producers to improve animal care on Canadian pig farms. The code provided the foundation for the update of the Canadian Pork Council's Animal Care Assessment (ACA) which was previously part of the Canadian Quality Assurance (CQA) program. Given the importance of animal care, the ACA was elevated to "full program status" and renamed PigCARE.

2.2 CODE REVIEW

To ensure that the codes of practice are current with government policy, industry practices and scientific research, the NFACC establishes that they should be reviewed every five years and revised at least every 10 years. The *Code of Practice for the Care and Handling of Pigs*, released in 2014, was due for a review in 2019.

A review is intended to provide an opportunity to reflect upon the overall progress made since a code's last update, identify challenges and determine the relative priority level for that code's next full update.

A series of questions created by the NFACC were utilized to guide the review (Appendix A). They also served as a template for the CTP's report.

2.3 CODE TECHNICAL PANEL

NFACC establishes that a Code Technical Panel (CTP), put in place by the relevant producer group, will be responsible for reviewing the code. The CTP members must include representation from the relevant producer association or specialized industry group, research or veterinary community, animal welfare association and other expertise as needed.

The Code Technical Panel created by the Canadian Pork Council reflects the composition of the NFACC board. Its members were:

- Susie Miller, Panel Chair
- Claude Vielfaure, Pork producer - Manitoba
- James Reesor, Pork producer - Ontario
- Yvan Fréchete, Pork producer - Quebec
- Hans Kristensen, Pork producer - New Brunswick
- Dr. Egan Brockhoff, Veterinary Counsellor, Canadian Pork Council
- Geoff Urton, Humane Canada (British Columbia Society for Prevention of Cruelty to Animals)
- Dr. Jorge Correa, Canadian Meat Council
- Andrew Telfer, Retail Council of Canada
- Dr. Yolande Seddon, NSERC Industrial Research Chair in Swine Welfare, University of Saskatchewan
- David Trus, Agriculture and Agri-Food Canada
- Dr. Julie Nolin, Ministry of Agriculture, Fisheries and Food, Quebec

3 CODE AWARENESS AND IMPLEMENTATION

Is there an Animal Care Assessment Program in place based upon this code?

Yes, an animal care assessment program is in place based upon the code.

When was the program based upon this code implemented?

In 2005 the Canadian Pork Council became the first producer association to release an Animal Care Assessment (ACA) program. The standards described in that program reflected the recommendations in the 1993 *Recommended Code of Practice for the Care and Handling of Farm Animals — Pigs*, and the *Addendum Early Weaned Pigs and Transportation (2003)*.

Since January 2012, the ACA program has been a mandatory component of the Canadian Pork Council's Canadian Quality Assurance (CQA) program. Between 2014 and 2018, the ACA program was updated to reflect the current code of practice and renamed PigCARE.

In January 2017, two code of practice requirements relative to post procedure pain control (castrating and tail docking) were added to the ACA program.

The validation of the implementation of the remaining 102 code requirements listed in 2014 code began in January 2019 with the roll out of the Council's new on-farm programs: PigSAFE | PigCARE. As each producer must recertify every three years, by January 2022 approximately 6,000 farms will be registered on the new program.

Canadian pork producers that market pigs to a federally inspected processing plant are required to be registered on the on-farm programs. As federally inspected plants process 97% of market pigs produced in Canada, there is strong market incentive to register for PigSAFE| PigCARE.

The remaining 3% of Canadian pork is produced by small scale producers who may be less familiar with the code requirements. Based on data from the sector's national traceability program, there are about 7,000 of these smaller producers. They are not typically members of provincial pork producer organizations and often have limited knowledge of or access to information related to the care of their animals.

Recommendation 1

The CTP recommends that consideration be given by the Canadian Pork Council to work with its provincial members, provincial governments, veterinarians and humane societies to enhance the awareness of small, backyard operations about the Code of Practice for the Care and Handling of Pigs and its requirements.

Is the program based upon NFACC's Animal Care Assessment Framework (ACAF) and recognized by NFACC?

No, while the development of the PigCARE program followed the ACAF principles, the PigCARE program was not submitted to NFACC for official ACAF process recognition.

In developing the PigCARE program, the Canadian Pork Council completed a thorough review to ensure it reflected the code of practice requirements. The committee in charge of developing PigCARE included:

- an animal welfare scientist (Dr. Jennifer Brown) and an animal welfare specialist/assessor (Penny Lawlis), who was also a member of the 2014 code of practice development committee;
- staff from the Canadian Pork Council and provincial pork organizations responsible for program implementation;
- a swine veterinary practitioner; and
- a pork producer.

The NFACC Animal Care Assessment Framework specifies that in addition to the above, a representative from the Canadian Meat Council and a retail or foodservice representative should have been involved. Representatives from these groups were not included.

The principles of the ACAF were followed:

- the program is based on the code of practice and all code requirements applicable to the relevant stage of production;
- the program utilizes all three types of assessment measures (i.e., animal-based; resource-based; and management-based);
- the assessment measures are practical, and provide the producer with information on how the measures are linked to improved welfare, better productivity or other benefits
- critical points have been identified; and
- clear sampling procedures are established.

4 VALUE AND RELEVANCE OF THE CODE

Overall, is the code seen as valuable and relevant?

To farmers:

Yes, most producers agree that the code of practice is valuable. The code encourages a positive outcome by identifying good production practices and promoting changes. It also provides a reference point for questions from Canadian's regarding animal husbandry practices used in Canada.

To the domestic marketplace (including retailers, food service, and processors):

Yes, processors recognize the value of the codes and its relevance in Canada. Animal welfare standards are crucial for the domestic market. Federally inspected plants source pigs from farms that are registered under the PigSAFE|PigCARE. These on-farm programs complement the Government of Canada's humane transport and slaughter regulations.

Retailers have identified that the code is useful in informing consumers. However, they believe it could be leveraged to respond to consumer questions through the provision of additional support from the industry to explain how the code functions.

To the international marketplace:

No, Canada is an export dependant country with the United States of America, Japan and China as its three largest export markets. Buyers in these markets have not shown any significant interest in Canada's animal welfare standards. Food safety, price and reliable supply are the more important concerns. However, a limited number of consumers in markets such as Japan and China, are starting to link animal welfare and food safety. Where warranted, the industry is prepared to provide additional information to export markets to explain the codes, on-farm assessment, verification and enforcement.

Even though Canada's main international pork importers do not yet have animal care requirements, PigCARE is included as an important component of the Verified Canadian Pork platform that is used in both domestic and export markets.

To regulators:

Yes, the code establishes standards which are an important tool that encourages improved animal welfare and industry accountability. The code is referenced in the provincial regulations in Saskatchewan, Manitoba, New Brunswick, Prince Edward Island, and Newfoundland and Labrador.

Where it is not referenced, the Code is nevertheless used by provincial inspectors to inform their regulations and it may be used in court to provide guidance and interpretation to the regulator about “accepted” industry practices. It also includes useful information, for understanding and enhancing animal welfare, that is not generally included in regulation. The codes can assist animal care investigators in resolving complaints or animal welfare issues.

The code is recognized by governments as a valuable tool to inform the general public about modern production practices and provides a reference to respond to questions from concerned citizens.

Are there areas of the code that are seen as particularly valuable and relevant?

To farmers:

Yes. The code is viewed as a “package” of animal welfare standards for producers. As such there are no specific practices that have been identified as being more valuable and/or more relevant than others. Nevertheless, some practices, such as post-procedure pain control for castration and tail docking, have led to measurable, positive changes in piglet behavior and performance.

To the domestic marketplace (including retailers, food service, and processors):

No, there are no specific practices that have been identified as being more valuable and/or more relevant than others.

To the international marketplace:

No, there are no specific practices that have been identified as being more valuable and/or more relevant than others.

To regulators:

No, there are no specific practices that have been identified as being more valuable and/or more relevant than others.

Are there areas of the code that are NOT seen as valuable and relevant? This could include oversights/areas that should have been covered but were missed. Note distinction between this question and "challenges" question below.

To farmers:

No, there are no areas of the code that are NOT seen as valuable and relevant

To the domestic marketplace (including retailers, food service, and processors):

No, there are no areas of the code that are NOT seen as valuable and relevant.

To the international marketplace:

Yes. Overall to date, the code's animal care requirements have not been shown to be relevant for the international marketplace. Their overriding priorities are related to food safety.

To regulators:

No, there are no areas of the code that are NOT seen as valuable and relevant.

5 CHALLENGES IDENTIFIED WITH THE CURRENT CODE

5.1 CHALLENGE 1: DEFINING PERIODIC EXERCISE OR WHAT CONSTITUTES A SUITABLE GREATER FREEDOM OF MOVEMENT

The code sections 1.1.2 and 1.1.6 required specific attention from the CTP as it is stated that mated gilts, sows and boars could be housed "*in stalls, if they are provided with the opportunity to turn around or exercise periodically, or other means that allows greater freedom of movement. Suitable options will be clarified by the participating* ***stakeholders by July 1, 2019****, as informed by scientific evidence."*

A review of the scientific literature relating to how providing greater freedom of movement influenced the welfare of stall-housed pigs was completed. Additionally, the CTP reviewed the preliminary research results of recent studies at the Prairie Swine Centre, which evaluated the motivation of stall-housed sows for greater freedom of movement. A review of these findings is found in Appendix D - literature review.

Providing a greater freedom of movement could be achieved in existing stall-barns through walking individual sows around the barn, removing animals from stalls to a temporary pen, or converting stalls to enable animals to turnaround.

The scientific evidence suggests that sows show a level of motivation to exit their stalls and when presented with a choice will exit daily. Providing regular exercise (walking sows in laps around the barn several times per week) confers health benefits to stall-housed sows. However, considering the average sow herd size (325 sows and breeding gilts), it may not be practical for producers to remove sows from stalls and walk them daily or even several times per week.

Sows are individuals and there was evidence that not all sows are willing to be given exercise on a regular basis with a portion refusing to walk. Depending on the quality of the flooring in existing facilities, there was also evidence that an exercise regime could increase injuries to sows. It is unknown whether providing a greater freedom of movement to sows at a much lower frequency (i.e. once per month) would confer measurable welfare benefits. But even at this lower frequency, it would still require a large amount of labour.

The CTP concluded that neither walking sows around the barn at regular intervals, nor housing animals in stalls that enabled them to turn around, but still resulted in close confinement, were ideal solutions. Neither were equivalent to the freedom of choice, the amount of free movement and social interaction the sows can receive when housed in a group-gestation pen.

Periodically penning several stall-housed sows together to provide freedom of movement, opportunities to explore and increased social interactions, was deemed unacceptable. This approach may risk increased injury to the sows from the aggression that results from mixing unfamiliar animals. To support social recognition and reduce/prevent aggression upon regrouping, the same sows would have to be repeatedly penned together at regular intervals to provide a benefit to sow welfare and support social recognition. This would require a lot of labour, and thus was deemed an unsuitable approach.

Sows are motivated to perform exploratory behaviour and value access to environmental enrichment in their stalls that support expression of this behaviour. Trials assessing the motivation of sows to exit their stalls determined that sows spent the majority of their time when out of the stall in exploratory behavior. The motivation of sows to leave their stall is influenced by the provision of a high fibre feed in addition to the sow's standard gestation ration. On this basis, providing stall-housed sows with environmental enrichment that can support the expression of species-specific exploratory behaviour, and/or can improve satiety, could offer a more viable approach to supporting improved welfare for stall-housed sows.

Due to the potential for aggression between entire males, boars cannot be housed in a group. However, boars will receive exercise and social contact from sows several times per week as part of their routine heat detection of sows.

5.2 CHALLENGE 2: TRANSITIONING TO GROUP HOUSING

Producers remain committed to transitioning to group housing but the conversion to group housing is not a simple one. It requires a significant amount of financing, the implementation of a new production system and, potentially, of new breeding stock[1]. Given the complexity of the conversion process, not all producers will be able to convert prior to the 2024 deadline that was established as part of the development of the 2014 code of practice.

During the code development process that led to the 2024 conversion date, the physical complexities of adapting various barn designs was severely underestimated. Moreover, the importance of the quality of the space offered to animals might have been underestimated and the quantity of space overestimated. To date, there are still a lot of unknowns about the optimum way to convert to group housing. Every situation is unique (ex.: barn design, choice of feeding systems, etc.)

[1] Using breeding stock with behavioural traits conducive to reduced aggression, and improved sociability can improve the welfare of group-housed sows, reducing the level of aggression, risk of injury and negative impacts from chronic social stress.

Although committed to transitioning to group housing, producers previously considered that periodic exercise may be a viable option to turn to if they were unable to convert by 2024. However, the challenges identified at section 5.1 have had a direct impact on transition planning and resulted in a conclusion that periodic exercise would neither be adequately useful nor feasible.

Per sow conversion costs depend very much on individual circumstances and much of the variation relates to how much concrete work needs to be done during retrofit. Costs of $500 per sow are typical. A new farrow-to-wean facility, with electronic sow feeding, would cost in excess of $3,500 per sow space.

The difficulty in obtaining financing required to transition to group housing also poses a barrier to meeting the current requirements. In addition to higher costs, there are also a series of revenue related factors that make it difficult to secure bank financing, given the current economic climate in the industry:

- There are no price premiums for market hogs from sows housed in groups.
- For at least the first year of operation sow productivity levels may decrease as barn managers, their teams and the animals adjust to the new production environment.
- The group housed system requires more space. As a result, barns need to be enlarged (often requiring the navigation of a challenging permitting processes) or the number of sows in the barn reduced. A reduction in the number of animal results in a decline in overall farm revenues.
- Producers who built barns shortly before the changes to the code were announced have had insufficient time to repay the loans on their facilities. New barns are typically financed over a minimum twenty-year period. The equipment (e.g. penning, feeders etc.) installed in these facilities is also not ready for replacement and the repurposing of this equipment may not be possible or desirable from an animal welfare standpoint.

There is also a limited availability of experienced construction staff as the dairy and poultry sectors are also in the process of rebuilding barns.

All these challenges are proving to be especially difficult for smaller, independent producers. The failure to account for these issues will have the unintended consequences of:

- Forcing smaller farms out of business; or
- Risking a decline in the welfare of sows, as producers are forced to transition animals into inadequate facilities.

This risk of reduced animal welfare as a result of forced conversions has been accounted for in other codes developed in 2014 (e.g. layer and rabbit code). When a requirement was created that necessitated major physical changes and investment, producers were given 20 years to implement the changes.

The CTP agrees that:

- producers are committed to transitioning to group housing;
- not all producers will be able to transition by 2024;
- progress is being made. The Canadian Pork Council estimates that 60% of sows* will be raised in group housing systems by 2024;
- given the cost and no offsetting increase in revenues, producers cannot afford to transition unless it is part of a scheduled renovation/rebuilding of an existing facility or new construction;
- forcing producers to convert to poorly designed facilities will result in a worsening of the animal's welfare;
- as the code is used as a base for animal welfare enforcement activity in some provinces, it must be practical; and
- the code must remain credible.

Recommendation 2

The CTP recommends that Section 1.1.2 of the code be amended as followed:

As of July 1, 2029, mated gilts and sows must be housed:

• in groups*; or
• in individual pens.

** If housed in groups, individual stalls may be used for up to 28 days after the date of last breeding, and an additional period of up to 7 days is permitted to manage grouping.*

Through science and innovation, the Canadian pork producers are committed to full adoption of group housing designs/systems that offer more freedom of movement for sows.

The industry will continue to investigate feasible housing systems that allow sows greater freedom of movement through all stages, and that reduce the need for stalls during gestation.

The CPC commits to the development and implementation of a national strategy on management skills for handling sows and gilts in group housing by 2023.

Recommendation 3

The CTP recommends that Section 1.1.6 of the code be amended as followed:

As of July 1, 2029, boars must be housed:

• in individual pens with sufficient space to turn around.

The Canadian Pork Council is committed to supporting research to explore functional[2] and effective[3] enrichment options for sows and mated gilts kept in stalls. The results should be considered for the 10-year review of the code of practice planned for 2024.

Recommendation 4

Regarding enrichment

The CTP recommends that during the 2024 full review of the code, implementation of ***functional[2] and effective[3] enrichments*** *that show measurable welfare benefits to sows and gilts, supported by scientific research, be made a requirement for sows that remain in stalls.*

Recommendation 5

Regarding space allowance

The CTP proposes that the code be amended to make the recommended minimum space allowance referenced in Appendix B and outlined in section 1.2.1 of the code a requirement for all systems that convert to group housing after 2024. (Appendix B of the Code of Practice – Recommended Minimum Floor Space Allowances for Gilts and Sows in Group Housing")

These animal welfare research needs were compiled and submitted to NFACC (Appendix C) in 2014.

[2] Practical for producers to implement
[3] Bringing animal welfare benefit to the sow

The Canadian Pork Council contracted Dr. Yolande Seddon, NSERC Industrial Research Chair in Swine Welfare, University of Saskatchewan, to complete a literature review to identify the progress made on research needs. The literature review (Appendix D) was peer reviewed.

The CTP highlighted six research priorities that were identified during the completion of the pig welfare research literature review.

Recommendation 6:

Swine Innovation Porc should consider funding research on the following six research priorities:

1. *Sows, refinement of management*
2. *Environmental enrichment*
3. *Pain and injury management*
4. *Transport*
5. *Genetics for welfare*
6. *Space allowance for nursery pigs*

Recommendation 7

Regarding skills related to animal health and welfare

The CTP recommends that Section 3.4.1 of the code be amended as followed:

Stockpersons must be knowledgeable of normal pig behaviour and signs of illness, injury and disease.

Recommendation 8

Regarding stockmanship skills related to animal welfare

The CTP recommends that Section 4.2 of the code be amended as followed:

Handlers must be competent in low-stress pig handling methods and managing pig housing systems, including group housing where applicable.

6 RESEARCH PRIORITIES AS IDENTIFIED BY THE REVIEW OF RESEARCH PROGRESS

Have other animal welfare research needs been identified since the Code's publication? YES

1. Sows, refinement of management
    a. Reducing /managing aggression at grouping – reducing injury; aggression at entry to the Electronic Sow Feeder (ESF), management of sows on ESF and the interaction with group size.
    b. Space refinement: 1.8 – 2.4m^2: Exploring quality vs quantity, interaction with feeding system.
    c. Reducing duration of confinement in breeding stalls: Identifying feasibility when operating dynamic ESF and competitively fed systems.
2. Environmental enrichment
    a. Species relevant enrichment, that can deliver a biological improvement, in unbedded systems.
        i. Roles for reducing aggression (esp. sows – combined with nutrition); improving immune responsiveness, litter performance.
    b. Point-source enrichment in unbedded systems:
        i. Pig to enrichment ratio, cost-benefit and feasibility.
3. Pain and injury management
    a. Control of tail-docking pain
    b. Cost-effectiveness and practicality of lidocaine with analgesic for castration.
    c. Management of lameness – links to addressing sow housing concerns.
    d. Improved flooring for sow housing – progress has been made in the last SIP round of research, but the question over improved flooring is not fully answered. What work remains to finish this off? Flooring for mixing pens?
4. Transport
    a. Boarding practices to improve compartment temperatures
        i. Mitigate/resolve potbelly design issues
    b. Evaluation of rest-stops vs on-board watering for different classifications of pigs.
5. Genetics for welfare
    a. Largely untapped & evidence suggests there is potential for useful developments.
    b. Some challenges will require genetic input, i.e. reducing sow aggression.
6. Space allowance for nursery pigs
    a. The effects of higher space allowance for nursery pigs to determine the optimal break-point for ADG.

Have other animal welfare research needs been identified since the Code's publication?

Yes, identifying enrichment that can be functional (practical for the farmer to implement) and effective (bringing welfare benefit for the animals), that can be provided to sows and gilts housed in gestation stalls is needed in support of recommendation 4.

The literature review (Appendix D) identified that while there is evidence that sows show a preference for different enrichment materials, and value enrichment provision in their stall, exactly what enrichment(s) should be provided to sows in stalls to produce and sustain measurable welfare benefits, and that the producer can practically implement, is a research need.

7 SUMMARY: CODE TECHNICAL PANEL RECOMMENDATIONS

The Code Technical Panel identified eight recommendations.

7.1 RECOMMENDATION 1

The CTP recommends that consideration be given by the Canadian Pork Council to work with its provincial members, provincial governments, veterinarians and humane societies to enhance the awareness of small, backyard operations about the Code of Practice for the Care and Handling of Pigs and its requirements.

7.2 RECOMMENDATION 2

The CTP recommends that Section 1.1.2 of the code be amended as followed:

As of July 1, 2029, mated gilts and sows must be housed:

• in groups*; or
• in individual pens.
** If housed in groups, individual stalls may be used for up to 28 days after the date of last breeding, and an additional period of up to 7 days is permitted to manage grouping.*

Through science and innovation, the Canadian pork producers are committed to full adoption of group housing designs/systems that offer more freedom of movement for sows.

The industry will continue to investigate feasible housing systems that allow sows greater freedom of movement through all stages, and that reduce the need for stalls during gestation.

The CPC commits to the development and implementation of a national strategy on management skills for handling sows and gilts in group housing by 2023.

7.3 RECOMMENDATION 3

The CTP recommends that in Section 1.1.6 of the code be amended as followed:

As of July 1, 2029, boars must be housed:

• in individual pens with sufficient space to turn around.

7.4 RECOMMENDATION 4

Regarding enrichment

*The CTP recommends that during the 2024 full review of the code, implementation of **functional[1] and effective[2] enrichments** that show measurable welfare benefits to sows and gilts, supported by scientific research, be made a requirement for sows that remain in stalls.*

[1] Practical for producers to implement
[2] Bringing animal welfare benefit to the sow

7.5 RECOMMENDATION 5

Regarding space allowance

The CTP recommends that the code be amended to make the recommended minimum space allowance referenced in Appendix B and outlined in section 1.2.1 of the Code a requirement for all systems that convert to group housing after 2024. (Appendix B of the Code of Practice – Recommended Minimum Floor Space Allowances for Gilts and Sows in Group Housing").

7.6 RECOMMENDATION 6

Swine Innovation Porc should consider funding research on the following six research priorities:

1. *Sows, refinement of management*
2. *Environmental enrichment*
3. *Pain and injury management*
4. *Transport*
5. *Genetics for welfare*
6. *Space allowance for nursery pigs*

7.7 RECOMMENDATION 7

The CTP recommends that Section 3.4.1 of the code be amended as followed:

Stockpersons must be knowledgeable of normal pig behaviour and signs of illness, injury and disease.

7.8 RECOMMENDATION 8

The CTP recommends that Section 4.2 of the code be amended as followed:

Handlers must be competent in low-stress pig handling methods and managing pig housing systems, including group housing where applicable.

8 APPENDIX A - NFACC QUESTIONNAIRE TO GUIDE REVIEW DISCUSSION

FIVE-YEAR REVIEW SUMMARY REPORT FOR THE CODE OF PRACTICE FOR THE CARE AND HANDLING OF PIGS YEAR PUBLISHED: 2014

PROGRESS ON RESEARCH NEEDS IDENTIFIED BY THE CODE DEVELOPMENT PROCESS

GESTATING SOWS IN GROUPS	
• Refine management of sows in groups with an emphasis on the transitions into groups and from groups into farrowing	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Assessing different methods of group housing with respect to social management, productivity, etc.	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**

• Area (space allowance) required for sows in group housing to manage aggression, influence on manuring patterns, etc.	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Grouping sows after breeding (i.e., no stalls for 28-35 days)	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Practical options for converting stall barns to group housing	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
PAIN RELIEF AND SICKNESS MANAGEMENT	
• Refinement and alternatives to painful procedures (e.g., castration, tail-docking)	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:**

	☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Care of sick and compromised animals	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Practical delivery methods for on-farm use of pain medication (e.g., compound with iron)	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Evaluation of pain relief for farrowing, nursing and regrouped sows	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Genetic influences, prevention and detection of lameness	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select**

	Comments: ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
EUTHANASIA	
• Refinement of on-farm methods	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Determining humane endpoints for euthanasia	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Evaluation of existing on-farm methods for mature pigs	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
TRANSPORTATION	
• Truck design to achieve climate control	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select**

	Comments: Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Handling on and off the truck	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Practical alternatives to the use of ramps for loading/unloading pigs in Canada	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
PRACTICAL METHODS FOR ASSESSING ON-FARM WELFARE	
	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**

IMPLICATIONS OF HIGH WELFARE SYSTEMS ON STOCKPERSONS	
• How to improve stockmanship	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Implications of high welfare systems on stockpersons	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
ENRICHMENT	
• Practical applications	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• Enrichment options for sows	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:**

	☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
• The use of enrichment to manage behavioural vices	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
FLOOR SPACE ALLOWANCES FOR WEANED/NURSERY PIGS	
	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
EXERCISE FREQUENCY, STRATEGIES, ETC. FOR SOWS AND BOARS HOUSED IN STALLS	
	Has research been conducted on this issue since the release of the Code? ☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**
EVALUATING THE EFFICACY OF KNOWLEDGE TRANSFER FOR ON-FARM APPLICATION	
	Has research been conducted on this issue since the release of the Code?

	☐ **YES** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does further research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO** What is the primary reason research has not been conducted? **Please select** **Comments:**

Have other animal welfare research needs been identified since the Code's publication?
☐ **YES** What other animal welfare research needs have been identified? **Comments:** Has research been conducted on these new animal welfare research needs? **Please select** **Comments:** Does the research inform any needed changes to the Code? **Please select** **Comments:** Does the research confirm existing Code requirements and/or recommended practices? **Please select** **Comments:** ☐ **NO**

CODE AWARENESS AND IMPLEMENTATION

Is there an Animal Care Assessment Program *in place* based upon *this* Code?
☐ **YES** When was the program based upon this Code implemented? (month year) **Comments (optional):** Is the program based upon NFACC's Animal Care Assessment Framework and recognized by NFACC? Please select **Comments (optional):** ☐ **NO** **Comments (optional):** Are there plans to develop an animal care assessment program based upon this Code? **Please select** **Comments (optional):** Is an animal care assessment program under development based upon this Code? ☐ **YES** Is the program's development following NFACC's Animal Care Assessment Framework? **Please select** When is the program expected to be implemented? (month year) ☐ **NO**

VALUE AND RELEVANCE OF THE CODE

Overall, is the Code seen as valuable and relevant?	To farmers	**Please select** **Comments:**
	To the domestic marketplace (including retailers, food service, and processors)	**Please select** **Comments:**
	To the international marketplace	**Please select** **Comments:**
	To regulators.	**Please select** **Comments:**
Are there areas of the Code that are seen as particularly valuable and relevant?	To farmers	**Please select** **Comments:**
	To the domestic marketplace (including retailers, food service, and processors)	**Please select** **Comments:**
	To the international marketplace	**Please select** **Comments:**
	To regulators	**Please select** **Comments:**
Are there areas of the Code that are <u>NOT</u> seen as valuable and relevant? This could include oversights/areas that should have been covered but were missed. Note distinction between this question and "challenges" question below.	To farmers	☐ **Yes Name area** **Why** **Degree of relevance** ☐ **No**
	To the domestic marketplace (including retailers, food service, and processors)	☐ **Yes Name area** **Why** **Degree of relevance** ☐ **No**
	To the international marketplace	☐ **Yes Name area** **Why** **Degree of relevance** ☐ **No**
	To regulators	☐ **Yes Name area** **Why** **Degree of relevance** ☐ **No**

CHALLENGES IDENTIFIED WITH THE CURRENT CODE?

This question is intended to focus on specifics from within the code (e.g., a particular requirement or recommended practice that is problematic or inconsistencies between different requirements/recommended practices).

Option to include the top five challenges, each with multiple choice option as follows:

Challenge #1	Description: Code reference (section, page number etc.) if applicable: • **Degree of relevance**
Challenge #2	Description: Code reference (section, page number etc.) if applicable: • **Degree of relevance**
Challenge #3	Description: Code reference (section, page number etc.) if applicable: • **Degree of relevance**
Challenge #4	Description: Code reference (section, page number etc.) if applicable: • **Degree of relevance**
Challenge #5	Description: Code reference (section, page number etc.) if applicable: • **Degree of relevance**

PLEASE NOTE IF CONSIDERATIONS, OTHER THAN THOSE ALREADY COVERED, WERE TAKEN INTO ACCOUNT IN FORMULATING THE CODE TECHNICAL PANEL'S RECOMMENDATION FOR THE REVIEW OUTCOME.

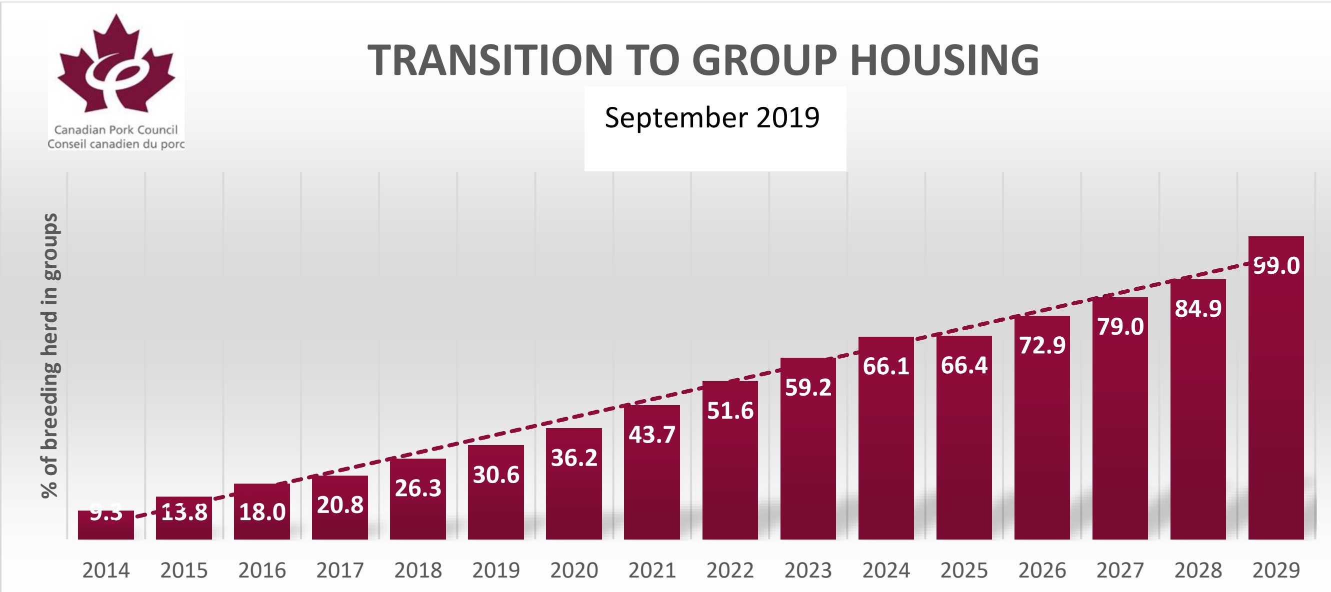
Comments:

The Code Technical Panel's recommendation for this Code of Practice is that: Please select

***Proposed timeline to begin an update (month year)**

9 APPENDIX B – GROUP HOUSING PROJECTIONS

Producers remain committed to transitioning to group housing and the process is underway.



Canada

Year	# of sows[1]	# of sows in group housing[2]	%
2014	**1,157,000**	**108,112**	**9.3**
2015	1,209,600	166,944	13.8
2016	1,220,700	220,276	18.0
2017	1,239,000	257,505	20.8
2018	1,245,368	327,139	26.3
2019	**1,254,068**	**383,991**	**30.6**
2020	1,249,725	451,918	36.2
2021	1,259,075	550,624	43.7
2022	1,265,323	652,677	51.6
2023	1,277,309	755,662	59.2
2024	**1,298,236**	**858,256**	**66.1**
2025	1,295,681	860,558	66.4
2026	1,302,539	949,700	72.9
2027	1,307,040	1,033,160	79.0
2028	1,308,195	1,110,486	84.9
2029	**1,325,320**	**1,311,531**	**99.0**

Source:
1 - **Number of sows –** Statistics Canada. "Sows" includes sows and gilts over six months
2 - **Number of sows in group housing –** Collected from provincial pork organizations. Estimates were based on a combination of producer surveys, local industry knowledge and direct contact with larger operations.

10 APPENDIX C - ANIMAL WELFARE RESEARCH NEEDS FOR PIGS

Following is a list of research priorities gaps identified during the pig code development process. Click here to visit the pig code web page for the Scientific Committee report.

Animal Welfare Research Needs for Pigs compiled in January 2014

1. Gestating sows in groups

Refine management of sows in groups with an emphasis on the transitions into groups and from groups into farrowing
Assessing different methods of group housing with respect to social management, productivity, etc.
Area (space allowance) required for sows in group housing to manage aggression, influence on manuring patterns, etc.
Grouping sows after breeding (i.e., no stalls for 28-35 days)
Practical options for converting stall barns to group housing

2. Pain relief and sickness management

Refinement and alternatives to painful procedures (e.g., castration, tail-docking)
Care of sick and compromised animals
Practical delivery methods for on-farm use of pain medication (e.g., compound with iron)
Evaluation of pain relief for farrowing, nursing and regrouped sows
Genetic influences, prevention and detection of lameness

3. Euthanasia

Refinement of on-farm methods
Determining humane endpoints for euthanasia
Evaluation of existing on-farm methods for mature pigs

4. Transportation

Truck design to achieve climate control
Handling on and off the truck
Practical alternatives to the use of ramps for loading/unloading pigs in Canada

5. Practical methods for assessing on-farm welfare

6. Implications of high welfare systems on stockpersons

How to improve stockmanship
Implications of high welfare systems on stockpersons

7. Enrichment

Practical applications
Enrichment options for sows
The use of enrichment to manage behavioural vices

8. Floor space allowances for weaned/nursery pigs

9. Exercise frequency, strategies, etc. for sows and boars housed in stalls*

10. Evaluating the efficacy of knowledge transfer for on-farm application

* Required by the time that the code of practice is reviewed; exercise statements in code of practice states that "suitable options will be clarified by the participating stakeholders by July 1, 2019, as informed by scientific evidence". Section 1.1.2 (Housing Systems: Gestating Gilts and Sows) and Section 1.1.6 (Housing Systems: Boars).

11 APPENDIX D - LITERATURE REVIEW

Progress made towards the Animal Welfare Research Priorities for Pigs: A review of research 2012 – 2019 for the Pig Code Technical Committee

M.K. Pedersen-MacNab, M. Tokareva, DVM and Y.M. Seddon, PhD

Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon

June 2019

Report reviewed by:

Jennifer Brown, PhD, Prairie Swine Centre, Saskatoon, SK

Nicolas Devillers, PhD, Agriculture and Agri-Food Canada, Sherbrooke, QC

Contents

Purpose

The purpose of this review is to identify the progress made on the research priority areas proposed by the Code of Practice Scientific committee, 2012. Per priority area, a summary of the main conclusions, knowledge gaps and overview of the works identified are given.

This review is not exhaustive, and the focus is kept to research published or performed since 2012, with reference to older works as appropriate. In addition to literature published in peer reviewed scientific publications, final project reports that have not been published are referenced in order to provide the Code Technical Committee with an understanding of the range of work completed or ongoing.

Per research item, the methodology has been described for readers to understand the context of the results where needed, and conclusions per article are summarized in bold italics. Main conclusions are given at the start of each section, followed by the main research gaps.

1.0 Gestating sows in groups

1.1.1 Conclusions

Refining sow management around transitions into groups:

1. **How the timing of grouping affects sow welfare and productivity varies across studies indicating that other management factors influence these outcomes. Breaking down the variables, it can be concluded: In smaller groups (14 – 25 animals) of non-competitively fed sows (free-access stall and ESF), performance and measures of welfare are comparable when sows are grouped at weaning, post-insemination, or upon confirmation of pregnancy (i.e. 28-35 days). In larger groups (58 – 85 animals) of non-competitively fed (ESF, canteen system) sows, performance can be comparable, or improved when grouped at day 35. Measures of sow welfare suggest the stress of mixing and risk for injury may be comparable across available mixing times, or lower at day 35.**
2. **Competitively fed and ESF fed sows may be at risk of lower conception rates and smaller litter sizes (from embryo loss) if grouped post-insemination, (vs day 35 post breeding), and competition at feeding or for entry to the ESF is not at manageable levels.**

Different methods of group housing with respect to social management and productivity:

3. **Pre-mixing sows to allow sub-group formation before introduction to a weekly mixed dynamic gestation group does not significantly reduce aggression or improve sow welfare. However, pre-mixing of sows in a larger pen area for several days before moving to groups benefits low ranking sows, reducing injury.**
4. **Feeding regime (high fibre/a higher feeding level/nutrient alteration) influences aggressive behaviour at mixing, and dietary fibre levels interact with space allowance to influence sow behaviour and productivity. Further work should be performed to understand how feeding management around mixing can be used to reduce aggression.**
5. **Comparable productivity can be achieved in competitively-fed sows when penned in small and large groups (range of 10 – 80 sows/group). However, smaller group size (10 sows) results in fewer injuries and lower stress over the course of gestation.**
6. **The first three days after mixing is the critical period in which sow injury takes place, and controlling aggression at this time is important.**
7. **Grouping sows by parity reduces injuries and improves the reproductive performance of lower parity sows (parity 1) in groups.**
8. **Comparing static vs dynamic mixing: Dynamic grouping results in a greater number of injuries to sows, even when the addition of sows to the gestation group is staggered at five week intervals.**

9. **If weekly mixing into dynamic groups results in reduced performance, adding sows at five week intervals may support comparable reproductive performance to static groups.**
10. **Forming social groups based on the aggressiveness of sows as predicted by a standardized test, did not influence aggression at group formation.**
11. **Genetic selection for lower aggression in sows presents an opportunity to be explored.**

Space allowance and aggression:

12. **Space allowance influences productivity and aggression at feeding in competitively fed sows grouped post-insemination, static groups; lower space allowances (range 1.4m^2 – 3.m^2/sow) result in more aggression at feeding and lower farrowing rates.**
13. **In non-competitively fed, static group-housed sows, space allowance has minimal effect on productivity.**
14. **Low ranking sows experience increased aggression and injury at smaller space allowances.**
15. **Sows will adjust their behaviour to cope with reduced space, reducing total activity and social interactions. Given that a benefit of group-housing is increased movement of the sow, this may not be beneficial and reduced activity is a concern. The long term effects of reduced space on sow welfare and productivity have not been explored.**
16. **Data from commercial sow herds operating a range of feeding systems and genetics, found a decrease in lameness three days following mixing when sows were given a larger space allowance (3m^2/sow) on partially-slatted floors.**
17. **The space allowance that gilts are raised at will influence injury (hoof lesions), and may influence the onset of puberty.**
18. **Providing greater space in the loafing area behind free-access stalls, sows will use it, but use is influenced by social hierarchy. Provide reduced space behind free-access stalls, sows limit their use of the area, potentially to avoid social stressors, reducing the benefit of groups.**

Converting stalls to group housing:

19. **Converting from stalls to competitively fed group-housing under good management principles (i.e. 2.5m^2/sow, adequate feeding spaces) has been documented to increase productivity.**
20. **Lower productivity has been documented when converting stalls to competitively-fed groups against good management principles (lower space 1.5m^2/sow), with group size impacting the degree of production loss.**

Flooring and manure management:

21. **Manure management will influence sow leg health. Bedding results in lower lameness, and dirty pens with high ammonia levels have been related to increased lameness. Slat design can be used to improve sow comfort; initial tests indicate a redesign of slat gap widths to improve sow comfort, need not alter manure patterns, or air quality.**
22. **Gaseous emissions can be lowered in partly slatted pens by providing 15% drainage openings on the solid portion.**

1.1.2 Knowledge gaps

Research is needed in the following areas.

- Refinement of management within feeding systems i.e.:
    - How group size in ESF fed sows influences aggression at the feeder entrance (Bench et al. 2013b).
    - The influence of management strategies on productivity and welfare of ESF fed sows when grouped post-implantation.
- The use of bedded, or matted mixing pens to reduce lameness and injury resulting from aggression at mixing before moving sows to a group.
- Feeding/nutritional management to reduce aggression at grouping.
- The influence of quality of space, vs space allowance on sow aggression, injury and longevity.
- Space allowance studies within specific feeding systems, over multiple parities.
- Continued work to improve sow flooring.
- Genetic selection of sows for different group systems.
- Prenatal effects of group housing (Dr. Brown, Canada – has an SIP funded project that will explore the influence of prenatal stress from dynamic grouping on piglets).

Two comprehensive reviews were conducted to identify how: feeding regime, resource allocation, genetic factors (Bench et al. 2013a), space allowance, group size and composition, and flooring affect sow welfare (Bench et al. 2013b), when group housed with individual feeding. Readers can consult these reviews for further information on knowledge gaps related to group gestation. Encouragingly, a large number of the research gaps identified by Bench et al. (2013a,b) are now starting to be addressed, such as examining the influence of space allowance within specific group management systems, comparing different flooring prototypes, regrouping times, enrichment, feeding strategies, and the effects of different social management practices on sow welfare and productivity. This review shall examine a number of these studies.

1.2 Refine management of sows in groups with an emphasis on the transitions into groups and from groups into farrowing and grouping sows after breeding

Section 1.1.2 of the Code of Practice for the Care and Handling of Pigs (Housing facilities – gestating sows and gilts) requires that "…all holdings newly built or rebuilt or brought into use for the first time after July 1, 2014, mated gilts and sows must be housed in groups. Individual stalls may be used for up to 28 days after the date of last breeding and an additional period of up to 7 days is permitted to manage grouping," (NFACC, 2014, pp.11)

The temporary increase in aggression that arises at mixing poses a risk for distress and injury to the sow, compromising her welfare, longevity and reproductive performance. Whether mixing at different stages of the reproductive cycle can reduce aggression and is more beneficial for reproductive performance has been explored. Three periods have been identified for transitioning sows into groups for gestation: i) at weaning, ii) post-insemination (grouping within 5 days of breeding), iii) upon confirmation of pregnancy (day 35). Because the aggression following mixing lasts only a few days, grouping at these times can avoid aggression during the implantation period, which may cause reductions in conception rate or litter size (Arey and Edwards, 1998).

Mixing time: Knox et al. (2014) studied the effect mixing sows on days 3-7, (D3: pre-implantation); days 13-17, (D14: during implantation); or day 35 post-breeding, (D35: post-implantation), on the reproductive performance and welfare on static grouped, ESF fed, mixed parity sows. Group animals were held at 58/pen, 1.74m^2/sow, on fully slatted floors. Sows (n = 1,436) housed in individual stalls were studied as a control group. Sows grouped at D35 and D14 did not differ in conception rate (92% & 89% respectively), with D3 being lower (87%) than both. Farrowing rate was greater in D35 sows (91%) than D3 sows (83%) with D14 being no different to either (88%). There were no differences in litter performance among the treatments, or in the percentage of sows rebred within 10 days of weaning. Aggressive interactions within 24hr of mixing were 33% fewer in D14 sows, and no different in D3 and D35 sows. Rise in serum cortisol in response to mixing was greatest in D35 sows, than D3, and D14 did not differ.

A greater percentage of sows scored as lame following mixing in D35 sows, however, over the course of gestation, the percentage of lame sows reduced in D35 sows, and increased in D3 sows. Body lesion scores differed in all treatments postmixing, with D3 having the greatest, D35 the lowest, and D14 being intermediate. Body lesions reduced in all groups over gestation, while vulva lesions increased in D3 and D35 groups.

The results of Knox et al. (2014) suggest that when fed via ESF, mixing sows into groups at the start of implantation (D14) or later (D35) may improve reproductive performance, compared to mixing post-insemination. However, there is general consensus to avoid mixing over the implantation period, and the results of Knox et al. (2014) illustrate how variable results can be across studies. With regards to welfare, the results are less clear. The D14 treatment was intermediate for measures, but groups D3 and D35 differed and welfare could be regarded as better or worse depending on the measures considered. Considering the results related to aggression - lower cortisol and lower lameness scores post-mixing, suggest that the severity of aggression was less severe when mixed at D3, compared to D35. However, the lower conception and farrowing rates for D3 suggest an effect of assembling order to feed at the ESF on

performance. Lameness being greater in D3 groups over the course of gestation could be a result of sows being in groups for a longer period of time.

A significant reduction in the frequency of aggression, cortisol and injuries occurred when sows (n=800, 85 sows/pen, 2.3 m^2/sow, deep bedded on rice hulls, individual canteen fed – whole pen moved to individual feeding stalls once per day), were mixed into static groups at 35 days post-insemination, compared to mixing pre-implantation (day 1-7 post-insemination), with no difference in reproductive measures (Stevens et al. 2015).

A comparison of mixing of sows into groups, i) Early: at weaning, ii) Post-insemination: within 7-8 days of weaning, and iii) Late: at confirmation of pregnancy four weeks post-breeding, has been studied by Connor, (2018, unpublished) in three housing systems: ESF fed, part-slatted; ESF-fed straw bedded, and free-access stall, fully slatted. A total of 573 sows were studied over six replicates in the free-access system (14 sows/pen, 2.25m^2/sow), four replicates of 25 sows/pen (2.2m^2/sow) in the part-slatted ESF, and two replicates in the straw-bedded ESF (25 sows/pen, 2.7m^2/sow). Genetics differed between the free-access stall system and the ESF systems. Analysed with sow as the experimental unit, across treatments there were no differences in reproductive performance. The report makes no mention of effect of housing system, and it is not sure if this was explored. Salivary cortisol was increased 24 hrs post-mixing in sows mixed early and post-insemination, with the Late sows not differing from baseline levels. Injury scores were greater in early mixing and mixing post-insemination groups, than late mixed sows. But total number of aggressive interactions (free-access system only) were no different.

The results indicate that under the conditions studied, reproductive performance was comparable across mixing times, but sow injury and stress at mixing was lower when sows were mixed Late, after confirmation of pregnancy. In the study by Connor (2018), sows were individually fed, had larger space allowances, smaller group sizes and reduced feeding pressure, (with fewer sows being fed on one ESF over a 24 hour period), compared to commercial practice. These factors likely contribute to why reproductive performance was comparable across mixing times, in contrast to the results of Knox et al. (2014).

Grouping sows (n = 252, 14/pen, 2.2m^2/sow) at weaning vs 35 days gestation, in a slatted, free-access stall system resulted in no difference in aggression. Sows mixed at weaning had a higher conception rate (98%) than sows mixed at 35 days (87%), and a lower number of stillborn piglets, with no other differences in productivity. No differences in aggression, injury, or cortisol levels were observed, but sows mixed at weaning engaged in more frequent and longer durations of estrus behaviours (Brown, 2015, unpublished). This study also examined whether performance could be improved for sows by pre-socializing them; mixing for two days after weaning, bred in stalls and maintained in stalls until regrouping at 35 days gestation. Pre-socializing sows resulted in a lower incidence of skin lesions (following mixing at weaning) and lameness, but a greater severity of injuries upon remixing at 35 days, with no productivity benefits.

Brown (2015) concluded that welfare outcomes from mixing were similar across treatments. Pre-mixing sows before stalling for breeding and implantation, added labour and held no reproductive or welfare benefit, so is less practical than either early or late mixing. Based on

these results (in small groups and a non-competitive feeding system) both early and late mixing are viable options, but mixing at weaning may improve measures of reproductive performance including conception rate and stillborns.

Pre-mixing: The effect of familiarity (pre-mixing) and method of introducing (singularly, or as a group) sows into a large dynamic, ESF fed gestation group of 130 sows (1.86m^2/sow) has been explored (Pierdon and Parsons, 2018). Flooring type is not given, but conducted in the USA, it is assumed to be at least part slatted. Premixing at weaning, before insemination and introduction into a dynamic gestation group increased the risk of lesions before entering the dynamic group, but lesion number and severity were similar between treatments after day 11 post entry to the dynamic group. No other effects were seen on lameness or lesion prevalence between treatments, and no effect on productivity. However, parity impacted outcomes, with younger sows at a higher risk for lesions (number and severity) and lameness post-mixing into the dynamic group (Pierdon and Parsons, 2018). The risk of lameness in sows also increased from days 15 – 62 in the dynamic groups, compared to at weaning.

The work of Pierdon and Parsons (2018) suggests that pre-mixing sows at weaning does not obviously improve welfare of sows moved into dynamic groups, and may increase the duration of time sows are at risk of sustaining skin-injuries (due to two mixing events). That lameness was increased from days 15 – 62 is a cause for concern and may be due to weekly introductions to the dynamic group at a lower end of recommended space allowance (NFACC, 2014).

Feeding a tryptophan-enriched diet (220% tryptophan concentration above that in the control diet), five days prior to, and for two days after mixing, reduced sow aggression at mixing, increased sow activity, and exploratory behaviour (n = 71) penned in groups of four (3.5m^2/sow), on solid unbedded floors. The tryptophan diet also reduced sham chewing in older sows (parity 5-9) when housed in a stall (premixing) (Poletto et al. 2014). Results suggest ***a short-term tryptophan-enriched diet could be beneficial for group formation, but the scope of this study was limited due to the small group sizes tested.***

No research exploring the transition of sows from group gestation to farrowing was found.

There is overlap in topics between areas. Further research on group management that includes refinement of management and methods to reduce aggression at mixing, are discussed in sections 1.3 and 1.4.

1.3 Assessing different methods of group housing with respect to social management and productivity.

Group size: Group size (n=84 sows at 7 sows/pen, 2.25m^2/sow and n=240 sows at 30 sows/pen, 2.1m^2/sow) did not affect reproduction, injuries or lameness, in sows grouped 28 days post-insemination in part-slatted pens and competitively fed via shoulder-stalls, (modified from gestation stalls), drop fed twice daily (Morgan et al. 2018). To reduce competition, pens of seven sows had eight feeding stalls, and pens of 30 had 32 feeding stalls. In the same facility, sows in groups of 30 had higher salivary cortisol at the time of mixing than sows in groups of 7 or 15, but cortisol was no different between groups at any of the seven additional time points measured over the course of gestation (Morgan et al. 2018). In a study comparing group size and space allowance, Hemsworth et al. (2013) found few interactions between group size and space allowance, proposing it is legitimate to discuss the effects of group size without needing to refer to space allowance effects. Hemsworth et al. (2013) found no effect of group size on cortisol or productivity in floor-fed sows. But sows housed in smaller groups of 10, showed greater weight gain, and had lower neutrophil:lymphocyte ratios (N:L) on day two post-mixing (indicated as positive, considering that stressors can result in increased N:L ratios, Karlen et al. 2007), and lower total skin injuries measured throughout gestation (day 9, 23 and 51) than sows housed in groups of 30 or 80 (Hemsworth et al. 2013). ***The combined evidence from these two studies suggests that when competitively fed, penning sows in small or large group sizes can result in comparable production. However, housing sows in larger groups (30-80) appears to be related to greater stress at mixing and exposes sows to increased injury. The increased injury may arise from aggression, or from contact with pen fittings in avoiding other sows (Karlen et al. 2007). Considering that group-size could influence injury, the longer-term effect of increased injury over multiple parities to influence sow longevity is unknown.***

Genetics and aggression: The interaction between genetics (purebred Pietrain) and housing (Farm A: n = 302, bedded, dry feeder, 2.6m^2/gilt; Farm B (n =241): part-slatted, ESF fed, 3.9m^2/gilt) on aggression in gilts has been explored by Appel et al. (2013). The two nucleus farms group-housed closely genetically linked purebred Pietrain replacement gilts until a similar age (214 ±12.2 days) before moving them into groups of unacquainted animals. Farm A moved 23-34 gilts/group into a single quarantine pen with a solid concrete floor covered in wood shavings at 2.6 m^2/sow, fed *ad libitum* in a single dry feeder. Farm B moved 14-22 gilts/group into 4 pens, where they were kept in partially-slatted pens (3.9 m^2/sow) with enrichment (scratch brush) and an electronic sow feeder (ESF). The aggressive behaviour of gilts was evaluated upon mixing with unfamiliar animals. The average frequency and number of gilts involved in aggressive attacks and reciprocal fights was higher on Farm B. Aggressive behaviour had a low heritability on Farm A and moderate heritability on Farm B, while genetic correlation between attacks and fights on both farms was $r_g = 1.00$, indicating that behaviour was partially controlled by the same genes. ***Genetic selection for lower aggression to improve welfare and management of sows in groups presents an opportunity.***

Fibre and satiety: Two studies have investigated the role of satiety in reducing aggression and improving productivity in group-housed sows. DeDecker et al. (2014) tested the combined effect of diet and space allowance on aggression in floor fed sows grouped at 35 days gestation (10 sows/pen). A balanced mix of first-parity gilts and parity 2-4 sows were tested with a combination of either a control gestation diet, or high-fibre diet (control diet + soybean hulls and wheat middlings) at a floor allowance of either 1.7 or 2.3 m^2/sow (n=40 sows/treatment). Aggression frequency and duration were not affected by treatment, but fiber-fed sows had reduced plasma cortisol and less severe body and vulva lesions, but tended have increased severity of head lesions. Fibre-fed sows, housed at 1.7m^2 had improved reproductive performance (heavier litters, more piglets weaned, fewer mummified fetuses) than fibre-fed sows housed at 2.3m^2. Whereas, at 2.3m^2, control sows had improved reproductive performance (total litter weight, total live litter weight, lower number of mummified fetus's) compared to fibre-fed sows at 2.3 m^2. Lastly, bodyweight gain was higher on day 65 and 90 but lower on day 100 for all fibre-fed sows, while fibre-fed parity 2 and 3 sows at 1.7m^2 were heavier overall than those on control diets and/or kept at 2.3 m^2. This suggests ***an interactive effect of diet and space allowance on sow performance and behaviour. A high-fibre diet and lower space allowance improved the short-term productivity and well-being of sows kept in small groups. That provision of increased fibre in diets can influence productivity (Oelke et al. 2018), and aggression (Sapkota et al. 2016) is known. However, that indicators of aggression were lower at the smallest space allowance may be a product of sows restricting their behaviour in the smaller space allowance, a finding also observed by Mack et al. (2014). The results of DeDecker et al. (2014) are likely the product of these factors combined. The long term implications of lower space allowance on sow welfare (i.e. over multiple parities) is unknown.***

Satiety, or lack thereof, is considered to contribute to aggressive behaviour in sows post-mixing. Greenwood et al. (2019) examined the effect of feeding strategies before and during mixing on aggression and behaviour in floor-fed, group-housed sows. Ninety-six sows, housed individually for 10 days pre-trial, were mixed into small, multi-parity groups at 3-5 days post-insemination (six sows/pen, 2m^2/sow, part-slatted floors). Groups were allocated to one of four dietary treatments: control (2.5 kg/day standard gestation ration), high intake (HI, standard gestation ration increased to 4 kg/day for four days from mixing), or a high-fiber diet (2.5 kg/day, 2.5% lignocellulose) supplement, provided either at weaning until day 15 post-mixing or from mixing, days 0 to 15 of mixing. Sows fed a high fibre diet from mixing fought less frequently but for longer duration than control and sows fed a high fibre diet from weaning, while both high fibre groups sustained significantly more injuries than groups of sows fed a standard gestation ration at high intake. ***The results indicate that increasing fiber in the diet influenced sow aggressive behaviour and injury outcomes in different ways, depending on whether the diet was fed before or after mixing. Muller et al. (2015) also found provision of a higher feeding level, or an edible foraging block influenced aggressive behaviour in group-housed sows. Further research on the physiological impact of dietary fiber on digestion, satiety and aggression is needed to understand how fiber sources or different feeding regimes can enhance welfare and reduce aggression in sows.***

Static and dynamic mixing: Social groupings may be static, where all sows are at the same stage of gestation, or dynamic, with sows at different gestation stages regularly entering and leaving the group (Li and Gonyou, 2013). While dynamic groups provide flexibility for group management and space utilization, the repeated regrouping may negatively impact productivity and welfare of sows. In a study of 10 commercial herds in Belgium (mean group size=70, min: 20; max: 170), Bos et al. (2016) found that sows in static groups (n=132 sows, five herds, 1 x ESF-fed, 1 x free access stall, 3 x vario-mix fed) had lower lameness scores and prevalence of skin lesions than those in dynamic groups (n=138 sows, five herds, all ESF fed) at the end of gestation. Incidence of lameness and skin lesions peaked three days after sows were mixed, regardless of grouping type, but did not differ from day three to the end of gestation, indicating the first three days after regrouping is a critical period for lameness to occur. ***The management type (static vs dynamic) will influence injury level, with fewer injuries in static groups. Regardless on grouping practice, the first three days after regrouping is a critical period for injuries to occur.***

Similar results were found in large dynamic groups by Li and Gonyou (2013) in a study comparing the effect of social management (large dynamic [105-120 sows] vs. smaller static groups [35-40 sows]) and stage of mixing (pre-implantation [2-9 days] vs. post-implantation [35 days]).Sows (n=1569, parity 1-9, including sows over multiple gestations), were group-housed in partially-slatted pens fed by ESF. Dynamic groups with 35-40 sows replaced every five weeks had a higher risk of skin lesions and lameness than static groups of sows. Skin lesions and lameness were lower in sows mixed pre-implantation than in those mixed post-implantation, however farrowing rate was also lower. Reproductive performance was not affected by social management. While the ratio of sows to feeders (35-40 sows/feeder) and space allowance (1.9 to 2.2 m^2/sow) were the same for all treatments, differences in group size may have also played a role in aggression. However, by adding/removing sows every five weeks in the dynamic groups, post-implantation sows only experienced one mixing event in early gestation. ***It can be concluded that dynamic groups (35-40 sows replaced every five weeks) had a higher risk of skin lesions and lameness than static groups. Li and Gonyou (2013) suggest that staggering the mixing of sows into dynamic groups may improve the reproductive performance of dynamic groups, making it similar to that of static groups. A regular occurrence of mixing in dynamic groups may contribute to the observation of Pierdon and Parons (2018) of an increased risk of lameness in sows during gestation in ESF fed dynamic groups, with sows added weekly.***

Grouping by parity: Methods of group-formation to improve social management of sows housed in dynamic or static groups, have been explored, given that younger animals tend to be subordinate and are recipients of more frequent aggression in group housing.

Li et al. (2012) looked at the effect of sorting by parity to reduce aggression towards gilts and first-parity sows in dynamic groups. Sows and gilts (n=180) were assigned to small (15 sows/pen) groups of mixed parity (control, n=90) or treatment (low parity: gilts and parity one sows; n=90) pens in a straw-bedded hoop barn with free-access stalls (3.7m^2/sow). Housing younger animals together had a positive effect, with all animals in treatment pens receiving fewer scratches. While, first-parity sows fought more frequently and for longer durations in treatment pens, they sustained fewer injuries and had lower total injury scores after mixing than first-parity sows in control pens. Body condition and backfat thickness before farrowing was greater in the treatment pens and first-parity sows gained more weight and were heavier at their subsequent farrowing. The farrowing rate of parity one sows was also increased in the treatment pens compared to parity one sows in control pens (94% vs 67%, respectively). The results of Li et al. (2012) confirm that first-parity sows are dominant over gilts but subordinate to older sows. Despite increased aggression towards gilts, all pigs in parity grouped pens sustained fewer injuries, and sorting by age protected parity one sows from severe injuries. ***Grouping sows by parity results in fewer injuries for younger parity sows, and can improve reproductive performance in groups.***

Predicting aggression to improve group management: Methods to predict the behaviour of individual sows, with the goal of using such information to inform on social management, have been explored. Verdon et al. (2017) examined whether a social stimulus test, the 'model-pig test'- in which the latency and duration of contact with a model pig in an adjacent gestation stall is recorded - could predict the behavioural response of pregnant sows (n=200, parity 2) to mixing

(10 sows/group, 1.8m^2/sow). Second gestation sows with a short latency to contact an unfamiliar pig (≤5s) or the model pig (≤3s) in the social stimulus test, were much more likely to deliver high levels of aggression on day two following mixing (Verdon et al. 2017). However, the test did not predict aggressive behaviour in gilts. Forming groups of sows with a higher proportion of animals predicted to be aggressive, as based on the model-pig test response, had no effect on aggression at mixing or feeding (drop-fed, 4 x a day), injuries, cortisol, body condition and performance, when compared to groups of randomly selected sows (Verdon et al. 2018). ***Predicting the aggressive behaviour of sows in a model pig test had no effect on aggression or injuries once grouped.***

The behavioural expression, or body language, of sows when mixed was studied in 10 groups of mixed parity (1-9) sows in static groups fed in free-access stalls (n = 100, 10 sows/pen), (Clarke et al. 2018). Video clips of sows from different parities during the first 90 minutes of mixing were observed by a panel of 16 observers. A generalized procrustes analysis (GPA) score was assigned for each sow, representing a consensus profile of behavioural scoring responses. The behavioural response of sows differed by parity. Young sows (parity 2) scored as calm/tired, and curious/inquisitive. While older sows (parity 6) scored as calm/tired, and anxious/frustrated. Parity 4 sows scored as active/energetic, and anxious/frustrated. Correlations between qualitative behaviour expression and activity indicated that calm/tired sows spent more time standing, while active/energetic sows spent more time performing avoidance behaviours. ***Clarke et al. (2018) attributed the differences in behaviour to differing affective states and coping styles in response to mixing, which were influenced by sow parity. Clark et al. (2018) suggest future research on the use of qualitative behaviour assessment to sort groups of sows, and explore the effect of single-parity groupings may be of value.***

1.4 Area (space allowance) required for sows in group housing to manage aggression, and the influence on manuring patterns

Salak-Johnson et al. (2012) compared the effects of stall-housing (5 sows, 1.34m^2/sow) to group-housing with floor feeding at three space allowances (1.4m^2, 2.3m^2 or 3.3m^2 per sow, 5 sows/pen), on sow behaviour and immunity. One-hundred and fifty-two sows were measured during one gestation, and 65 of these sows were measured during a second gestation (total n=217). Between group space treatments, sows given more space (2.3 and 3.3 m$^{2)}$ stood, walked and drank more, but laid less than sows at 1.4 m^2. Aggression was increased with increasing space allowance. More floor-directed oral-nasal-facial behaviour was performed at 2.3 m^2 and more sham-chewing was performed at 1.4 m^2. Natural killer cell cytotoxicity was greater, but lymphocyte proliferation lower in sows penned at 1.4m^2 than at the other space allowances, which the authors interpreted as a potential sign of trying to rebalance the T-helper cells (Th1 and Th2), which were affected by stress. ***Salak-Johnson et al. (2012) concluded that neither floor space tested provided adequate or quality of space, and that the behavioural and physiological responses of sows to their housing system allowed them to adapt without detrimental effects on health, performance or reproduction which is reported in Salak-Johnson et al. (2007).***

The effect of group size (10, 30 or 80 sows/pen) and space allowance (1.4, 1.8, 2.0, 2.2, 2.4, or 3.0 m^2/sow) on the performance and welfare of group-housed sows (n = 3,1280 in 4 x replicates), introduced to pens 1-7 days post-insemination, and floor fed on partially-slatted floors, 4 x a day has been explored by Hemsworth et al. (2013). Increasing floor space resulted in a linear decreases in aggression at feeding (bouts per sows), and plasma cortisol on day two post-mixing. There was no relationship between space and these measurements on day 9 and 51, and no relationship between space and group size on these measures at any day. Space influenced farrowing rate, with a linear increase in farrowing rate from 60 – 75% as floor space increased from 1.4m^2 – 3.0m^2, but did not influence litter characteristics. Backfat gain was greatest in sows housed at 1.4m^2/sow, and sows housed at 1.4m^2 and 3m^2 showed higher neutrophil:lymphocyte (N:L) ratio at day 9 only. Group size and space allowance interacted for skin lesions. However, Hemsworth et al. (2013) note it is difficult to explain the response biologically, and these results could be by chance. ***The findings of Hemsworth et al. (2013) indicate that higher space allowances increased productivity and reduced aggression at feeding, and confirm that the effects of space allowance are most pronounced in the days following mixing. Hemsworth et al. (2013) state that since this study shows few interactions between group size and space, that these factors act independently on static groups. However, whether this relationship holds true for dynamic groups is unknown. Based on these results, Hemsworth et al. (2013) proposed that space of 1.4m^2 is too low, but refinement of investigating the space allowance between the range of 1.8 – 2.4m^2/sow needs to be performed.***

Space allowance (1.93, 2.68, or 3.24 m^2/sow) had little measurable effect on the health, physiology and productivity of sows (n = 189, 7 sows/pen) housed in static groups, in a non-competitive, fully-slatted, free-access stall pens from 35 days gestation (Mack et al. 2014). Sows at 1.93 m^2 spent less time in the group area (more time in stalls) than the other two space allowances. Sows at 3.24 m^2 spent the most time in social groups than those at 1.93m^2, with sows at 2.68m^2 being intermediate. ***That sows adjust their behaviour to cope with the reduced space allowance may indicate avoidance of social stressors, or reduced comfort in smaller pens. The long-term effects of coping with a reduced space on the reproductive performance and welfare have not been studied over multiple parities. To fully understand the effect of reduced space on sow performance and longevity in groups, studies over multiple parities should be performed. The effect of pen design should be incorporated, as it is known that pen features, such as visual barriers can influence sow aggression and behaviour.***

Five space allowances, 1.5, 1.7, 1.9, 2.1 m^2/sow, and 2.1/1.5m^2/sow (1.5m^2/sow, with greater space [2.1m^2/sow] given in the first week of mixing), were examined, to determine the minimum space allowance required for group-housed sows fed via ESF on fully-slatted floors. Space allowances were achieved by changing both pen and group size (total n=928, group sizes of 42, 46 or 51 sows/pen). Space allowance did not affect any measures of reproductive performance or skin lesions (Li et al. 2018). Incidence of lameness was greater two days after mixing in sows provided 2.1/1.5m^2/sow and 2.1m^2/sow, than the other space treatments. But no difference in lameness was observed between treatments when sows were moved to farrowing. ***Li et al. (2018) hypothesized that reducing competition through use of an ESF may have improved welfare, and that lower space allowances are acceptable under similar management in ESF systems.***

In contrast, a study of 810 sows across 15 Belgian sow herds (mean herd size 400, range 144 - 750), found that an increase in space allowance from 1.7 to 3.0 m^2 decreased the risk of developing lameness 3-5 days after mixing, in sows kept in partially-slatted gestation pens, (Pluym et al. 2017). This indicates that, while individual trials may show differing results, ***under commercial conditions, with variability in feeding type, genetics, and potentially flooring quality, an increased space allowance can play an important role in decreasing injury.*** Lameness appeared to be unaffected by contact aggression, as evaluated by skin lesion prevalence.

Considering that the initial mixing period is the time when aggression needs to be managed, and that increased floor space is related to decreased aggression during mixing (Hemsworth et al., 2013), a short-term increase in space in designated mixing pens may be beneficial. This concept was explored by Greenwood et al. (2016) in a study where sows (parity 1-7) were grouped for four days (6/pen) post-insemination, in floor-fed mixing pens at either 2 m^2/sow (n=48 sows), 4 m^2/sow (n=42 sows) or 6 m^2/sow (n=42 sows). Space allowance did not influence levels of aggression or injury received by sows in days 1- 4, nor from day 5 when pen size was equalized at 2m^2/sow. Production measures also did not differ among treatments. However, providing more space in the mixing pen increased sow activity, exploration and the number of non-aggressive contacts. Cortisol concentration, pooled across days 0-4 was greater at 4 and 6m^2/sow, than 2m^2/sow. Analysis at the individual sow level showed increased injury in low ranking sows at 2m^2/sow compared to 6m^2/sow, and less fighting in groups at 6m^2/sow, than at 2 or 4m^2/sow. ***Positive exploratory and social behaviours increase with increased space, pre-mixing in a larger pen space can benefit low ranking sows within groups, and a reduction in space upon moving to gestation pens does not appear to cause additional stress. Considering the results of Li et al. (2018) that lameness increased when mixing in a larger space, improving flooring conditions in mixing pens may help to reduce lameness.***

Different space allowances (0.77m^2/gilt, 22 gilts/pen vs 1.13 m^2/gilt, 15 gilts/pen) during the rearing of gilts (n = 1,257), did not influence production measures (growth, total pigs produced over three parities, removal rate), (Young et al. 2009). However, gilts raised at 1.13 m^2/gilt reached puberty at a younger age (<185 days); earlier puberty was associated with improved growth rate, increased backfat thickness at first breeding (200 days of age) and number of piglets born and weaned over the first three parities. Early-puberty gilts were more likely to be removed during rearing, while a greater number of later-puberty gilts were removed in parities 2 and 3. ***While space at rearing did not affect productivity or removal rate, rearing gilts with more space may allow gilts to reach puberty at a younger age, with long term benefits for production. Gilts reared at the lower space allowance had more cracks in rear hooves, but did not affect locomotion***.

It should be noted that all reported studies explore the effect of space on aggression at the time of group formation. Methods to reduce aggression at the time of group formation are important. But other factors such as early life socialization and genetics can also influence aggression and have not been fully explored. Early life socialization has been studied in growing pigs, with results suggesting a link between the early social environment and regulation of aggression (Verdon et al. 2017b).

1.5 Practical options for converting stall barns to group housing

The Swine Innovation Porc funded National Sow Housing Conversion Project tracked the progress of six barns through conversions, and collected information on the experience and decision making progress of six barns that had already converted to groups (both conversions and new builds). Documentation on these barns can be found at groupsowhousing.com. This project provides knowledge transfer on how barns were converted, providing details of facility layouts, decisions made, challenges and benefits of a system. This project also captured some of the innovative solutions producers have developed to challenges encountered during barn renovations. Details from groupsowshousing.com indicate that ESF and competitively fed sows are the main group choices, with space allowances ranging from 1.8m^2 – 7m^2/sow. Some of the documented producers are offering enrichment, ranging from wood on chain, old disc chain and a perforated barrel filled with straw. Two producers report problems with purebreds within the group system (legs and ESF use), and one in managing gilt aggression. The barns shared varying levels of productivity data, which overall suggests comparable/acceptable levels of productivity being maintained in groups. Producers reported fewer stillborns, improved locomotion and easier handling when moving to farrowing. Further productivity data on Canadian barns which have converted would be of benefit, including details on when sows are moved to groups (i.e. pre/post implantation). ***The National Sow Housing Conversion project provides valuable firsthand accounts of producer experience when converting to groups. It would be beneficial for the website (groupsowhousing.com) to be maintained for the benefit of producers considering a change to groups.***

Two studies have examined the productivity of sows in group-housing facilities converted from gestation stall barns. Johnston and Li (2013) evaluated the performance and well-being of mixed parity sows (parities 1-8) housed in small (5.5 by 1.7 m, 6 sows/pen, n =156) and large (5.5 by 7.3 m, 26 sows/pen, n = 338, 1.5m^2/sow) part-slatted pens, retrofitted from gestation stalls. The performance was compared to that of sows in stalls (n = 320), over one gestation. All sows were grouped at five weeks post-insemination and drop-fed once daily on a solid-floor section of the pens. Sows in large group pens performed significantly worse than sows in stalls, gaining less weight over gestation than sows in stalls and small group pens. Sows in large group pens had a lower farrowing rate and the highest removal rate, with sows in small group pens being intermediate. ***The small space allowance, combined with the competitive feeding system and multiple parities housed together, is believed to have contributed to the reduced performance of group-housed sows in this study (Li and Johnson et al. 2013). Although Hemsworth et al. (2013) suggested that group size can be considered independently of space allowance the results of Li and Johnson (2013) may provide evidence that larger groups of competitively fed sows, when penned at lower space allowances will fare worse.***

Campler et al. (2019) reported on the behaviour and productivity of small static groups of single entry ESF sows, new to groups, over two gestations. Sows were penned in groups of 20 animals, 1.87m^2/sow, in partially slatted pens. Existing stall barn slatted flooring formed a portion of the floor, with the slat gaps being 2.54cm wide. Campler et al. (2019) identified that aggression was greater in the first parity, but lower in the second gestation as sows accustomed to groups. This is reflected in the sow injury level, being 22% in the first gestation, and lower at 16% in the second gestation. A greater amount of aggression was observed around the entrance to the ESF feeder, and acceptable, and consistent productivity levels were observed over the two gestations. ***This study has value in providing data on aggression, injury and productivity levels in sows in small group ESF pens, produced in a converted stall barn. Understanding how aggression and injury levels compare when sows are fed via different ESF feeders would be of value. An observation also identified by Bench et al. (2013a).***

The performance of sows over a period of six years, before (period A, 2 years), during (period B, 2 years) and after (period C, 2 years) of a large commercial farm's transition from confinement stalls to part-slatted, shoulder-stall, drop fed, group-housing (total n=20,238 sow cycles, herd size not given) has been recorded by Morgan et al. (2018). The transition from stalls to groups (periods A – C), improved productivity with an increase in farrowing rate, number of total and born alive piglets, and shortened mean cycle length. For all measures, values for period B were intermediate between periods A and C, however, production in each period was significantly different. This study captures data on the ***productivity of sows over a retrofit, and indicates when managed in accordance to good practice principles, productivity need not reduce, and can improve in the years following the conversion. Sows in this study were provided with 2.5m^2/sow, and competitively fed, but with extra shoulder stall feeding spaces per pen.***

1.5.1 Pen Design & Feeding System

A cross-sectional study of 108 farms in France was performed to investigate whether group-housing system design influenced leg disorders (Cador et al. 2014). Farms managing sows in large groups (ESF fed, dynamic and/or static) were more likely to be associated with leg problems than farms operating small groups, fed competitively with partial-stalls, or walk-in/lock-in. Managing sows in small groups fed via the walk-in/lock-in stall system was the most protective against leg disorders. ***These results stress the importance of improving group management and flooring. Further work to reduce lameness on concrete floors is needed, and to reduce aggression in groups at mixing, and around entrance to the ESF.***

Provision of loafing areas in free-access/walk-in/lock-in stall pen designs have been found to be used by >95% of sows within a group, but greater than 50% of sows spend less than 5% of time outside of the stalls, with an average of 18% of time spent in the loafing area (Rioja-Lang et al. 2013).

Pen design (I vs T pen) influences the total space allowance and use of free-space by sows (n = 200, 25/group, 4 x I, 4 x T) housed in free-access/walk-in/lock-in stalls (Rioja-Lang et al. 2013). The I-pen design consisted of a concrete slatted-floor loafing area of 3.0m x 10.7m between a row of stalls (0.65m x 2.1 m each) on either side; providing a space allowance of 2.7 m^2/sow. T-pens had an additional solid concrete floored section (3.8m x 7.1m) for a space allowance of 3.8 m^2/sow. ***T-pens provided more space, and increased space utilization by sows,*** with sows in T-pens spending significantly more time in the loafing area than sows in I-pens. However, parity also played a role in use of space, with heavier sows and those in middle parities (parities 3 and 4 in T-pens, parities 2, 3 and 4 in I-pens) spending more time in the loafing area (Rioja-Lang et al. 2013).

Increased use of the loafing area in T-pens may be partially explained by the greater space allowance afforded, but also the availability of solid floor area for lying; sows in T-pens spent more time lying on the solid-floor sections than on the slatted floor. While sows in the study of Rioja-Lang et al. (2013) preferred lying on solid flooring, ventilation must be considered when designing a new or converted group barn: adding solid floor sections, and solid wall partitions to create defined lying areas, can decrease air flow and can lead to changes in dunging patterns. A review of additional space and design considerations for free-access stalls with “I”, “T” and “L” pens designs, can be found in Rioja-Lang et al. (2013) and Harmon (2013).

The alleyway behind free-access stalls is recommended to be 2.1-3.0m (7-10ft), (Harmon, 2013). No research has explored whether alleyways wider than 10ft influence sow well-being, but ***narrower alleyways (3ft) may limit sow movement and expression of social behaviour (Pajor, 2011, unpublished). This suggests sows adjusting their behaviour to cope with limiting building designs, and limiting movement and social behaviour is not positive.***

1.5.2 Flooring, Bedding and Manure Management
Flooring is important for sow comfort, risk of injury and longevity, and manure management.

A cross-sectional study of 108 farms in France identified that a concrete slatted floor is a major risk factor for leg disorders, (as compared to a straw bedded floor). Flooring/manure management, influenced lameness, with dirty floors and high ammonia increasing the risk of leg disorders (Cador et al. 2014).

Concrete slats specially designed with a smaller slat/gap width (105 mm slat and 19 mm gap) to reduce injury, and improve sow comfort, did not negatively affect manure coverage, sow cleanliness or room air quality (as measured by ammonia), compared to more standard concrete slats (125 mm slat and 25 mm gap), over two gestations (Connor, 2018, unpublished, SIP funded).

Gaseous emissions (ammonia: NH_3, methane: CH_4, nitrous oxide: N_2O, carbon dioxide: CO_2 and water vapor: H_2O) are significantly lowered (range of 9 – 19%, depending on gas) when 15% drainage openings are added to the solid portion of partially slatted pens of group-housed sows (n = 30 sows, 5 sows/pen, 2.5m^2/sow), (Philippe et al. 2016).

How space allowance per animal (2.5m^2/sow vs 3m^2/sow) impacts greenhouse gas emissions from sows housed in deep-litter bedded pens (5 sows/pen, n= 20 sows/treatment) has been studied by Philippe et al. (2010). The impact of each space allowance is unclear: rooms at 3.0 m^2/sow produced significantly more NH_3 but less N_2O, CH_4, CO_2 and H_2O than at 2.5 m^2/sow. Bedded systems typically provide a more anaerobic environment than manure slurry pits: greenhouse gases (N_2O, CH_4, CO_2) are produced in aerobic environments, and so may be lower in bedded systems. Greater NH_3 emissions at the higher space allowance was thought to result from a larger emitting surface area (Philippe et al. 2010). However, the results from the small group size tested may differ from application in larger groups on commercial farms.

1.6 References

Appel, A. K., B. Voß, B. Tönepöhl, U. K. V. Borstel, and M. Gauly. 2013. Variance components of aggressive behavior in genetically highly connected Pietrain populations kept under two different housing conditions. J. Anim. Sci. **91**:5557–5564.

Arey, D.S. and S.A. Edwards. 1998. Factors influencing aggression between sows after mixing and the consequences for welfare and production. Liv. Prod. Sci. **56**: 61-70.

Bench, C.J., F.C. Rioja-Lang, S.M. Hayne, and H.W. Gonyou. 2013a. Group gestation housing with individual feeding – I: How feeding regime, resource allocation, and genetic factors affect sow welfare. Liv. Sci. **152**:208-217.

Bench, C.J., F.C. Rioja-Lang, S.M. Hayne, and H.W. Gonyou. 2013b. Group gestation sow housing with individual feeding – II: How space allowance, group size and composition, and flooring affect sow welfare. Liv. Sci. **152**:218-227.

Bos, E.-J., D. Maes, M.M.J.V. Riet, S. Millet, B. Ampe, G.P.J. Janssens, and F.A.M. Tuyttens. 2016. Locomotion Disorders and Skin and Claw Lesions in Gestating Sows Housed in Dynamic versus Static Groups. Plos One 11.

Brown, J. 2015. Weaning sows directly into group housing: Effects on aggression, physiology and productivity. NPB Final Research Grant Report.

Cador, C., F.P.M. Hamoniaux, V. Dorenlor, E. Eveno, C. Guyomarc, and N. Rose. 2014. Risk factors associated with leg disorders of gestating sows in different group-housing systems: A cross-sectional study in 108 farrow-to-finish farms in France. Prev. Vet. Med. **116**:102–110.

Campler, M., M. Pairis-Garcia, J. Kieffer, and S. Moeller. 2019. Sow behavior and productivity in a small stable group-housing system. J. Swine Health. Prod. **27**(2):76-86.

Connor, L. 2018. Optimizing Flooring and Social Management of Group Housed Gestating Sows (# 1231). Annual performance report to Canadian Swine Research and Development Cluster.

Clarke, T., J.R. Pluske, D.W. Miller, T. Collins, and P.A. Fleming. 2018. Parity Influences the Demeanor of Sows in Group Housing. J. Appl. Anim. Welf. Sci. **21**:17–26.

Dedecker, A.E., A.R. Hanson, P.M. Walker, and J.L. Salak-Johnson. 2014. Space allowance and high fiber diet impact performance and behavior of group-kept gestating sows. J. Anim. Sci. **92**:1666–1674.

Greenwood, E.C., K.J. Plush, W.H.E.J. Van Wettere, and P.E. Hughes. 2016. Group and individual sow behavior is altered in early gestation by space allowance in the days immediately following grouping. J. Anim. Sci. **94**:385–393.

Greenwood, E., C. Dickson, and W.V. Wettere. 2019. Feeding Strategies Before and at Mixing: The Effect on Sow Aggression and Behavior. Animals **9**:23.

Harmon J. 2013. Group housing systems: New and conversion construction. National Pork Board, Des Moines, IA, USA.

Hemsworth, P.H., M. Rice, J. Nash, K. Giri, K.L. Butler, A.J. Tilbrook, and R. S. Morrison. 2013. Effects of group size and floor space allowance on grouped sows: Aggression, stress, skin injuries, and reproductive performance1. J. Anim. Sci. **91**:4953–4964.

Johnston, L. J., and Y.Z. Li. 2013. Performance and well-being of sows housed in pens retrofitted from gestation stalls. J. Anim. Sci. **91**:5937–5945.

Karlen, G.A.M., P.H. Hemsworth, H.W. Gonyou, E. Fabrega, A.D. Strom, and J. Smits. 2007. The welfare of gestating sows in conventional stalls and large groups on deep litter. Appl. Ani. Behav. Sci. **105**: 87-101.

Knox, R., J. Salak-Johnson, M. Hopgood, L. Greiner, and J. Connor. 2014. Effect of day of mixing gestating sows on measures of reproductive performance and animal welfare. J. Anim. Sci. **92**:1698–1707.

Li, Y. Z., L.H. Wang, & L.J. Johnston. 2012. Sorting by parity to reduce aggression toward first-parity sows in group-gestation housing systems. J. Anim. Sci. **90**:4514–4522.

Li, Y. Z., and H. W. Gonyou. 2013. Comparison of management options for sows kept in pens with electronic feeding stations. Can. J. Anim. Sci. **93**:445–452.

Li, Y. Z., S. Q. Cui, X.J. Yang, L.J. Johnston, and S.K. Baidoo. 2018. Minimal floor space allowance for gestating sows kept in pens with electronic sow feeders on fully slatted floors. J. Anim. Sci. **96:**4195–4208.

Mack, L.A., D.C. Lay, S.D. Eicher, A.K. Johnson, B.T. Richert, and E.A. Pajor. 2014. Group space allowance has little effect on sow health, productivity, or welfare in a free-access stall system. J. Anim. Sci. **92:**2554–2567.

Morgan, L., E. Klement, S. Novak, E. Eliahoo, A. Younis, G. A. Sutton, W. Abu-Ahmad, and T. Raz. 2018. Effects of group housing on reproductive performance, lameness, injuries and saliva cortisol in gestating sows. Prev. Vet. Med. **160**:10–17.

Muller, T., M.J. Callaghan, R.J.E. Hewitt, and R.J. van Barneveld, 2015. Use of a nutritional lick block and higher feeding levels to reduce aggression and provide enrichment for sows in groups. Ani. Prod. Sci. **55** (12): 1498-1498.

National Farm Animal Care Council (NFACC). 2014. Code of Practice for the Care and Handling of Pigs. A Canadian Pork Council, NFACC publication. Available at: https://www.nfacc.ca/pdfs/codes/pig_code_of_practice.pdf. [Date Accessed: April 13, 2019].

Oelke, A., A. Machado Leal Ribeiro, M. Noro, M.L. Bernardi, C. Casagrande Denardin, P. Raymundo Nunes, F. Cézar Veit and J.C. Winckler. 2018. Effect of different levels of total dietary fiber on the performance of sows in gestation and lactation. R. Bras. Zootec. 47: e20170299.

Pajor E. 2011. Effect of alleyway width on sow behavior and welfare in a free access gestation stall. Pork Checkoff Project 07-083. 2011. [Abstr.].

Philippe, F.X., B. Canart1, M. Laitat, J. Wavreille, N. Bartiaux-Thill, B. Nicks and J. F. Cabaraux. 2010. Effects of available surface on gaseous emissions from group-housed gestating sows kept on deep litter. Anim. **4:10**, 1716-1724.

Philippe, F.X., M. Laitat, J. Wavreille, B. Nicks, and J.F. Cabaraux. 2016. Floor slat openings impact ammonia and greenhouse gas emissions associated with group-housed gestating sows. Anim. **10**:2027–2033.

Pierdon, M. K., and T.D. Parsons. 2018. Effect of familiarity and mixing method on gestating sow welfare and productivity in large dynamic groups. J. Anim. Sci. **96**:5024–5034.

Pluym, L.M., D. Maes, S.V. Weyenberg, and A.V. Nuffel. 2017. Risk factors for development of lameness in gestating sows within the first days after moving to group housing. Vet. J. **220**:28–33.

Poletto, R., F. C. Kretzer, and M. J. Hötzel. 2014. Minimizing aggression during mixing of gestating sows with supplementation of a tryptophan-enriched diet. Physiol. Behav. **132**:36–43.

Rioja-Lang, F. C., S.M. Hayne, and H.W. Gonyou. 2013. The effect of pen design on free space utilization of sows group housed in gestation pens equipped with free access stalls. Appl. Anim. Behav. Sci. **148**:93–98.

Salak-Johnson, J. L., S. R. Niekamp, S. L. Rodriguez-Zas, M. Ellis, and S. E. Curtis. 2007. Space allowance for dry, pregnant sows in pens: Body condition, skin lesions, and performance. J. Anim. Sci. **85**:1758–1769

Salak-Johnson, J. L., A.E. Dedecker, M.J. Horsman, and S.L. Rodriguez-Zas. 2012. Space allowance for gestating sows in pens: Behavior and immunity1. J. Anim. Sci. **90**:3232–3242.

Sapkota, A., J. N. Marchant-Forde, B. T. Richert, and D. C. Lay Jr. 2016. Including dietary fiber and resistant starch to increase satiety and reduce aggression in gestating sows. J. Anim. Sci. **94**: 2117-2127.

Stevens, B., G.M. Karlen, R. Morrisson, H.W. Gonyou, K.L. Butler, K.J. Kerswell, and P.H. Hemsworth. 2015. Effects of stage of gestation at mixing on aggression, injuries and stress in sows. Appl. Anim. Behav. Sci. **165:**40-46.

Verdon, M., R.S. Morrisson, M. Rice, K.L. Butler and P.H. Hemsworth. 2017a. The short-term behavioural response of sows, but not gilts, to a social stimulus is related to sow aggressiveness in groups. Behav. Processes. **140:**216-225.

Verdon, M., R.S. Morrison, and P.H. Hemsworth. 2017b. Reprint of "Rearing piglets in multi-litter group lactation systems: Effects on piglet aggression and injuries post-weaning." Appl. Ani. Behav. Sci. **192**: 35-41.

Verdon, M., R. Morrison, and P. Hemsworth. 2018. Forming groups of aggressive sows based on a predictive test of aggression does not affect overall sow aggression or welfare. Behav. Processes. **150**:17–24.

Young, M.D., M.D. Tokach, F.X. Aherne, S.S. Dritz, R.D. Goodband, j.L. Nelssen, and T.M. Loughin. 2008. Effect of space allowance during rearing and selection criteria, on performance of gilts over three parities, in a commercial swine production system. J. Anim. Sci. **86**(11):3181-3193.

2.0 Pain relief and sickness management

2.1.1 Conclusions

Refinement and alternatives to painful procedures:

1. **Performing multiple painful procedures at one processing increases piglet stress and risk of mortality in low birthweight pigs when procedures are performed on day one, rather than day three. Performing procedures on average birth weight pigs at one day of age may be of benefit, but further research is needed.**
2. **Butorphanol is associated with adverse side effects during castration; NSAIDs such as meloxicam, flunixin meglumin and ketoprofen reduce cortisol in the hours post-castration, but do not control incision-site pain. Evidence suggests that intratesticular administration of lidocaine helps to control procedural pain, but greater evidence on the delivery technique, and areas to which lidocaine is delivered (i.e. base of spermatic cords and testes) is warranted.**
3. **Tail docking decreases but does not eradicate tail biting. Tail docking short (mean length remaining 2.9cm) reduces biting risk over leaving increased tail length. The long and short term pain experienced by pigs from docking, is still inconclusive. A topical anaesthetic cream applied via an occlusion dressing provides improved pain control for docked pigs than intramuscular injected meloxicam or injected lidocaine.**
4. **Tail docking has the greatest effect on reducing tail biting damage, but raising pigs with the provision of straw and at a low stocking density, can support reductions in tail-biting damage that are as effective as tail docking alone.**
5. **The handling stress of the multiple injections required for immunocastration is minimal compared to the pain and distress experienced by pigs due to castration. Under the right management conditions, immunocastration improves feed intake, weight gain and carcass quality of male finisher pigs and is effective at reducing boar taint.**
6. **Ear tagging of piglets is painful as measured by cortisol response, and provision of pain control for this procedure should be considered. A vapocoolant spray is a practical and effective method for reducing pain during ear notching or tagging.**

Practical delivery methods for on-farm use of pain medication:

7. **Mixing iron dextran and the analgesic ketoprofen reduces the number of injections at processing and does not affect the bioavailability of the compound. When mixed separately with iron dextran, there is evidence that both ketoprofen and meloxicam can provide pain relief for post-procedural castration pain. Further work on the bioavailability of meloxicam should be explored, and some work on this may be pending. Research to address food safety concerns of compounding (tissue residues) should be explored.**

Care of sick and compromised animals:

8. **Limited research exists on hospital pen facilities, use and benefits.**

Pain relief for sows:

9. **NSAIDs such as ketoprofen, meloxicam and flunixin meglumine are appropriate for reducing pain during parturition, and for reducing non-infectious lameness in sows. Pain control at farrowing appears to be most beneficial for older sows, and this may be related to older sows having other ailments. Timing of administration, dose and frequency are important and refinement is needed.**

Prevention and detection of lameness:

10. **Objective measurements such as force plates, pressure mats and mechanical or thermal nociception threshold tests are effective at detecting lameness in sows. Pressure mats may be most practical for on-farm use. Automated lameness detection is under development, but current progress and time to commercialization is unknown.**
11. **Flooring is a key factor contributing to lameness in group-housed sows. Use of rubber matting on flooring is beneficial, but durability and longevity of such flooring is unknown. A novel slat gap width and the use of rubberized concrete overlay shows promise to improve flooring for sows, reducing claw lesions. Further testing of this new slat/gap design is warranted.**
12. **Lameness in group-housed sows can be reduced with mineral supplementation (copper, manganese, zinc), and may result in productivity benefits.**

2.1.2 Knowledge gaps

- The use of vapocoolant spray for pain control in other painful procedures, for example tail-docking pain.
- Improved flooring for group-housed sows to reduce lameness, including further exploration of the newly developed slat/gap width and floor with rubberized concrete overlay.
- Hospital pen best management practices, timing of moving pigs to hospital pens for treatment and recovery.
- Diagnosis, detection, and treatment of lame sows – success of strategies and cost benefit, incorporating use of on-farm automated detection to improve outcomes.
- Explore practicality of the approach, and the cost-benefit to the welfare advantage for the use of intratesticular injections of lidocaine for controlling the procedural pain of castration.
- Bioavailability of certain NSAIDs for compounding, i.e. meloxicam. Evaluation of food safety concerns related to compounding for NSAIDs and iron dextran.
- Genetic evaluation and techniques to improve leg and claw health, and reduce lameness in sows.

2.2 Refinement and alternatives to painful procedures

2.2.1 Timing & combining of procedures

Similar stress responses ensue when multiple painful procedures are performed in one processing, regardless of whether the procedures performed are the more stressful, or least stressful version

(Marchant-Forde et al. 2014). This may be due to the length of time procedures take to carry out. Duration of procedures impacts the level of stress experienced by piglets during processing (Marchant-Forde et al. 2009), and therefore multiple procedures delivered during one processing will increase the duration of restraint, and may have an additive effect (Marchant- Forde et al. 2014).

Piglets receiving three procedures in combination (castration, iron injection and ear tagging), had a greater cortisol response, for up to four hours longer than piglets that handled or castrated only (Übel et al. 2015). Administration of an NSAID (meloxicam) pre-procedure reduced cortisol for up to half an hour after castration and for up to four hours in piglets that received three procedures. Mixing meloxicam and iron dextran eliminated one procedure (iron injection), improved local tolerance at the injection site when compared to iron injection alone, and was equally as effective at reducing cortisol for up to four hours post procedure, than meloxicam delivered separately. ***It can be concluded that reducing the number of procedures and the length of time at processing can improve the welfare of piglets. When multiple procedures are performed, provision of meloxicam is beneficial to reduce piglet stress in the hours post processing. The effect when procedures are spread out over multiple days is not known. Mixing iron and meloxicam did not appear to reduce efficacy.***

A greater number of deaths occurred overall and after processing (tail docking and ear notching) in low birth weight (LBW; 0.6-1.0 kg), than average birth weight (ABW ≥1.2kg) piglets (n = 120) and when piglets were processed on day 1 than day 3 (Bovey et al. 2014). The average frequency (Hz) of distress calls was higher for ABW piglets processed on day 3, but the number of high-frequency calls did not differ by birth weight category. LBW piglets spent more time dog-sitting and less time lying after processing than ABW. LBW males also spent less time nursing and lying with the sow than all other piglets. Serum immunoglobulin concentrations (IgA, IgG and IGF-1) were all lower on day 5 for LBW than ABW piglets. The authors concluded that ***processing average birth weight piglets at day 1 may reduce reactivity to the procedure, but that delaying processing for low birth weight piglets may save labour and eliminate unnecessary painful procedures due to the higher mortality rate associated with birth weights less than 1 kg.***

2.2.2 Refinement and alternatives – Castration

A meta-analysis of 52 studies exploring pain-mitigation for painful procedures performed on piglets including castration, tail-docking, ear notching/tagging and teeth clipping has been performed by Dzikamunhenga et al. (2014). The authors reported only studies that measured cortisol, β-endorphins, vocalizations and/or pain-related behaviours, and those that compared the effects of pain mitigation methods within 60 minutes of the procedure (procedural pain) or 1-24 hours after the procedure (post-procedural pain), against controls receiving no pain mitigation. The following conclusions were made:

1. General anesthesia (CO_2/O_2) does not reduce cortisol concentration within 60 minutes of painful procedures.
2. Piglets undergoing castration under general anesthesia have lower mean β-endorphins within 60 minutes of the procedure.

3. Piglets receiving the non-steroidal anti-inflammatory drugs (NSAIDs) meloxicam, flunixin meglumin or ketoprofen have lower procedural and post-procedural cortisol concentrations.

Dzikamunhenga et al. (2014) found measures of vocalization and pain-related behaviour to have insufficient standardization and a potential for bias, and so conclusions were not drawn for these measures. Following the review of Dziamunhenga et al. (2014), O'Connor et al. (2014) assembled a committee panel to provide recommendations for the use of general anesthesia, NSAIDs and local anesthesia (lidocaine) for pain control of piglets 1 to 28 days old undergoing castration. Teeth clipping, ear notching and tail docking were excluded from recommendations due to insufficient study numbers covering those procedures in the meta-analysis by Dzikamunhenga et al. (2014). The committee (O'Connor et al., 2014), composed of 19 voting members, identified seven critically important outcomes related to procedural (within 60 minutes of castration) and post-procedural (1-24 hours after castration) pain. These outcomes were: cortisol, norepinephrine, and b-endorphin concentrations, frequency or pitch (Hz) of vocalizations, energy or loudness (dB) of vocalizations, vocalization rate or risk (the number of vocalizations per piglet per unit time during and after castration, or the percent of piglets that vocalized), and frequency of pain-associated behaviors. Only evidence quantifying these outcomes was reviewed, and the strength of the data was evaluated based on a Grading of Recommendations Assessment, Development and Evaluation (GRADE) process.

The panel (O'Connor et al., 2014) strongly recommended against the use of CO_2/O_2 general anesthesia based on overall very low quality of evidence, weakly recommended for the use of NSAIDs and weakly recommended against the use of lidocaine for pain mitigation during castration.

NSAIDs (e.g. meloxicam, flunixin meglumin, ketoprofen) were weakly recommended to control post-procedural pain for castration because, while NSAIDs are useful to control inflammatory pain, they are unlikely to control pain associated with the incision site. The quality of NSAID study results was voted as "high", with NSAID use associated with a reduction in mean cortisol at 60 minutes and 24 hours after castration. However, likely due to the mechanism of action of the drugs, piglets that received NSAIDs showed an increase in vocalization energy (dB) and pain-related behaviours; other outcomes were not measured, weakening the reliability of the evidence evaluated. The panel also identified FDA regulations on analgesia in food animals in the United States to be a major barrier to recommendations of NSAIDs for castration pain (O'Connor et al. 2014).

O'Connor et al. (2014) weakly recommended against the use of lidocaine to control procedural pain largely because of lack of evidence, as energy or loudness of vocalization (dB) was the only measured outcome voted on by the committee. Two studies on lidocaine for castration were included; their results were graded as moderate, but the quality of evidence was deemed to be very low. ***The panel thus concluded that further evidence on lidocaine is needed for its use to be recommended.***

An intramuscular (IM) injectable anesthesia protocol has been evaluated for suitability in use of on-farm castration of 8-14-day old piglet (Rigamonti et al. 2018). A dosage algorithm was developed to test combinations of IM ketamine, azaperone and romifidine when added to a constant dose of 0.2 mg/kg of butorphanol and 0.4 mg/kg meloxicam. Dosages were adjusted to meet the authors' criteria of a guaranteed calm induction and sufficient quality of anaesthesia without excitations, with a maximum of two hour recovery. If two or more piglets were insufficiently anesthetized, a new dosage combination was used until the criteria was met; if analgesia was deemed insufficient, piglets received a 2% intratesticular injection of lidocaine. A combination of 3 mg/kg azaperone, 0.2 mg/kg romifidine, 15 mg/kg ketamine and 0.2 mg/kg butorphanol met the first two criteria, but recovery lasted longer than 2 hours. ***Refinement of this protocol was recommended by Rigamonti et al. (2018) to investigate appropriate field-suitable anesthesia/analgesia combination protocols that will shorten the recovery period.***

Pain management during castration may be refined through the use of appropriate anesthesia and analgesics drugs: Hug et al. (2018) compared the effect of administering IM butorphanol (0.2 mg/kg) or meloxicam (0.4 mg/kg), or intratesticular lidocaine (4 or 8 mg/kg) to piglets castrated under 1.8% isoflurane anaesthesia at 7-14 days old. Anesthesia quality was assessed through measures of movement during the procedure, heart rate, respiratory rate, blood pressure, end-tidal carbon dioxide, post-operative bleeding, procedure and recovery time, and postoperative behaviour. Hug et al. (2018) found that 10 out of 14 pigs (5 at 0.2 mg/kg and 5 after adjustment to 0.1 mg/kg) that received butorphanol experienced adverse side effects including salivation, cyanosis, dyspnea, vomiting, movement during castration and excitatory behaviour after recovery. None of these side effects were seen with other drugs in the trial. Butorphanol was subsequently removed from the trial; the authors noted that other studies using butorphanol have not reported adverse reactions in pigs, although they have been described in other species (cats, horses, sheep). Meloxicam usage resulted in more frequent defense movements under anesthesia than intratesticular lidocaine; the study found lidocaine to have the most beneficial analgesic effect with no side effects noted at either 4 or 8 mg/kg, but a minimum of 2 minutes delay after lidocaine injection is required for best results. ***Intratesticular lidocaine is beneficial for reducing pain at the point of castration, but will require careful training for drug administration.***

Immunocastration, an alternative to physical castration, involves immunization against gonadotropin-releasing hormone (GnRH) to prevent sexual development in intact male pigs, and reduce or eliminate skatole accumulation in fat tissue, consequently eliminating boar taint (Han et al., 2019). McGlone et al. (2016) found that the pain and/or stress of handling and intramuscular or subcutaneous injection for immunocastration is not sufficient to change behaviour of weaning pigs, while finishing pigs given the injection subcutaneously reduced feeding behaviours post-treatment. ***This is seen as a significant improvement compared to the pain-related behavioural changes associated with physical castration***. Other factors to consider for raising immunocastrated barrows include welfare, behaviour and handling of the pigs, performance, and carcass traits including the presence/absence of boar taint.

In a blinded study, Guay et al. (2013) compared behaviour and handling of physically castrated (PC) and immunologically castrated (IC) market pigs from 9 weeks of age to marketing.

Immunocastrated barrows received one injection of Improvest 7 weeks into the grow-finish period, and a second injection 4-7 weeks after (4-, 6- and 7-week immunizations recorded separately). A total of 96 pens of 21-24 pigs/pen (48 pens/treatment) were tested. Preimmunization, intact males (IC group) spent less time feeding and more time engaged in aggressive interactions than PC barrows; mortality did not differ between treatments at this point, nor did human-pig interactions. Following the second Improvest injection, most behaviour frequencies were similar between treatments, apart from an increased number of approaches towards human observers in IC barrows. At marketing, there were dead-on-arrival and non-ambulatory, non-injured pigs from the PC groups (about 1% of pigs), but none from the IC groups. ***The work of Guay et al. (2013) concludes no major differences in behaviour or handling between PC and IC barrows, and numerically fewer dead and down pigs during transport,*** indicating the potential benefits for use of immunocastration as an alternative to physical castration.

Multiple studies have demonstrated that immunocastrated barrows perform the same as, or better than, physically castrated barrows based on productivity measures and carcass traits (Batorek et al., 2012, Poulsen Nautrup et al., 2018). Batorek et al. (2012) conducted a meta-analysis of 41 papers demonstrating the effect of immunocastration on productivity and boar taint factors, but the authors noted that at the time of writing, data on carcass and meat quality in IC barrows was somewhat limited. The review demonstrated that androstenone and skatole were significantly reduced in IC pigs when compared to intact males (IM), but slightly higher than PC pigs. Growth rate was found to be greatly increased in IC barrows when compared to both PC and IM pigs, with feed conversion ratios much lower than PC and only slightly higher than IM pigs.

A more-recent meta-analysis of the effect of immunocastration on growth performance and carcass characteristics by Poulsen Nautrup et al. (2018) examined 78 articles comparing PC, IC and IM pigs. Most conclusions drawn reflected those found by Batorek et al. (2012). The following conclusions on IC pigs were made by Poulsen Nautrup et al. (2018):

1) Average daily gain is 32.54 g/day higher than PC pigs and 65.04 g/day higher than IM pigs,
2) Feed conversion ratio is lower, -0.234 kg feed/kg gain than PC pigs and +0.075 kg/kg gain higher than IM pigs,
3) Higher live weights than PC or IM pigs,
4) Hot carcass weights lower than PC pigs and higher than IM pigs,
5) Dressing percentage lower than PC and similar to IM pigs,
6) Gain of valuable meat (ham and shoulder) +0.628 kg higher than PC pigs and +1.385 kg higher than IM pigs,
7) Risk of elevated skatole and androstenone levels (leading to boar taint) is similar to PC pigs but significantly lower than IM pigs.

2.2.3 Refinement and alternatives - Tail Docking

Much research has been conducted on the effects of tail docking in piglets, its efficacy in preventing or reducing tail-biting and methods to refine or eliminate the procedure. However, research is still somewhat inconclusive on the duration and intensity of pain experienced from docking, and whether docking is associated with short or long-term changes in pain experienced by pigs (Giminiani et al., 2017). When docking is performed, the method used, and the length of tail removed should be considered.

A great deal of research has been produced as part of the international collaborative project, FareWellDock (2013 - 2016). The objectives of this collaboration can be found here: http://farewelldock.eu/project-objectives/

Understanding the pain associated with, and determining whether pigs experience lasting trauma from tail docking was a central objective of the FareWellDock project. The following work is from this project.

Docking length (short: 2.9 cm, medium: 5.7 cm, long: 7.5 cm, and undocked), influenced the risk of a tail-biting outbreak in 258 litters from four commercial herds. Short docked pens had a lower risk, than undocked and medium length docked pigs (Thodberg et al. 2018). ***Only the short docking length reduced biting risk, however none of the docking treatments completely prevented tail-biting outbreaks (Thodberg et al. 2018).***

The behaviour of 295 piglets docked at 2-4 days of age by hot cautery, with either 0%, 25%, 50% or 75% of their total tail length removed, and the effect of receiving a local anaesthetic injection at the tail base (0.3 mL Lidocaine at 20 mg/mL; n=76), or an IM injection of an NSAID (0.4 mg/kg meloxicam at 20 mg/mL; n=72), both (n=77), or neither (n=70) was examined by Herskin et al. (2016). Docking at any length led to signs of pain, but this was reduced through use of lidocaine. Pre-emptive use of meloxicam did not reduce signs of procedural pain. Behaviour was similar across the different docking lengths but was affected by age, with piglets docked at two days spending more time close to their dam and less time in the creep area than those docked at four days. While previous studies have reported pain behaviour up to 90 minutes after docking, this study observed pain-related behaviours persisting through the 5-hour observation period post-docking. Post-surgical pain behaviours were unaffected by either meloxicam or lidocaine across all tail docking lengths (Herskin et al. 2016). ***In conclusion, more research is needed to develop practical methods of pain relief for docked piglets.***

Kells et al. (2017) further investigated the efficacy of pain mitigation by performing an electroencephalographic (EEG) assessment of acute nociceptive responses to tail docking with cautery iron (CAUT) or with clippers when given no analgesia (CTL), oral meloxicam (MEL) or a topical anaesthetic cream (2.5% lignocaine and 2.5% prilocaine; EMLA) given by occlusion dressing. Ten pigs were assigned to each pain mitigation treatment and to the control group; all procedures were done under halothane anaesthesia (total n=40 piglets aged 20-22 days). EEG recordings were taken during tail docking until 10 minutes after the procedure. Movement during docking occurred in 30% of piglets: two from CAUT, three from CTL, three from EMLA and four from MEL. The authors expected to see an increase in median frequency (F50) and 95% spectral edge frequency (F95) and a decrease in total power (P_{TOT}) in EEG readings associated with noxious stimuli; these responses should be dulled or removed by successful analgesia application. CTL and MEL pigs saw an increase in F50 and decrease in P_{TOT} indicative of nociception; CAUT pigs experienced a reduction in P_{TOT} but no change in F50, and nociceptive responses were eliminated by EMLA treatment. The EEG responses to tail docking methods demonstrate that ***a***

topical anaesthetic cream applied via an occlusion dressing provided significant reduction in nociception during tail docking, while docking with cautery is less noxious than docking with clippers using either no analgesia or oral NSAIDs.

Alternative methods of reducing or preventing tail biting, beyond docking, are being investigated. Larsen et al. (2018) aimed to identify which was the most protective method for reducing tail biting: docking, providing straw, or reducing stocking density. Finisher pigs (n = 1,624, raised from 30 kg to slaughter) were assigned to one level of each of the three treatments: 1) tail docked or undocked, 2) 150 g of straw provided per pig per day or no straw provided, and 3) low or high stocking density (1.21 m^2/pig v. 0.73 m^2/pig). Additionally, all pens were provided with wooden blocks for enrichment in accordance with EU legislation. Tail damage occurred in 55 of the 112 pens over the trial, with more tail biting occurring in undocked pigs (73% of undocked pens v. 28% of docked), in pens with no straw provided (59% of no-straw pens v. 39% with straw) and pens with a higher stocking density (57% of high density v. 41% of low density pens). Docked pigs with straw provision and lower stocking density had the lowest percentage of pens in which tail biting occurred; changing any of the three parameters increased the frequency of tail biting. The protective effect of tail docking was, however, higher than the effect of straw provision, with no significant difference seen from lowered stocking density alone. ***From this study it can be concluded that tail docking has the greatest effect on reducing tail biting, but that straw provision also reduced incidence, and that the combined effect of straw and low stocking density had a similar tail-biting reduction effect to tail docking alone.***

2.2.4 Other painful procedures

Unlike castration and tail docking, research on the physiological effects and refinement of other routine procedures such as teeth clipping, ear notching or tagging is somewhat limited, as are the options for refinement. However, there is evidence that ear tagging causes significant distress and that analgesia should be provided during this procedure (Numberger et al., 2016). In a comparison of ear tagging, castration and tail docking done with or without analgesia (n=210), Numberger et al. (2016) found the mean cortisol response to ear tagging to be similar to that of tail docked pigs (both without analgesia) at all time points studied (30 min, 60 min, 4 hours, 7 hours). However, the total cortisol response (intensity and duration) was higher for ear tagging, than tail docking. Analgesia (meloxicam) significantly reduced the post-procedural cortisol response of all three treatments, although it reduced cortisol only at four hours for castration. ***Castration was confirmed to elicit the greatest intensity and duration of cortisol response, but the physiological effect of ear tagging suggests the need for pain control or alternative methods. Whether ear tagging is better than notching could be re-evaluated.***

2.3 Care of sick and compromised animals

Hospital pens are commonly used to isolate and treat sick and compromised animals (Pierozan et al. 2017). Pigs in these pens may benefit from the removal of social stress and competition for resources while they recover, in a location where stockpersons are better able to observe and treat the animals. Legislation in countries such as Denmark specifies the required design of hospital pens, but on-farm application may differ from recommendations. Pierozan et al. (2017) conducted a descriptive study on the design of hospital pens in 47 commercial farms in Brazil in order to identify their strengths and weaknesses. Forty-six out of 47 farms had at least one infirmary area available with a design reflecting reduced competition for resources, but design components varied greatly. Notable improvements in comfort of hospital pens included solid flooring (89.7% of farms), provision of a small shallow pool (72.2%) or full shallow pool (11.3%), and provision of enrichment (15.5%). In 94% of farms, the criteria for transferring pigs to a hospital pen was 'impaired, hurt, suffering.' ***The hospital pens present were generally considered by Pierozan et al. (2017) to meet requirements, but the standardization of pen design could improve the welfare of sick and compromised pigs. There was no consistent response from surveyed farms on what to do with the pigs once recovered.***

Thomsen et al. (2016) surveyed Danish pig farms to determine trends in attitudes towards the legal requirements for hospital pens. The authors received 508 responses to a questionnaire designed to test the farmers' knowledge of, and attitude towards legislation on the care of compromised pigs. The majority of respondents agreed that the legal requirement for at least one hospital pen made "good sense" (66%) or "partial sense" (27%). Most respondents (90%) reported their herd veterinarian as their primary or only source of information regarding legal requirements for hospital pens; 80% were correct in their understanding of these requirements. Respondents rarely identified lack of time or labour as a barrier to care of sick pigs, despite ***Danish authorities reporting that the majority of non-compliance cases during welfare control visits were related to a lack of appropriate housing and treatment for sick and injured pigs, indicating a failure that should be addressed.*** Lastly, farmers largely agreed with most design elements required in hospital pens apart from a 'possibility of cooling,' which only 17% believed was necessary for the care of sick and compromised pigs.

2.4 Practical delivery methods for on-farm use of pain medication

Novel pain control methods for neonatal piglets include the use of a vapocoolant spray before ear notching and the use of transmammary-delivered meloxicam before and after castration and tail docking.

Lomax et al. (2018) tested a topical vapocoolant spray (VS) to reduce the nociceptive response to ear notching through rapidly cooling the tissue. Piglets ear notched with no anesthetic were more likely (99% probability) to display pain responses (behavioural struggling and vocalizations, scored as present vs absent). Piglets ear notched having received the vapocoolant spray, or a lignocaine injection into the ear, were no different from piglets handled and not ear notched (sham, no painful procedure performed) (Lomax et al. 2018). This study identified that spraying the edge of the ear for 2 seconds, from a distance of 10cm was optimal for application (Lomax et al. 2018). ***Data from Lomax et al. 2018 suggests that vapocoolant spray may be sufficient to reduce or eliminate the acute behavioural response to pain in piglets from ear notching. The method of application is quick and practical to apply on-farm. Further use of cryoanesthesia, such as the vapocoolant spray, should be explored with regards to providing pain control for other procedures such as tail docking, which has also been shown to benefit from a topical pain application (Kells et al. 2017).***

Transmammary-delivery of analgesia has been explored. Piglets nursing from lactating sows fed oral meloxicam at 30mg/kg in their daily feed from days 5-8 post-farrowing, had a mean plasma meloxicam concentration of 569 ± 106 μg/ mL in blood sampled on days 5-8 days post-birth. Following castration and tail-docking, piglets that suckled from meloxicam treated sows displayed lower cortisol response for 10 hours post castration, had lower cranial temperature as measured by infra-red thermography compared to piglets from control sows, and monocytes of treatment piglets showed ex-vivo inhibition of prostaglandin production (PGE_2) for all time points, with the exception of 24 hours after drug administration (Bates et al. 2014). Collectively the results demonstrate a successful transmammary transfer of meloxicam from sows to piglets, and a corresponding analgesia effect in piglets. However, it should be noted: the target meloxicam dose for treating sows is 0.5mg/kg. Therefore, the successful transmammary-delivery of meloxicam from sow to piglets reported by Bates et al. (2014) required a dose 60 x the recommended dose. This dose could severely compromise sow health, such as through gastric ulceration and bleeding. Brown (2013) found, injecting sows with meloxicam at just over double the dose, at 1mg/kg, resulted in only 2.65ng/ml of meloxicam in piglet serum five hours post administration. ***This being 1/200th of the required dose. The efficacy of this dose in piglet serum was not explored by Brown (2013, unpublished). Pharmacokinetic analysis is needed to confirm the dose need to achieve transmammary delivery, at a level sufficient to provide pain control to the suckling litter. Alteration of the drug may be needed to facilitate uptake in the milk when given at lower doses.***

The efficacy of analgesic to provide pain control when mixed with iron, to be administered to piglets in one injection, saving time, limiting piglet handling and reducing the number of injections has been explored. Administering iron dextran mixed with either meloxicam or flunixin meglumine increased blood haemoglobin sufficiently, but the blood concentration of analgesics did not rise to required levels, indicating a drug interaction (Johnson et al. 2014), despite Übel et al (2015) reporting an apparent pain controlling effect when meloxicam was mixed with iron dextran.

The bioavailability of ketoprofen mixed with iron dextran has been explored by O'Sullivan (2018). Results indicated there was no difference in bioavailability of ketoprofen when mixed with iron, compared to when given alone. However, meloxicam had reduced bioavailability when mixed with iron, compared to when given alone, which suggests that pain relief maynot be adequate if meloxicam is given with iron (Reynolds et al. 2017). Behaviour trials evaluating the efficacy of ketoprofen and meloxicam (when mixed individually) with iron dextran suggest that analgesia provided by the compounded formulations were equivalent to that provided by the NSAIDs administered alone. However, an evaluation of potential food safety concerns associated with compounding NSAIDs and iron dextran (i.e. the potential for violative NSAID tissue residues), should now be performed (O' Sullivan, 2018).

2.5 Evaluation of pain relief for farrowing, nursing and regrouped sows

Studies on the use of NSAIDs to control postpartum pain in sows are numerous. Ketoprofen (3mg/kg, IM injection) administered to sows for three days postpartum, with the first dose administered approximately 90 minutes after farrowing, resulted in smaller losses in BCS, an increase in backfat, a shorter duration of constipation, slower shoulder score deterioration and later incidence of feed refusal than control sows (saline placebo), (Viitasaari et al. 2013). Results demonstrate ketoprofen is beneficial for sows in the first weeks post-farrowing, however elevated blood levels of aspartate aminotransferase for all sows and serum amyloid A in parity 2-5 sows on day five postpartum for sows given ketoprofen suggests some local tissue irritation resulted from drug administration. Higher parity sows (parity 6-9) showed a greater improvement; the authors theorized that this was related to subclinical conditions or underlying pain that may have been treated by the ketoprofen.

Conversely, Ison et al. (2018) found no difference in pain behaviour or postpartum markers of inflammation (salivary cortisol, cytokines and C-reactive protein) between sows given one IM injection of 3 mg/kg ketoprofen (n=11 gilts, 16 sows) and controls given saline (n=13 gilts, 16 sows) 90 minutes post-partum. However, Ison et al. (2018) also found a parity effect, with multiparous sows exhibiting more frequent pain behaviour, higher salivary cortisol at farrowing and higher plasma tumor necrosis factor-α than primiparous gilts. Gilts, however, had higher C-reactive protein concentrations overall and greater salivary cortisol three days postpartum. Notably, the two studies differed in variables measured and in frequency of ketoprofen injection (injections over 3 days vs. 1 injection 90 minutes postpartum). ***But both studies suggest a benefit of pain control for older sows. Cost-benefit analysis has not been performed and could be useful.***

Two similar studies looked at the performance of farrowing sows given an IM injection of meloxicam (0.4 mg/kg) compared to controls given saline. Mixed parity sows (n= 24/treatment) given one IM injection of meloxicam (0.4mg/kg), 90 minutes after the end of farrowing spent significantly less time lying on day three postpartum than controls, however, feed intake, rectal temperature and pre-weaning piglet mortality were no different between treatments (Mainau et al. 2012). Mixed-parity sows (n = 289) given meloxicam (IM, 0.4mg/kg) within 12 hours of birth showed a tendency for better growth rates in medium-sized litters (11-13 piglets), than saline treated sows. However no differences were found in behaviour, rectal temperature, feed intake, piglet survival or growth between the treatment and control sows (Tenbergen et al. 2014). ***An IM dose of meloxicam at the timing and dosage tested therefore did not significantly improve sow or piglet performance in either study. Where performance has been seen to improve, (i.e. Viitasaari et al. 2013), analgesic has been given for a number of days.***

Reproductive performance including litter size and piglet survival were not affected in sows (n = 15) given oral meloxicam (0.4mg/kg) at the beginning of farrowing, however, piglet average daily gain and weight at weaning were significantly increased in litters from sows given meloxicam, compared to controls (n = 15, Mainau et al. (2016)). It was hypothesized that administering oral meloxicam at the onset of farrowing may have improved results by providing pain relief prior to onset of inflammation (Mainau et al. 2016). Serum immunoglobulin G (IgG) concentrations were also significantly higher at birth in piglets from meloxicam-treated sows, but did not differ between treatments at day 20. Mainau et al. (2016) concluded that higher IgG intake likely contributed to the improved performance of the treatment group over the controls. ***This study indicates timing of NSAID is important, and provision before farrowing, or lasting for extended time once farrowed may be the best approach for benefits.***

Lameness and injuries are common problems during mixing of group-housed sows, and effective pain mitigation is important for the welfare and productivity of affected sows. The efficiency of oral ketoprofen given at a dose of 2 or 4mg/kg has been evaluated in a randomized, double-blinded, placebo controlled trial, on 141 sows, housed over 10 farms in Finland (Mustonen et al. 2011). Group-housed sows with a lameness score ≥2, (0 – sound, 4 – non-weight bearing, 2 = limb visible, but animal unconcerned and exercises normally), were given either 2 or 4 mg/kg ketoprofen (n=46 and 47, respectively) or an oral placebo (n=48) for five consecutive days. Only sows with non-infected lameness (as identified though blood samples and clinical examination) were included. Lameness scores on day five were significantly reduced by ketoprofen when compared to the placebo, and no difference was seen between treatment dosages. ***The authors concluded that 2mg/kg of oral ketoprofen given for a 5-day period is suitable for pain mitigation of non-infectious lameness in sows. Treatment success was regarded as a lameness score changing to 0, or 1. On this basis, the medication only successfully treated lameness in 54% of sows at 4 mg/kg and 53% of sows at 2 mg/kg, suggesting that further refinement may be needed. No further work to determine if the lameness returned upon cessation of the ketoprofen was explored. The ability of NSAID provision to reduce sow removals has not been explored.***

Pairis-Garcia et al. (2015a, 2015b) used automated biomechanical analysis and behavioural evaluation to test the analgesic efficacy of two NSAIDs (meloxicam and flunixin meglumine) for treating lameness in sows. Pairis-Garcia et al. (2015b) induced lameness via chemical synovitis, three separate times in 24 multiparous sows to test each of the three treatments: 1.0 mg/kg oral meloxicam, 2.2 mg/kg IM flunixin meglumine, or a volume of IM saline equivalent to the volume of flunixin meglumine. Meloxicam-treated sows laid less frequently than saline-treated sows 48-72 hours post-induction; flunixin meglumine treated sows did not differ significantly in lying frequency with saline-treated sows but tended to stand more and lie less 48-72 hours post-induction. Postural changes in sows treated with oral meloxicam were considered consistent with pain reduction (Pairis-Garcia et al. 2015b). Analysis of weight distribution with an embedded force plate mat revealed meloxicam and flunxin meglumine treated sows distributed more weight to their lame leg than saline-treated sows (Pairis-Garcia et al. 2015a). ***The work of Pairis-Garcia et al. (2015a, 2015b) concluded that oral meloxicam and intramuscular flunixin meglumine reduce pain sensitivity in lame sows. NSAIDS are effective at reducing pain sensitivity in sows. However, correct diagnosis of the lameness is needed, and multiple doses would be required. A cost-benefit analysis would be useful.***

2.6 Genetic influences, prevention and detection of lameness

2.6.1 Genetic influences

Lameness and leg injuries are serious concerns in swine production. While lameness may result from injury or adverse environmental conditions, genetic predispositions are also instrumental in the development of leg and claw disorders (Le et al., 2017). Identification of genomic regions that influence conformation and soundness would help to guide precise selection for these low to moderately heritable traits (Le et al. 2017).

A Genomewide Association Study (GWAS) performed on 431 Chinese Sutai and 922 White Duroc x Erhualian (F2 population) finisher pigs found 12 chromosomal regions strongly associated with measured leg weakness traits, including a locus for gait score of front legs reported for the first time (Guo et al. 2013). Prevalence of all leg weakness-associated traits (higher leg and gait scores, heavier and longer biceps brachii muscle), except for gait score of front legs, was significantly higher in the F2 population than in the Sutai population. In both populations, legs of males were weaker than females. ***The researchers recommended validation of the significant regions for other pig breeds, and exploration of marker-assisted selection to improve leg soundness in swine (Guo et al. 2013).***

A GWAS for traits of front leg, back and hind legs, and overall conformation, has been performed on 23,898 Landrace, 24,130 Yorkshire and 16,524 Duroc pigs (all Danish bred, Le et al. 2017). Between breeds, 14 significant quantitative trait loci (QTL) regions were found in Landrace pigs, 12 for Yorkshire and 13 for Duroc; several regions were associated with more than one breed and candidate genes were identified for many of these regions. Thirty-six significant SNP regions were found across all breeds, including confirmation of several QTL regions found in single-breed analysis and identification of novel candidate genes. Genes identified in this study were associated with bone and skeleton development, muscle and fat metabolism and growth processes. Refer to Le et al. (2017) for a complete list of QTL regions associated with confirmation traits.

Investigation of a severe lameness syndrome in piglets on a commercial farm identified a genetic basis for the lameness, with a recessive form of inheritance. Matika et al. (2019) identified a mutation causing a premature stop codon within exon three of the myostatin (MSTN) gene. The condition presented with a high within-litter proportion of piglets affected with severe leg weakness (23% ±0.7 vs overall on-farm prevalence of 6.3%). Homozygosity mapping of 10 affected and 10 unaffected full-sib controls revealed the presumed causative mutation on chromosome 15. Heterozygotes remaining in the herd had dramatically increased muscle depth and decreased fat depth at slaughter. ***Matika et al. (2019) noted that balancing selection allows many harmful alleles to persist in commercial populations due to advantageous traits associated with heterozygosity of that allele.*** This is seen in the mutation identified in this study, as the heterozygous MSTN mutation is associated with improved muscle and reduced fat while the homozygous mutation results in piglet mortality.

2.6.2 Detection of lameness

Four studies have been included that tested automated methods for detecting lameness in swine including accelerometers, force plates and pressure mats, and infrared thermography. The following papers focus on objective lameness diagnosis to detect and treat early lameness for improved welfare and productivity; automated detection may improve reliability over traditional methods like gait scoring.

Conte et al. (2014) tested static and dynamic methods of assessing lameness in 61 sows using a force plate, kinematics and accelerometers. Sows from parities 1-8 were gait-scored between weeks 6-10 of gestation; 24 sows were scored 0 (normal gait, even strides), 20 sows scored 1 (abnormal gait, lameness not easily identified) and 17 sows scored 2 (lameness detected, shortened strides, avoids putting weight on one leg). Kinematic measures of speed, stride length, swing time, stance time, foot height, and carpal and tarsal joints angle average and amplitude were analyzed from a video of each sow walking along a corridor. The force plate only detected differences between lameness scores for weight shifting frequency (higher for fore and hind legs in gait score 2 sows) and the ratio between weights applied by contralateral limbs (decreased with increasing lameness score for hind legs). Only gait scores of 1 were reflected in kinematics, showing lower swing and stance tarsal joint angles and higher amplitude of swing tarsal angle compared to scores of 0 or 2. Lack of differences for sows scored 2 was likely explained by the differences in visual scoring, whereby scores of 2 were largely dictated by lack of weight-baring, which was detected by the force plate. Conte et al. (2014) thus identified that ***force plates are most effective for identifying altered weight-bearing while gait alteration was better detected by kinematic measures; a combination of static and dynamic lameness analysis may be needed for comprehensive automated lameness detection.***

Pressure mats, which detect both objective loading and movement information during pig locomotion, may offer a refined method of detecting lameness (Meijer et al., 2014). Studying the kinetic data of 10 lame (gait scores from 2-4 on a 0-5 scale) and 10 sound weaned piglets identified contralateral forelimb asymmetry-indices for peak vertical force, load rate and vertical impulse were higher for pigs lame on a front leg. Contralateral hind limb asymmetry-indices were also higher for peak vertical force and vertical impulse in front limb lame pigs, explained by increased weight load shifted to a diagonal sound limb. For pigs lame on hind limbs, asymmetry-indices increased for vertical impulse but not peak vertical force; contralateral forelimb asymmetry-indices increased for vertical impulse in these pigs as well. For all pressure mat parameters, correlation with visual lameness scoring was high. Left-right asymmetry-indices diagnosed lame pigs with 100% sensitivity and specificity. ***These results show strong indications for the usefulness of pressure mats in early detection of lameness in pigs.***

The SowSIS (sow stance information system) has been developed by the University of Ghent to detect lameness in sows. Using measures from both a force plate analysis and visual stance analysis from image processing, the system is able to distinguish lame animals, from sound animals (Pluym et al. 2013a). The force plate can be inserted into a feeding stall/ESF feeding chute, so is practical for frequent screening of sows on farm. To date it appears only preliminary work has been done and it is not clear whether the system is available for purchase. For more information see: https://isense.farm/content/sow-stance-information-system-sowsis

The use of a pressure algometer (Wagner Force Ten™ FDX 50 Compact Digital Force Guage, CT, USA) and an analgesia meter (IITC Plantar Analgesia Meter, CA, USA) have been evaluated for use as objective pain assessment tools by Mohling et al. (2014), on sows with chemical induced lameness of the hind limb.

Lame sows had a decreased tolerance to pressure from the algometer, and thermal stimulation by the analgesia meter on all three zones of the lame limb tested from day -1 (before lameness induction) to day +1, (lameness induction). When tested on sound limbs, tolerance of pressure and thermal stimulation increased day-1 to day+1. ***Both tests were therefore successful in detecting greater pain sensitivity thresholds in lame sows. However, the practicality of these tools has not been explored in commercial practice.***

Infrared thermography (IRT – FLIR T300 camera, 2008, FLIR systems, MA, USA), detected differences in temperature in the lame limb of sows gait scored at 1, compared to sows gait scored as 0. A gait score of 2 was also significantly correlated with increased temperatures over sows gait-scored 0 in the upper metatarsi, lower metatarsi, and phalanges. Leg conformation had a significant effect on IRT temperatures: sows with normal or straight hind leg positions had lower IRT temperatures along the lame limb than those with forward-positioned hind legs (Amezuca et al. 2014). Considering the significant correlations between leg temperatures of lame and sound sows, the lack of asymmetry in IRT temperatures between sound and lame limbs was thought to result from lameness in more than one limb rather than inaccurate lameness detection. The researchers concluded that ***IRT could be used to detect moderate lameness, but further refinement is needed. Measures of IRT from lame sows should be combined with other methods of assessment. Additionally, the cameras required are expensive and may not be practical for veterinary or on-farm use presently.***

2.6.3 Lameness Prevention

A review of research literature on the prevention of lameness and claw disorders in group-housed sows identified claw conformation, flooring/bedding type, nutrition and claw management as key areas for prevention of claw disorders and resulting lameness (Plyum et al. 2013b). In brief, the review discusses, claw size asymmetry as heritable and correlated with increased risk of lameness and that genetic selection for more balanced claws could contribute to prevention of claw disorders. Flooring that is slip-resistant, cushioned and clean has a demonstrated effect on reducing lameness; with deep straw bedding reducing the frequency and severity of claw lesions. Claw management, including trimming and foot baths, may be beneficial to reduce toe erosion and manage overgrowth when natural abrasion is prevented by bedding. A diet with appropriate levels of biotin, fatty acids, amino acids (particularly cysteine and methionine), minerals (copper, selenium, manganese, chromium) and vitamins A, D and E may improve sow foot health. However, research on how nutrition influences lameness is inconclusive.

In a field study of 3,240 sows on 108 farms in France, Cador et al. (2014) found concrete slatted floors to be associated with significantly increased incidence of leg disorders (lameness, claw and leg lesions/injury, dewclaw overgrowth) when compared to straw-covered solid flooring. While flooring type was found to be strongly predictive of major leg disorders in the Cador et al. (2014) study, straw bedding was also found to inhibit horn erosion (causing long toes) and to increase the frequency of heel-sole junction lesions; however, neither condition was associated with lameness. Frequency of leg disorders also increased when floors were dirty (poor removal of excrement, greasy floors) and when ammonia levels were high (>10 ppm). ***This indicates that flooring characteristics and cleanliness in the lying and dunging areas of a pen likely influence the development of lameness.***

Work to increase flooring comfort and reduce injury has largely focused on the provision of rubber mats. Sows (n = 164 gilts over 2 x parities, 8 gilts/pen) housed on concrete slatted floors (slat width 130 mm, gap width 20mm) with a rubber mat provided in the free-access stall and group areas (rubber covered slats) had a reduced risk of lameness than sows housed on concrete slats. However, sows with rubber mats were more likely to have scores greater than the median for toe overgrowth and/or claw lesions (heel/sole cracks, white line hoof damage or hoof wall cracks), but reduced risk of swelling and wounds of the limbs (Calderón Díaz et al. 2013). Toe overgrowth and lesions were not associated with an increased risk of lameness. Pens without rubber mats received better cleanliness scores through the experiment, but sows housed with rubber mats did not have greater scores for the percentage of manure on the body than those on cement slatted floors. Calderón Díaz et al. (2013) concluded that use of rubber mats improved locomotory ability and welfare for group-housed sows when compared to those housed on slatted concrete.

Rubber flooring covering part of the solid lying area, and 100% of the slatted area (slat width 80mm, gap width 20mm) improved gait scores of sows (n = 126, studied over three gestation cycles, 21 sows/group), measured in late gestation, and white line and claw length scores at the end of lactation. Mid-gestation (day 50) scores for heel overgrowth/erosion and heel-sole cracks were better for sows on rubber mats than those on concrete, but scores for vertical cracks in the wall horn were worse (Bos et al. 2016). Like Calderón Díaz et al. (2013), Bos et al. (2016) ***concluded that rubber mats improved the leg health and locomotion of sows from mid to late gestation. Longevity of the flooring has not been studied, nor the use of this flooring with larger group sizes.***

Devillers et al. (2019) identified slatted flooring of 105mm slats, and 19mm gaps, improved sow comfort when walking over slats, and resulted in lower hoof lesion scores and improved scores for indicators of hind-limb discomfort, suggesting improved sow comfort, compared to the commonly used gap slat widths of 125mm and 25mm, respectively. However, there were no differences in lameness and productivity when studied over two gestations. Application of rubberized concrete overlay material to slatted flooring produced a surface softer than concrete, with a greater surface friction, good durability and cleanliness (Connor, 2018, unpublished). There is great potential for this new slat configuration and use of concrete overlay materials to improve flooring for sows, and further research of its use on sow lameness and productivity should be explored.

The influence of floor type (partially slatted floors vs bedded with woodshavings) on osteochondrosis (OC) development in replacement gilts has been explored, but ***no relationship between OC development and flooring type was found (de Koning et al. 2014).***

Mineral supplementation has been proposed as a method for preventing lameness in pigs; Lisgara et al. (2016) tested chelated copper, managanese and zinc supplementation for effects on hoof lesions in 518 loose-housed sows in three herds over one (n=186) or two (n=332) gestations. Lesions on all hoof sites (sole, heel, white line, wall, toe length and dew claw length) except coronary band were affected by diet; probability of higher lesion scores after 1 or 2 gestations decreased with mineral inclusion, while odds of higher lesion scores were increased during a sow's second gestation in the trial. ***Results suggest that supplementation of chelated minerals improve hoof integrity and reduce degeneration. The flooring type and true level of supplementation is not clear from the paper.*** Faba et al. (2019) studied the impact of the same supplemental minerals (10, 20 and 50 mg/kg of copper, manganese and zinc, respectively) with and without additional methionine (102% methionine: lysine) on 360 young gilts from during rearing through their first 2 parities. The hypothesis was that mineral and methionine supplementation would promote healing and joint development during weaning, resulting in lower lameness. During the rearing phase and at weaning, control sows fed a basal diet had the highest prevalence of lameness with no between mineral treatment differences seen. ***Lameness was significantly correlated with fewer***

piglets weaned; supplementation of methionine and/or copper, zinc and manganese was therefore shown to reduce lameness and may improve reproductive performance.

2.7 References

Amezcua R, Walsh S, Luimes PH, Friendship RM. 2014. Infrared thermography to evaluate lameness in pregnant sows. Can Vet J. **55**(3):268–272.

Bates JL, Karriker LA, Stock ML, Pertzborn KM, Baldwin LG, et al. (2014) Impact of Transmammary-Delivered Meloxicam on Biomarkers of Pain and Distress in Piglets after Castration and Tail Docking. PLoS ONE 9(12).

Batorek, N., M. Čandek-Potokar, M. Bonneau, and J. V. Milgen. 2012. Meta-analysis of the effect of immunocastration on production performance, reproductive organs and boar taint compounds in pigs. Animal **6**:1330–1338.

Bos, E.-J., M. M. J. V. Riet, D. Maes, S. Millet, B. Ampe, G. P. J. Janssens, and F. A. M. Tuyttens. 2016. Effect of rubber flooring on group-housed sows gait and claw and skin lesions. J. Anim. Sci. **94**:2086–2096.

Bovey, K. E., T. M. Widowski, C. E. Dewey, N. Devillers, C. Farmer, M. Lessard, and S. Torrey. 2014. The effect of birth weight and age at tail docking and ear notching on the behavioral and physiological responses of piglets. J. Anim. Sci. **92**:1718–1727.

Brown, J. 2013. Translactational analgesia to reduce pain during piglet castration. National Pork Board Research Report #12–063.

Cador, C., F. Pol, M. Hamoniaux, V. Dorenlor, E. Eveno, C. Guyomarc'H, and N. Rose. 2014. Risk factors associated with leg disorders of gestating sows in different group-housing systems: A cross-sectional study in 108 farrow-to-finish farms in France. Prev. Vet. Med. **116**:102–110.

Connor, L. 2018. Optimizing Flooring and Social Management of Group Housed Gestating Sows (# 1231). Annual performance report to Canadian Swine Research and Development Cluster.

Conte, S., R. Bergeron, H. Gonyou, J. Brown, F. C. Rioja-Lang, L. Connor, and N. Devillers. 2014. Measure and characterization of lameness in gestating sows using force plate, kinematic, and accelerometer methods. J. Anim. Sci. **92**:5693–5703.

Calderón Díaz, J. A., A. G. Fahey, A. L. Kilbride, L. E. Green, and L. A. Boyle. 2013. Longitudinal study of the effect of rubber slat mats on locomotory ability, body, limb and claw lesions, and dirtiness of group housed sows1. J. Anim. Sci. **91**:3940–3954.

De Koning, D.B., E.M. van Grevenhof, B.F. Laurenssen, P.R. van Weeren, W. Hazeleger, and B. Kemp. 2014. The influence of floor type before and after 10 weeks of age on osteochondrosis in growing gilts. J. Anim. Sci. **92**(8):3338-47.

Devillers, N., E. Janvier, F. Delijani, S. Méthot, K. J. Dick, Q. Zhang, and Laurie Connor. 2019 Effect of slat and gap width of slatted concrete flooring on sow gait using kinematics analysis. Animals. **9**, 206, doi:10.3390/ani9050206.

Dzikamunhenga, R. S., R. Anthony, J. Coetzee, S. Gould, A. Johnson, L. Karriker, J. Mckean, S. Millman, S. R. Niekamp, and A. M. O'Connor. 2014. Pain management in the neonatal piglet during routine management procedures. Part 1: a systematic review of randomized and non-randomized intervention studies. Anim. Health Res. Rev. **15**:14–38.

Fabà, L., J. Gasa, M. D. Tokach, E. Varella, and D. Solà-Oriol. 2019. Effects of supplementing organic microminerals and methionine with or without limiting growth during the rearing phase of replacement gilts on lameness, growth, and body composition. Translational Animal Science. **3** (2).

Giminiani, P. D., A. Nasirahmadi, E. M. Malcolm, M. C. Leach, and S. A. Edwards. 2017. Docking piglet tails: How much does it hurt and for how long? Physiol. Behav. **182**:69–76.

Guay, K., G. Salgado, G. Thompson, B. Backus, A. Sapkota, W. Chaya, and J. J. Mcglone. 2013. Behavior and handling of physically and immunologically castrated market pigs on farm and going to market1. J. Anim. Sci. **91**:5410–5417.

Guo, Y. M., X. F. Zhang, J. Ren, H. S. Ai, J. W. Ma, and L. S. Huang. 2013. A joint genomewide association analysis of pig leg weakness and its related traits in an F2 population and a Sutai population1. J. Anim. Sci. **91**:4060–4068.

Han, X., M. Zhou, X. Cao, X. Du, F. Meng, G. Bu, F. Kong, A. Huang, and X. Zeng. 2019. Mechanistic insight into the role of immunocastration on eliminating skatole in boars. Theriogenology **131**:32–40.

Herskin, M., P. D. Giminiani, and K. Thodberg. 2016. Effects of administration of a local anaesthetic and/or an NSAID and of docking length on the behaviour of piglets during 5 h after tail docking. Res. Vet. Sci. **108**:60–67.

Hug, P. J., V. H. Cap, J. Honegger, G. Schüpbach-Regula, A. Schwarz, and R. Bettschart-Wolfensberger. 2018. Optimization of analgesia for piglet castration under isoflurane anaesthesia with parenteral butorphanol, meloxicam or intratesticular lidocaine. Schweiz Arch Tierheilkd **160**:461–467.

Ison, S. H., S. Jarvis, S. A. Hall, C. J. Ashworth, and K. M. D. Rutherford. 2018. Periparturient Behavior and Physiology: Further Insight Into the Farrowing Process for Primiparous and Multiparous Sows. Front. Vet. Sci. 5.

Johnson, R. 2014. Evaluation of Compounding Iron-dextran with NSAIDs for Use in Piglets at Time of Castration. Ontario Pork. [Abstract] Available from: http://www.ontariopork.on.ca/Research/Active-Recently-Completed/evaluation-of-compounding-iron-dextran-with-nsaids-for-use-in-piglets-at-time-of-castration-1 [Date Accessed: May 7, 2019]

Kells, N. J., N. Beausoleil, M. Sutherland, R. Morrison, and C. B. Johnson. 2017. Electroencephalographic assessment of oral meloxicam, topical anaesthetic cream and cautery iron for mitigating acute pain in pigs (Sus scrofa) undergoing tail docking. Vet. Anaesth. Analg. **44**:1166–1174.

Larsen, M. L. V., H. M.-L. Andersen, and L. J. Pedersen. 2017. Which is the most preventive measure against tail damage in finisher pigs: tail docking, straw provision or lowered stocking density? – CORRIGENDUM. Animal **12**:1268–1268.

Le, T. H., O. F. Christensen, B. Nielsen, and G. Sahana. 2017. Genome-wide association study for conformation traits in three Danish pig breeds. Genetics Selection Evolution **49**.

Lisgara, M., V. Skampardonis, and L. Leontides. 2016. Effect of diet supplementation with chelated zinc, copper and manganese on hoof lesions of loose housed sows. Porcine Health Management 2.

Lomax, S., E. Hall, L. Oehlers, and P. White. 2018. Topical vapocoolant spray reduces nociceptive response to ear notching in neonatal piglets. Vet. Anaesth. Analg. **45**:366–373.

Mainau, E., J. L. Ruiz-De-La-Torre, A. Dalmau, J. M. Salleras, and X. Manteca. 2012. Effects of meloxicam (Metacam®) on post-farrowing sow behaviour and piglet performance. Animal **6**:494–501.

Mainau, E., D. Temple, and X. Manteca. 2016. Experimental study on the effect of oral meloxicam administration in sows on pre-weaning mortality and growth and immunoglobulin G transfer to piglets. Prev. Vet. Med. **126**:48–53.

Marchant-Forde, J. N., D. C. Lay Jr., K. A. McMunn, H. W. Cheng, E. A. Pajor, and R. M. Marchant-Forde. 2009. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered separately. J. Anim. Sci. **87**:1479–1492.

Marchant-Forde, J. N., D. C. Lay, K. A. Mcmunn, H. W. Cheng, E. A. Pajor, and R. M. Marchant-Forde. 2014. Postnatal piglet husbandry practices and well-being: The effects of alternative techniques delivered in combination12. J. Anim. Sci. **92**:1150–1160.

Matika, O., D. Robledo, R. Pong-Wong, S. C. Bishop, V. Riggio, H. Finlayson, N. R. Lowe, A. E. Hoste, G. A. Walling, A. L. Archibald, J. A. Woolliams, and R. D. Houston. 2019. Balancing selection at a premature stop mutation in the myostatin gene underlies a recessive leg weakness syndrome in pigs. PLoS Genet. **15**(1).

McGlone, J., K. Guay, and A. Garcia. 2016. Comparison of Intramuscular or Subcutaneous Injections vs. Castration in Pigs—Impacts on Behavior and Welfare. Animals **6**:52.

Meijer, E., M. Oosterlinck, A. V. Nes, W. Back, and F. J. V. D. Staay. 2014. Pressure mat analysis of naturally occurring lameness in young pigs after weaning. BMC Veterinary Research 10.

Mohling, C.M., A.K. Johnson, J.F. Coetzee, L.A. Karriker, K.J. Stalder, C.E. Abell, H.D. Tyler, and S.T. Millman. 2014. Evaluation of mechanical and thermal nociception as objective tools to measure painful and nonpainful lameness phases in multiparous sows. J. Anim. Sci. **92**:3073–3081.

Mustonen, K., E. Ala-Kurikka, T. Orro, O. Peltoniemi, M. Raekallio, O. Vainio, and M. Heinonen. 2011. Oral ketoprofen is effective in the treatment of non-infectious lameness in sows. Vet. J. **190**:55–59.

Numberger, J., M. Ritzmann, N. Übel, M. Eddicks, S. Reese, and S. Zöls. 2016. Ear tagging in piglets: the cortisol response with and without analgesia in comparison with castration and tail docking. Animal **10**:1864–1870.

O'Connor, A., R. Anthony, L. Bergamasco, J. Coetzee, S. Gould, A.K. Johnson, L.A. Karriker, J.N. Marchant-Forde, G.S. Martineau, J. Mckean, S.T. Millman, S. Niekamp, E.A. Pajor, K. Rutherford, M. Sprague, M. Sutherland, E.V. Borell, and R.S. Dzikamunhenga. 2014. Pain management in the neonatal piglet during routine management procedures. Part 2: Grading the quality of evidence and the strength of recommendations. Anim. Health Res. Rev. **15**:39–62.

O' Sullivan, T. 2018. Assessing the efficacy of ketoprofen and meloxicam when mixed with iron dextran on pain relief following castration in piglets. Project: 16-011 Summary of final report to Ontario Pork. Available at: http://www.ontariopork.on.ca/Research/Active-Research/assessing-the-efficacy-of-ketoprofen-and-meloxicam-when-mixed-with-iron-dextran-on-pain-relief-following-castration-in-piglets Date accessed: 16th June 2019.

Pairis-Garcia, M. D., A. K. Johnson, C. A. Abell, J. F. Coetzee, L. A. Karriker, S. T. Millman, and K. J. Stalder. 2015a. Measuring the efficacy of flunixin meglumine and meloxicam for lame sows using a GAITFour pressure mat and an embedded microcomputer-based force plate system. J. Anim. Sci. **93**:2100–2110.

Pairis-Garcia, M., A. Johnson, K. Stalder, C. Abell, L. Karriker, J. Coetzee, and S. Millman. 2015b. Behavioural evaluation of analgesic efficacy for pain mitigation in lame sows. Anim. Welf. **24**:93–99.

Pierozan, C.R., C.P. Dias, and C.A. da Silva. 2017. Environment, facilities, and management of hospital pens in growing and finishing pig farms: a descriptive study. Revista Brasileira de Zootecnia **46**:831–838.

Pluym, L., D. Maes, J. Vangeyte, K. Mertens, J. Baert, S. van Weyenberg, S. Millet and A. van Nuffel. 2013a. Development of a system for automatic measurements of force and visual stance variables for objective lameness detection in sows: SowSIS. Biosystems Engineering. **116**: 64-74.

Pluym, L., A. Van Nuffel, and D. Maes. 2013b. Treatment and prevention of lameness with special emphasis on claw disorders in group-housed sows. Liv. Sci. **156**: 356-43.

Pluym, L., D. Maes, S. van Weyenberg, and A. Van Nuffel. 2017. Risk factors for development of lameness in gestating sows within the first days after moving to group housing. The Vet. J. **220**: 28-33.

Poulsen N. B., I.V. Vlaenderen, A. Aldaz, and C. Mah. 2018. The effect of immunization against gonadotropin-releasing factor on growth performance, carcass characteristics and boar taint relevant to pig producers and the pork packing industry: A meta-analysis. Res. Vet. Sci. **119:**182–195.

Reynolds, R., R. Johnson, S. Enouri, B. Friendship, J. Brown, R. Gehring, T.L. O'Sullivan. 2017. Assessing the efficacy of ketoprofen and meloxicam when mixed with iron dextran on pain relief following castration in piglets. Proc. University of Guelph Swine Research Day, University of Guelph, Canada. Guelph, Ontario. Available from: https://www.uoguelph.ca/osrn/sites/uoguelph.ca.osrn/files/public/Proceedings_website.pdf [Date accessed: May 9, 2019]

Rigamonti, S., R. Bettschart-Wolfensberger, A. Schwarz, and I. Nussbaumer. 2018. Evaluation of a field-suitable injection anesthesia protocol for the castration of 8 to 14 days old piglets. Schweiz Arch Tierheilkd **160**:469–474.

Tenbergen R., R. Friendship, G. Cassar, M.R. Amezcua, and D. Haley. 2014. Investigation of the use of meloxicam post farrowing for improving sow performance and reducing pain. J Swine. Heal. Prod. **22**:10–5.

Thodberg, K., M.S. Herskin, T. Jensen, and K.H. Jensen. 2018. The effect of docking length on the risk of tail biting, tail-directed behaviour, aggression and activity level of growing pigs kept under commercial conditions. Animal **12**:2609–2618.

Thomsen, P.T., A. Klottrup, H. Steinmetz, and M.S. Herskin. 2016. Attitudes of Danish pig farmers towards requirements for hospital pens. Res. Vet. Sci. **106**:45-47.

Übel, N., S. Zöls, W. Otten, S.-L. Carola, K. Heinritzi, M. Ritzmann, and M. Eddicks. 2015. Impact of the simultaneous implementation of husbandry procedures on suckling piglets. Tierärztliche Praxis Ausgabe G: Großtiere / Nutztiere. 43. 10.15653/TPG-150385. [Abs.]

Viitasaari, E., L. Hänninen, M. Heinonen, M. Raekallio, T. Orro, O. Peltoniemi, and A. Valros. 2013. Effects of post-partum administration of ketoprofen on sow health and piglet growth. The Veterinary Journal **198**:153–157.

3.0 Euthanasia

3.1.1 Conclusions

1. **Stockperson attitude, personality traits and knowledge play an important role in the timely and humane euthanasia of animals. Understanding how these factors influence decision making around euthanasia presents training opportunities.**
2. **There remains disagreement between industry experts on the appropriate timing of euthanasia for compromised pigs based on clinical signs. However, conditions deemed to require immediate euthanasia involved those where recovery will be prolonged or unlikely, and the animal is severely compromised.**
3. **An interactive computer training program has been developed to guide and educate caretakers on the decision-making processes involved in euthanasia, but the effectiveness of this program is unknown.**
4. **The Cash Dispatch non-penetrating captive bolt is effective at euthanizing pigs from 2-<200 kg with a single shot, but mature pigs (>200kg) may require a second shot to ensure insensibility and death. Refinements in equipment design and/or application may be needed to ensure reliable performance for the weight class of pigs being euthanized.**
5. **Electrocution using specifically designed equipment has been evaluated as an efficient and practical method of on-farm euthanasia for pigs ranging from 5-105 kg. Currently the Code guide for methods of acceptable euthanasia (NFACC, 2014, appendix N, pp. 61) only permits electrocution as an acceptable method in pigs up to 68kg.**
6. **Gas euthanasia with use of CO_2 or argon is aversive, with N_2O being less aversive than CO_2.**

3.1.2 Knowledge gaps

- Electrocution for mature animals, clarification of acceptable equipment for on-farm use.
- Effectiveness of stockperson training to resolve barriers to euthanasia, including effectiveness of developed training programs.
- Viability of N_2O in gas euthanasia as a more humane method, cost effectiveness.
- Mass euthanasia preparedness and approaches.
- Low atmospheric pressure stunning.

3.2 Determining humane endpoints

Humane endpoints must be in place for animals used in production or research, and all persons responsible for euthanasia decisions must be trained to recognize compromised individuals and effectively administer the appropriate euthanasia method (AVMA, 2013). Stockperson knowledge of, and attitude towards, compromised animals and euthanasia plays a crucial role in the timely provision of a humane death (Rault et al. 2017). Timely euthanasia requires stockpeople to correctly identify compromised animals, and be able to perform euthanasia in a variety of environments.

Mullins et al. (2017) surveyed 37 members of the National Pork Board (NPB) Animal Welfare Committee, to understand how the current US industry euthanasia guidelines are understood, and to explore the challenges associated with timely euthanasia on farm. Survey participants consisted of swine producers and stockpersons (29.7%), animal scientists and swine researchers (32.4%), pork packers (10.8%), veterinarians (8.1%) and other industry personnel (17.8%). Respondents were asked to assign a euthanasia score indicating the appropriate time of euthanasia for compromised pigs with 26 medical conditions (Mullins et al., 2017). The conditions were further grouped into 10 categories of clinical signs: locomotory, gastrointestinal, integument, body condition, hernia, prolapse, respiratory, reproductive, neurological and systemic conditions. ***No categories reached a consensus where all respondents selected the same euthanasia score for a clinical sign or condition;*** the proportion of respondents selecting a single score varied more widely for decisions to euthanize an animal immediately (Score 1) than they did in the decision not to euthanize, and to re-evaluate if condition worsens (Score 5). ***Conditions deemed most serious and in need of immediate attention in mature pigs, based on average euthanasia score ranking, were non-ambulatory/severely weak (breeding stock: 1.4, non-breeding: 1.7)*** and least-serious clinical signs were gastrointestinal disease (breeding stock: 5.0) and skin injuries (breeding stock: 4.9, non-breeding stock: 4.3). In ***pre-weaning pigs, body condition score (BCS) of 1 was reported as most serious (average rank 1.7)*** with systemic conditions, gastrointestinal disease and skin injuries ranked as least-concern (4.1, 4.0 and 4.1 respectively). Focus groups with members of the NPB Animal Welfare Committee identified ***an unsupportive farm culture as a barrier to timely-euthanasia, and caretaker characteristics as important for the success of a euthanasia program (Mullins et al. 2017). The work of Mullins et al. (2017) identifies that even between experts within a field, it is a challenge to reach consensus on conditions that would be deemed to require euthanasia. Conditions deemed in need of immediate euthanasia involve those where recovery will be prolonged or unlikely, and the animal is severely compromised.***

Recognizing that stockperson beliefs about, knowledge of, and attitudes towards euthanasia, play a role in the treatment and euthanasia of compromised animals, Campler et al., (2018), surveyed 84 swine caretakers to evaluate relationships between caretaker attitudes, perceived knowledge and confidence in performing euthanasia. Cluster analysis of survey responses identified three types of caretaker: i) confident and empathetic; ii) confident, knowledgeable and detached; iii) unconfident and lacking in knowledge. Participants tended to be more likely to be confident and empathetic if they were female. Two or more years of swine experience increased the likelihood to be 'confident, knowledgeable and detached' attitudes; while less than two years of experience decreased the likelihood to be 'unconfident and lacking knowledge.' Euthanasia knowledge, experience and confidence was correlated with caretakers from small- or medium- sized farms (<1500 to 3000 pigs), but no relationship was found between caretakers from large farms (>3000 pigs) and negative attitudes/workload-related frustrations (Campler et al. 2018). ***Increased understanding about caretaker attitudes can help to support the implementation of appropriate training protocols on farm. Concerns regarding timely euthanasia require human training to be addressed. Sociology/psychology research may be beneficial in this area.***

Through conducting a questionnaire of 120 stockpeople on 10 Australian pig farms, Rault et al. (2017) identified challenges to euthanasia concerning the decision of which animal to euthanize, and the act itself. Confidence was a predictor of stockpeople being comfortable with euthanasia, while lack of knowledge on the procedure and empathy predicted trouble deciding, or avoidance of euthanasia. Empathy affect, lack of knowledge and perceived time constraints predicted stockpeople feeling bad about euthanizing. Women reported greater difficulty with euthanasia than men, and the desire for more knowledge if they had not euthanized an animal before working with pigs. The results of Rault et al. (2017) identify how euthanasia can affect stockpeople, and areas for which training could support staff in better decision making and more timely euthanasia.

An interactive computer-based training program based on the National Pork Board's 2015 Common Swine Industry Audit (CSIA) euthanasia guidelines, has been developed to improve caretaker ability to identify compromised pigs reaching humane end points, and administer timely and effective euthanasia (Mullins et al. 2018). The training program uses case studies to provide opportunities for users to make care decisions based on clinical signs, treatment history and condition severity. Five case studies are available for each production stage covered (breeding, piglets and wean to grow-finish pigs). The program may be used to train new stockpersons and provide existing personnel with a way to practice decision-making, review CSIA guidelines and ensure that appropriate decisions are made regarding timely care and euthanasia of compromised animals. ***Mullins et al. (2018) describe the development of the training program, but not whether users find it helpful, or whether it has been shown to generate an improvement in the application of timely euthanasia.***

3.3 Evaluation and refinement of existing on-farm methods for pigs

The Code of Practice (2014) states three acceptable methods of euthanasia for mature (≥200kg) pigs: anesthetic overdose (veterinarian administered only), gunshot to the head and penetrating captive bolt conditional to correct training of personnel for bolt placement. Each method presents challenges to the euthanasia of mature pigs, while the ease of euthanasia protocol has been identified as a barrier to euthanasia (Mullins et al. 2017). The most recent edition of the American Veterinary Medical Association (AVMA) Guidelines for the Euthanasia of Animals (AVMA, 2013) updated recommendations for the humane euthanasia of swine from the AVMA 2007 edition. The AVMA (2013) guidelines are largely in agreement with the Code of Practice (2014) but appear to differ slightly by allowing the use of electrocution for euthanasia of mature pigs. It should be noted that the AVMA (2013) guidelines do not explicitly state electrocution for mature pigs, but include sows in the category. The AVMA (2013) guidelines with regards to electrocution equipment and parameters are limited, and seems to suggest reference to use of handheld tongs as typically performed in the abattoir.

Millman et al. (2012) validated the use of a Cash Dispatch penetrating captive bolt device as a single-step euthanasia method in both laboratory and on-farm settings. The Cash Dispatch kit includes four bolt lengths, including a non-penetrating bolt; the variation in length is designed for use on pigs of all sizes, and so was tested for efficacy on 210 pigs from seven weight classes (2-3kg, 7.5-10 kg, 15-20 kg, 30-40 kg, 100- 120 kg, 200-250 kg, >300 kg) in an on-farm trial. In accordance with AVMA Guidelines for Euthanasia of Animals (2013), Millman et al. (2012) confirmed that restraint of the pig's head via a snare was necessary for efficacy and for handler safety when compared to restraint in a chute or stall. All pigs were anesthetized prior to application of the captive bolt. Fifteen stockpersons with captive bolt euthanasia experience ranging from first time to weekly users were selected for the trial and given the same instructions by a single researcher. Upon application of the captive bolt, pigs were assessed for signs of sensibility (failure to collapse or an eye blink response); if present, a second shot was applied. Death was confirmed upon cessation of movement, heartbeat and respiratory function, occurring an average of three minutes after euthanasia (Millman et al., 2012). One pig was removed from trial due to a faulty cartridge, 202 of the remaining 209 pigs were successfully euthanized on first shot (97%), and seven mature pigs (>200 kg weight class) required a second shot. Millman et al. (2012) note respiration and vocalizations were observed in pigs that were successfully euthanized, indicating that neither is a reliable predictor of euthanasia success. ***The researchers concluded that use of the Cash Dispatch captive bolt is effective as a single-step euthanasia method for pigs <200 kg, but mature pigs >200 kg may require two shots to ensure complete insensibility leading to death, and stockpeople should be prepared to administer a second shot swiftly when administering to mature animals. Refinements in equipment design and/or application may be needed to ensure reliable performance for the weight class of pigs being euthanized.***

Appendix M of the Code of Practice for the Care and Handling of Pigs states electrocution is a conditionally acceptable euthanasia method in pigs from 2.3 to 68 kg, but is unacceptable in pigs under or over these limits (NFACC, 2014). Purpose-designed electric current equipment must be applied to the brain to render the animal insensible before application to the heart (two-step electrocution) or to the brain and heart simultaneously (one-step electrocution). While stunning at a slaughterhouse is commonly performed using a 300 VAC power supply carrying a current ≥ 1.3 A, availability and cost makes 110 VAC electrical equipment more practical for on-farm application (Denicourt et al., 2009, unpublished).

As previously identified by the Pig Code Scientific committee report (2012), Denicourt et al. (2009) tested the efficacy and welfare implications of on-farm electrocution using 110-120 VAC on pigs from 5 to 105 kg (n=95). Over four trial phases, the researchers tested:

1) Minimum time to induce unconsciousness with head-to-head stunning using 110 or 220 VAC (in anaesthetized pigs);

2) Best contact points based on impedance at low voltage (6 VAC, 600 Hz);

3) Which of the two best contact types/locations from phase 2 perform best at 110 VAC, 60 Hz;

4) Safety and efficiency of on-farm application of the best method determined in phase 3 using a mobile electrocution unit.

One-step head-to-back stunning was used for phases 2-4. Phase 1 revealed that a 3-second application was insufficient to stun pigs; 5 seconds was adequate to induce epileptiform insult consistent with insensibility, from which pigs recovered approximately 25 seconds later (n = 7 at 110 VAC, 1.7 A and n = 3 at 220 VAC, 3.3 A). A metal wire around the snout (head contact) with either a rectal probe or a metal belt around the abdomen (back contact) were the two lowest-impedance (maximum current flow) combinations tested at 110 VAC in phase 2; euthanasia was successful at currents ≥ 0.40 A. Phase 3 testing found performance of both combinations to be equal; a metal belt may be preferred based on aesthetic and welfare considerations. Body condition did not affect current delivered, but current was positively correlated with bodyweight. The final method (110 VAC, 5 second application via metal wire around the snout and metal abdominal belt) was validated for inducing efficient and practical on-farm euthanasia of pigs 5-105 kg while meeting welfare requirements. In a follow-up report, Denicourt et al. (2010) concluded that industry-standard application of 15 seconds is recommended to guarantee death during the first shock in >99% of the pigs. Application of the current for 15s also prevents the appearance of convulsions following cessation of the current (M. Dennicourt, personal communication, May 2019). This can be beneficial for staff wellbeing, because anecdotally, observing pigs convulse following euthanasia, although insensible at the time, is unpleasant. ***The method of electrocution developed by Dennicourt et al. (2009) can offer a humane method, that can also be beneficial for staff well-being. The Code (NFACC, 2014) permits electrocution by purpose-designed equipment only. The purpose built equipment arising from the work of Dennicourt et al. (2009) appears to be the single step mobile unit. This method has not been assessed on pigs heavier than 105kg, and this may be of value considering challenges to euthanize mature pigs. The Pig Code Scientific Committee report (NFACC, 2012) suggests concerns regarding handling of pigs to attach the equipment prior to euthanasia. It is proposed this should be reviewed and examined in different scenarios to determine if concerns are valid, and what range of purpose built equipment is available. Standard operating instructions for different scenarios and weight categories of pig may be of value.***

Blunt force trauma is a common method of euthanasia for non-viable piglets, but may be considered undesirable due to public perception, emotional effect on the stockperson, and subsequent risk of inconsistent application. Gas euthanasia is suggested as an alternative; Sadler et al. (2014) measured the effect of changing the gas mixture and flow rate to produce consistent and humane death in piglets. Nine gas combinations were assessed over two age groups (neonates: <3 days, 2.6 ± 0.1 kg; and weaned: 16-24 days, 4.8 ± 0.2 kg): a control (air only), two gas types (100% CO_2 and 50:50 CO_2: argon) and four flow rates (box volume exchange/min: slow = 20%; medium = 35%; fast = 50%; prefill = prefilled followed by 20%) (n=340). Piglets were euthanized in male-female pairs in a gas chamber fitted with video cameras to record behaviour for 10 minutes or until last movement. Seventy-five percent of weaned piglets were not euthanized successfully (last movement not achieved within 10 minutes) with slow flow at 50:50 CO_2:argon; this treatment was consequently not tested on neonates. Amongst all treatment combinations, medium or fast fill rates (both gas types) and 100% CO_2 produced shorter latency to open mouth breathing, shorter duration of ataxia, faster loss of posture and fewer righting attempts. Escape attempts were seen in the 50:50 treatment in weaned pigs and increased at slower fill rates. Oral/nasal behaviours were shortest at prefill flow rates for both gas types and longest in controls. Effect of treatment on all parameters was similar between neonates and weaned piglets except duration of ataxia (uncoordinated movements), which was shorter in neonates. ***Sadler et al. (2014) concluded that 100% CO_2 and fill rates of at least 35% produce better welfare outcomes, and that slow fill rates and 50:50 CO_2: argon should not be considered for on-farm euthanasia of piglets (weaned or neonates). Neonates succumb to the effects of gas euthanasia more quickly, and display fewer signs of distress. However, as detailed within this section (i.e. Sutherland et al. 2017), as CO_2 is highly aversive, alternative methods should be sought.***

Pigs at higher stocking rates (one, two or six piglets) tended to retain posture longer when placed in a Euthanex AgPro chamber prefilled with argon, but overall, stocking rate treatment did not have a large effect on piglet latencies to onset of neuromuscular excitation or last movement (Fielder et al. 2016). ***The results of Fielder et al. (2016) do not support that piglets need to be euthanized singularly in argon gas to support improved welfare.***

Sutherland et al. (2017) concluded that regardless of pig age (1 – 6 weeks tested), or CO_2 fill method, (prefill vs 20% exchange/min), CO_2 caused distress to piglets. Kells et al. (2018) evaluated the effects of different gas combinations on piglet welfare during euthanasia, concluding that whether using 100% CO_2, 100% argon, or a mixture of 60% argon/40% CO_2, piglets were in distress prior to loss of consciousness. ***Both Sutherland et al. (2017) and Kells et al. (2018) conclude that alternative methods should be sought.***

Nitrous oxide (N_2O) is much less aversive to piglets than CO^2, and when used at 90% concentration, can euthanize piglets (Rault et al. 2015). However, when used in conjunction with CO^2 for a two-step procedure (exposure to N_2O first with a 6 minute gradual fill, followed by CO^2 delivered at a 25% replacement rate/min), piglets showed signs of distress, ***and thus this methods is not recommended as humane (Smith et al. 2018).***

3.4 References

American Veterinary Medical Association (AVMA). 2013. Guidelines for the euthanasia of animals: 2013 edition. Schaumburg, Illinois: American Veterinary Medical Association. Available at: avma.org/KB/Policies/ Documents/euthanasia.pdf. [Date Accessed: April 15th, 2019]

Campler, M. R., M. D. Pairis-Garcia, J.-L. Rault, G. Coleman, and A. G. Arruda. 2018. Caretaker attitudes toward swine euthanasia. Translational Animal Science **2**:254–262.

Denicourt, M., C. Klopfenstein, V. Dufour, F. Pouliot, S. Labrecque, and S. D'Allaire. 2009. On-farm euthanasia: Efficient and safe (110 VAC) pig electrocution. American Association of Swine Veterinarians. pp. 249-254.

Denicourt, M., C. Klopfenstein, V. Dufour, F. Pouliot, S. Labrecque, and S. D'Allaire. 2010. Using an electrical approach to euthanize pigs on-farm: Fundamental principles to know. American Association of Swine Veterinarians. 2010. AASV Annual Meeting: Implementing Knowledge. pp. 451-486.

Fielder, K.H., R.L. Parsons, L.J. Sadler, and S.T. Millman. 2016. Effects of stocking rate on measures of efficacy and welfare during argon gas euthanasia of weaned pigs. Ani. Welfare. **25**: 83-89.

National Farm Animal Care Council (NFACC) 2012. Code of Practice for the Care and Handling of Pigs: Review of scientific research on priority issues. National Farm Animal Care Council. Available at: https://www.nfacc.ca/resources/codes-of-practice/pig/Pig_Scientists_Committee_report.pdf date accessed: 16th June 2019.

Kells, N., N. Beausoleil, C. Johnson, and M. Sutherland. 2018. Evaluation of different gases and gas combination for on-farm euthanasia of pre-weaned pigs. Animals. 8:40.

Millman, S., J. Woods, J. Hill, K. Schwartz, T. Grandin, R. Brooks, Jr., A. O'connor, A. Johnson. 2012. On-farm validation of captive bolt technology as a single stage euthanasia method. National Pork Board, Des Moines, IA.

Mullins, C. R., M. D. Pairis-Garcia, M. R. Campler, R. Anthony, A. K. Johnson, G. J. Coleman, and J.-L. Rault. 2018. Teaching Tip: The Development of an Interactive Computer-Based Training Program for Timely and Humane On-Farm Pig Euthanasia. J. Vet. Med. Educ. **45**:405–412.

Mullins, C., M. Pairis-Garcia, K. George, R. Anthony, A. Johnson, G. Coleman, J.-L. Rault, and S. Millman. 2017. Determination of swine euthanasia criteria and analysis of barriers to euthanasia in the United States using expert opinion. Anim. Welfare **26**:449–459.

National Farm Animal Care Council (NFACC 2014). Code of Practice for the Care and Handling of Pigs. A Canadian Pork Council, NFACC publication. Available: https://www.nfacc.ca/pdfs/codes/pig_code_of_practice.pdf. [Date Accessed: April 15th, 2019].

Rault, J-L., N. Kells, C. Johnson, R. Dennis, M. Sutherland, and D. Lay Jr. 2015. Physiol. And Behav. **151**: 29-37.

Rault, J.-L., T. Holyoake, and G. Coleman. 2017. Stockperson attitudes toward pig euthanasia. J. Anim. Sci. **95**:949–957.

Sadler, L.J., C.D. Hagen, C. Wang, T.M. Widowski, A.K. Johnson, S.T. Millman. 2014. Effects of flow rate and gas mixture on the welfare of weaned and neonate pigs during gas euthanasia. J. Anim. Sci. **92**(2): 793-805.

Smith, R.K., J-L. Rault, R.S. Gates, and D. Lay Jr. 2018. A two-step process of nitrous oxide before carbon dioxide for humanely euthanizing piglets: On-farm trial. Animals. 8:52.

4.0 Transportation

4.1.1 Conclusions

1. **The microclimates in pot-belly trailers vary between compartments and seasons, presenting a concern that some compartments will result in worse welfare outcomes than others. Double-decker trucks may reduce in-trailer variability.**
2. **Sprinkling pigs on trailers (when over 23˚C), and the use of misting banks with forced ventilation fans, can improve thermal comfort for pigs in stationary vehicles during warmer months.**
3. **Trailer type impacts pig welfare at loading and unloading, with pig welfare improved by hydraulic lift decks.**
4. **Internal ramps and 180° turns inside trailers may increase loading and unloading times, body temperatures of pigs, and the risk of slips/falls.**
5. **Flat ramps and shallow angles (≤ 20˚) of entry improve the ease of handling when loading and unloading pigs. Bedding on ramps can also improve pig handling.**
6. **The use of a loading gantry improves loading, and can lead to reductions in transport mortality and non-ambulatory pigs.**
7. **Transporting pigs in pot belly trailers in accordance with Transport Quality Assurance guidelines when outside temperatures are outside of the 5-27˚C range can result in unfavourable conditions inside the truck, impacting pig welfare. Further work to understand boarding, bedding and watering practices outside of this temperature range is warranted.**

4.1.2 Knowledge gaps

- Boarding patterns to improve compartment temperatures in trailers, and to reduce the variability of temperatures within pot belly trailers in particular.
- Understanding bedding and watering (for drinking and cooling) practices in extremes of temperature.
- Understanding use of insulated, or climatically controlled trucks for extremes of temperature.
- Evaluation of rest stops for different classifications of pigs to be beneficial on long journeys exceeding 28 hrs, vs on-board provision of feed and water.
- Stockperson and trucker pig handling. Now that Don and Nancy Lidster have retired, is the industry at a shortage of help if needed?

A comprehensive review of research on swine transportation priority issues in Canada was published by Rioja-Lang et al. (2019). Topics covered by this review include: transportation duration and distance, feed/water during transport, rest intervals, environmental conditions (and how to mitigate them), loading density and special considerations for young animals. Readers should consult this review for further information.

4.2 Truck design to achieve climate control

Temperature, bedding and position within the truck all impact the stress, comfort and survival rate of pigs during transport (Newman et al., 2014, Sommavilla et al., 2017). Given the extreme temperatures reached above and below the thermoneutral zone of pigs in much of Canada, climate control is one of the most important issues in swine transportation (Rioja-Lang et al., 2019). Pot-belly (PB) trailers are commonly used for swine transport, particularly for hauling larger groups, but the design presents poorer climate control than double decker (DD) straight or flat-deck designs. Compartments within pot-belly trailers, particularly those fitted with passive ventilation systems, can differ greatly in microclimate, subsequently affecting the physiological stress of transport (Conte et al., 2015, Xiong et al. 2015). PB trailers have been shown to increase the number of dead and non-ambulatory pigs and incidence of rectal prolapse on arrival when compared to DD trucks (Correa et al., 2013).

Conte et al. (2015) investigated the effect of temperature, truck design and compartment location on core body temperature in pigs. Overall, change in gastrointestinal tract temperature was not different between pot-belly and double deck trucks in either season. However, within pot-bellied trucks there were compartment effects, with pigs transported in top front, rear top and bottom rear compartments of pot-belly trailers in the summer in Canada (9.1 to 20.7°C, mean temperature 18.4°C) having a greater increase in gastrointestinal tract temperature during pre-travel and initial travel periods than those loaded in other compartments. The greatest increase in temperature was found in pigs loaded in the top front compartment. However, the effect of compartment on the change in gastrointestinal temperature was insignificant in winter (-22.3 to -9.7°C, mean temperature -10.4°C). Changes in core body temperature were assumed to result from the greater physical effort required to climb the ramp to the top compartment, in combination with decreased ventilation and increased ambient temperature in the three PB truck compartments listed. The increase in gastrointestinal tract temperature was greater in summer than winter during the pre-travel periods, likely due to increased ambient heat in summer than winter (Conte et al., 2015). No significant differences were found in temperature between compartments in double deck trailers. ***Differences in compartmental temperatures on PB trucks represent an area for refinement in truck design to achieve better climate control.***

An observational-study of 34 trips of 1-4 hours in duration in summer and winter, in Midwestern USA (outdoor temperature range from -14 to 38°C), recorded air and skin surface temperature of pigs travelling in the front, middle and rear compartments on top and bottom decks of pot-bellied trucks (Xiong et al. 2015). The maximum surface temperature recorded was reached in the rear compartments on 79% of the trips (front compartments: 18%, middle compartments: 3%). The minimum surface temperatures were recorded most frequently in the middle compartments (49% of trips, front compartments: 24%, rear compartments: 27%). Pig surface temperatures were found to be independent of trailer boarding percentage. When outdoor temperatures ranged from 5˚C to 27˚C, following the Transport Quality Assurance guidelines for boarding resulted in acceptable trailer thermal conditions. However, outside of this temperature range, pigs on board experienced unfavourable conditions, and ***the assessment of boarding, watering and bedding in extreme conditions is warranted. Stopping the trucks resulted in rapid temperature increases of 3-4˚C within 5 minutes. Therefore stops could be included to warm trailers in winter, but should be avoided in hot weather conditions. Xiong, et al. (2015) recommended further study into how alternative boarding may alter the ambient and pig surface temperatures during transport. Given the results of this study, rear compartments represent the zones where pigs may experience the most heat stress in the summer and the most comfortable (warm or thermoneutral) environment in the winter. While front compartments represent the zones where pigs are cooler, potentially reducing heat stress in the summer but causing heat losses in the winter***. ***Boarding removal in the middle of the trailer was suggested to encourage more uniform ventilation in the front and rear zones.***

Temperatures inside trailers have been recorded to increase by 6 – 8°C greater than the external temperature (Fox et al. 2014). To combat heat stress, trucks may be outfitted with a sprinkler system to increase thermal comfort in warmer months. The use of a sprinkler system in stationary, naturally-ventilated, pot-belly trailers for five minutes pre-departure, and five minutes upon arrival before unloading, reduced the rise in temperature in trailer compartments, and did not affect ammonia levels. Pigs on sprinkled trailers tended to experience a greater reduction in gastrointestinal tract temperature from baseline to arrival than those on the control trucks, and also spent less time drinking in lairage. Sprinkling tended to reduce pig internal body temp on arrival when ambient temp was >24°C. Unloading behaviour of animals (slips/falls) was not influenced by sprinkler treatments (Fox et al. 2014). This study was conducted in summer conditions in Ontario. ***Sprinkling pigs on stationary trucks when temperatures exceed +23°C appears to be beneficial to help avoid increases in body temperature during short (2 hrs) transportation, without detrimental effects on unloading behaviour of animals.***

The use of a fan-misting bank for 30 minutes on trailers parked at the abattoir receiving bay in summer temperatures (July – August, ambient temperature range 16.9 – 21.7°C), reduced the average compartment temperature and temperature-humidity index, but increased the relative humidity, compared to trailers parked with no fan-misting (Pereira et al. 2018). There was no difference in internal body temperature between pigs on trucks, whether fan-misted or not, indicating that the compartmental differences in temperature observed, had no effect on the thermal status of the pigs in this study. However, after 1 hr in lairage, pigs from fan-misted trucks had a smaller change in internal body temperature, indicating a lower need to release core body heat as a result of the fan-misting (Pereira et al. 2018). ***The application of a 30-minute fan-misting routine (10 minutes of fan-assisted ventilation, followed by 10 minutes of ventilation and water misting, and 10 minutes of fan-assisted ventilation), appeared to be effective at improving the thermal comfort of pigs on a stationary trailer in summer. However, the efficiency of the fan-misting varied by compartment.***

4.3 Handling on and off the truck and Practical alternatives to the use of ramps for loading/unloading pigs in Canada

Relatively little has been published in the last five years on the handling of pigs during transport. A review published by Goumon and Faucitano (2017) evaluated the influence of handling practices (tools, group size, use of shipping pens, mixing) and physical features of the barn, (light and sound, alley and exit design and loading dock design) on the stress response of pigs pre-slaughter. In brief, Goumon and Faucitano (2017) identified that the quality and design of the loading facilities, staff training and truck design play key roles in the ease of handling and stress experienced by pigs. Neophobia makes pigs reluctant to move, and methods to reduce this effect would be of use. The review also states that further research into the development of low-stress handling tools to load and unload pigs in challenging areas, research into understanding the interaction between group-size and alleyway/ramp width and implementation strategies to reduce fighting are needed.

Loading is one of the greatest challenges to stress and welfare during transportation, marked by increased heart rate, internal temperature, blood cortisol and lactate (Rioja-Lang et al., 2019). Factors affecting loading stress include group size and mixing, handling, and the design of the alleys, vehicle and ramp/platform to the truck. Several studies have reported increased stress behaviour, time to load and adverse physiological effects for pigs loaded into trailers/compartments via ramps (Conte et al., 2015, Fox et al., 2014, Torrey et al., 2013a, 2013b). Loading pigs in large groups (more than four pigs at a time) is also associated with increased heart rate and longer loading time, despite being a common practice on-farm (Goumon and Faucitano, 2017).

Moving pigs over internal trailer ramps is a challenging area, influencing pig stress and loading time. A tendency towards increased loading and unloading time has been observed in compartments with internal ramps and/or 180° turns, with pigs slipping more when unloaded from compartments with internal ramps (Torrey et al. 2013b). Pigs loaded by ramp onto the upper deck of a pot-belly trailer show increased heart rates and internal body temperature values in the summer than those loaded into lower compartments (Conte et al. 2015), confirming a greater physical exertion from climbing internal ramps. Use of hydraulic lift decks eliminates the need for internal ramps. Pigs loaded onto a double-deck truck using a hydraulic upper deck and a level entrance onto the lower deck had less variability in change in internal body temperature during winter and summer transport than those loaded via ramps onto a pot-belly (PB) trailer (includes internal ramps), (Conte et al. 2015). ***Modifications to the PB trailer are recommended to improve the ease of loading and unloading, and temperature variation between compartments, or alternatively, phasing out of the PB truck for more favourable designs.***

Brockhoff et al. (nd, unpublished) evaluated 30 loads of finisher pigs transported in either a hydraulic lift deck trailer (HD), or a pot belly trailer (15 loads/trailer design) for their effect on pig welfare during loading, transport and unloading. Trailer type strongly influenced pig behaviour and measures of welfare. Measures of pig welfare were worse in the PB trailer, with increased electric prod use, slips, falls, overlaps (pig jumping upwards and forward onto the animals adjacent/in front of it), vocalizations, slaps upon loading, and similar results for unloading.

However, there was an increase in slaps and vocalizations in the HD trailer at unloading, which may be a result of a group of pigs proving very challenging to leave the trailer. Between trailer types, loading and unloading times, and temperature and humidity measures were similar. The HD truck could transport the same number of pigs at a lower loading density, but is limited by axel weight requirements. ***It can be concluded that trailer design significantly influences pig behaviour and welfare at loading and unloading, with hydraulic lift decks being favourable for pig welfare, and easier for stockpeople to work within. The level of human/pig contact (slaps, prod use) observed at loading and unloading, suggests continual need for pig handling training to improve welfare, with emphasis on 'less is more', and the application of pressure and release for calmly moving pigs.***

Over three experiments (n=280 pigs each), Goumon et al. (2013) examined the effect of angle at the entrance to the ramp (AOE; 90°, 60°, 30°, or 0°), ramp slope (0°, 16°, 21°, or 26°), and use of an initial 20cm step up to the ramp on ease of handling, heart rate and pig behaviour. Pigs balked less frequently and required less handling when unloaded at entrance angles of 0° or 30°, with the best results at 30°. An AOE of 60° produced intermediate results, with the highest worker and pig heart rates, longest unloading time and poorest handling score and pig behaviour outcomes seen with a 90° AOE. Flat (0°) ramps provided the easiest unloading with the lowest number of balks and use of paddle or voice by handlers. A ramp angle of 21° had similar ease-of-handling results to flat ramps, but the steepest (26°) slope had the highest number of balks, backing up and use of handling techniques (touches, slaps and pushes), as well as the longest unloading times. Goumon et al. (2013) noted that the flat ramp configuration required pigs to move through a narrow corridor, which may explain the similar physical and psychological difficulty between the 0° and 21° ramps. Addition of a single 20-cm step up to the 16°, 21°, and 26° ramps increased the pigs' heart rate and increased physical difficulty for handlers; pigs were most reluctant to move up the step towards the 16° ramp. Ramp configuration plays an important role in the ease of loading in pigs. ***A steep ramp angle and an initial step are design features that are move aversive to pigs and make it harder to move them. The current trailer design in pot-bellies creates challenging conditions. In light of the greater risk of rough handling from pigs that stop, making modifications to loading facilities to reduce aversion will improve flow of pigs, which should reduce stress and welfare problems.***

To refine ramps currently used for loading and unloading pigs, Garcia and McGlone (2015) explored the separate and interactive effects of bedding types, ramp angles and bedding moisture on the time to load/unload, pig heart rates and the number of slips, falls and vocalizations. The parameters tested over 2,400 market pig observations were: Three ramp angles (0°, 10° or, 20°), five bedding types (nothing, sand, feed, wood/pine shavings, or wheat straw), two moisture levels (dry or wet bedding or floor), over two seasons (>23.9°C to <37.8°C summer, >−6.7°C to <23.9°C winter). Slope and bedding had no effect on scores of slips, falls and vocalisations, but heart rate and time to load and unload increased with increasing ramp slope. During the summer, all bedding types, except wheat straw on the ramp reduced the total time to load/unload; during the winter, wood shavings, feed and sand reduced heart rates significantly, especially at a 0° ramp slopes. The effects of moisture varied by bedding type and season, and no clear pattern was distinguished between wet or dry bedding during either season. ***These results suggest that adjustments to slope***

and bedding of ramps may be practical and relatively low-cost ways to improve efficiency of loading and unloading.

Potential alternatives to ramps include loading gantries and hydraulic tail-lifts, although little research has been conducted on these systems (Goumon and Faucitano, 2017). Berry et al. (2012) designed a prototype loading gantry from a metal-covered traditional chute. The loading gantry differed from the metal chute in having a flat pivot section fitted on each end of the chute, enabling the gantry to fit the angle at which trailers pulled up to the chute, and a cushioned bumper dock eliminated gaps from the barn to the loading gantry (total size: 91.4 cm wide x 3.1 m high x 9 m long). The sloped section of the chute was 7.9 m long (7° angle to the bottom deck, 18° to the top deck) with epoxy-coated metal flooring designed to replicate concrete and improve comfort for the pigs, easing the transition from pen to chute. Metal cleats spaced 20.3 cm apart were also added to form an 'inverted stair step' which reduced the loading angle by ~5°. Welfare measures were evaluated for 74 loads, and 497 loads were evaluated for performance measures (number of animals stressed or crippled on arrival, and in the plant), and transport losses, comparing the loading gantry to a traditional chute (76.2 cm wide x 2.3 m high x 4.6 m long) with metal presenting a 19° angle to the bottom deck and 23° angle to the top deck. ***Berry et al. (2012) found that all welfare measures (electric prod use, slips, falls, vocalizations and pile-ups) were improved with the use of the loading gantry. Performance measures were unaffected by treatment, but trailers loaded with the loading gantry tended to have fewer dead and non-ambulatory pigs upon arrival, saving 0.5 pigs/load; the authors noted that this would result in significant economic gains for producers.***

4.4 References

Berry, N.L., A. K. Johnson, J. Hill, S. Lonergan, L. A. Karriker, K. J. Stalder. 2012. Loading gantry versus traditional chute for the finisher pig: Effect on welfare at the time of loading and performance measures and transport losses at the harvest facility. J. Anim. Sci. **90**(11): 4028-4036.

Brockoff, E. (nd) Optimization of animal welfare through implementation of advanced movable livestock transport technology. Final Report, Prairie Swine Health Services, Red Deer, Alberta, Canada.

Conte, S., L. Faucitano, R. Bergeron, S. Torrey, H. W. Gonyou, T. Crowe, E. Toth Tamminga, T. M. Widowski. 2015. Effects of season, truck type, and location within truck on gastrointestinal tract temperature of market-weight pigs during transport, J. Anim. Sci. **93**(12): 5840–5848.

Correa, J.A., H.W. Gonyou, S. Torrey, T. Widowski, R. Bergeron, T. G. Crowe, J.P. Laforest, L. Faucitano. 2013. Welfare and carcass and meat quality of pigs being transported for two hours using two vehicle types during two seasons of the year. Can. J. Anim. Sci. **93**(1): 43-55.

Fox. J, T. Widowski, S. Torrey, E. Nannoni, R. Bergeron, H.W. Gonyou, J.A. Brown, T. Crowe, E. Mainau, and L. Faucitano. 2014. Water sprinkling market pigs in a stationary trailer. 1. Effects on pig behaviour, gastrointestinal tract temperature and trailer micro-climate. Livest. Sci. **160:**113-123.

Garcia, A. and J. McGlone. 2015. Loading and Unloading Finishing Pigs: Effects of Bedding Types, Ramp Angle, and Bedding Moisture. Animals. **5**(1). 13-26.

Goumon, S., L, Faucitano, R. Bergeron, T. Crowe, M.L. Connor, and H.W. Gonyou. 2013. Effect of ramp configuration on easiness of handling, heart rate and behavior of near-market pigs at unloading. J Anim Sci. **91**:3889–98.

Goumon S, Faucitano L. 2017. Influence of loading, handling and facilities on the subsequent response to pre-slaughter stress in pigs. Livest. Sci. **200**:6–13.

Newman, D., J. Young, C. Carr, M. Ryan, E. Berg. 2014. Effect of Season, Transport Length, Deck Location, and Lairage Length on Pork Quality and Blood Cortisol Concentrations of Market Hogs. Animals **4:** 627-642.

Pereira, T., E.A. Titto, S. Conte, N. Devillers, R. Sommavilla, T. Diesel, F.A. Dalla Costa, F. Guay, R. Friendship, T. Crowe, and L. Faucitano. 2018. Use of fan-misters bank for cooling pigs kept in a stationary trailer before unloading: effects on trailer microclimate, and pig behavior and physiological response. Livest. Sci. **216**:67–74.

Rioja-Lang, F. C., J. A. Brown, E. J. Brockhoff, and L. Faucitano. 2019. A Review of Swine Transportation Research on Priority Welfare Issues: A Canadian Perspective. Front. Vet. Sci. **6**:36.

Sommavilla, R., L. Faucitano, H. Gonyou, Y. Seddon, R. Bergeron, T. Widowski, T. Crowe, L. Connor, M. Scheeren, S. Goumon, and J. Brown. 2017. Season, Transport Duration and Trailer Compartment Effects on Blood Stress Indicators in Pigs: Relationship to Environmental, Behavioral and Other Physiological Factors, and Pork Quality Traits. Animals 7: 8.

Torrey, S., R. Bergeron, T. Widowski, N. Lewis, T. Crowe, J. A. Correa, J. Brown, H. W. Gonyou, and L. Faucitano. 2013a. Transportation of market-weight pigs: I. Effect of season, truck type, and location within truck on behavior with a two-hour transport. J. Anim. Sci. **91**:2863–2871.

Torrey, S., R. Bergeron, L. Faucitano, T. Widowski, N. Lewis, T. Crowe, J. A. Correa, J. Brown, S. Hayne, and H. W. Gonyou. 2013b. Transportation of market-weight pigs: II. Effect of season and location within truck on behavior with an eight-hour transport. J. Anim. Sci**. 91**:2872–2878.

Xiong Y, Green, A., Gates, R.S. 2015. Characteristics of trailer thermal environment during commercial swine transport managed under U.S. industry guidelines. Animals **5**:226–44.

5.0 Practical methods for assessing on-farm welfare

5.1 Conclusions

1. **On-farm assessments have a high level of inter-observer reliability when performed by correctly trained individuals. However, not all assessment programs that are reliable and feasible, accurately measure animal welfare. Assessment programs should be validated to ensure they are able to accurately assess the welfare of animals on-farm.**

2. **One study found that animal-based measures have a higher inter-observer reliability than resource-based measures. Resource-based measures must be precisely worded to support improved reliability. The majority of animal-based measures have high inter- and intra-observer reliability. However, certain measures (Qualitative Behavioural Assessment and bursitis) have been identified to have low reliability.**
3. **Certain animal-based measures are influenced by animal and housing factors. Relationships between environmental factors and animal-based measures of welfare provide evidence of certain environmental risk factors for welfare concerns.**
4. **Developing an index score from records of meat inspection, medicine treatment records and mortality does not reliably reflect the animal-based welfare measures captured through on-farm assessments.**

5.1.2 Knowledge gaps

Given the large breadth of work to be covered, the following research areas have value:

- Validation of novel measures that accurately reflect the welfare of pigs and can be used in a variety of systems
- Streamlining and validation of assessment schemes to detect welfare problems.

5.2. Research progress

Societal interest, and subsequently research, of animal welfare has increased rapidly in recent years (Renggaman et al., 2015). On-farm welfare assessments may include animal-, management- and/or environment- based measures to provide a comprehensive view of the welfare status of animals raised in farming systems. The parameters assessed may differ based on factors, including production stream (breeding animals, market hogs), standards/regulations and socioeconomic factors.

A review of the animal welfare standards and initiatives from eight European countries was performed to assess the scientific relevance of standards and their strengths and weakness with regards to protecting animal welfare. The review identified consensus between stakeholders that the steps to improve on-farm animal welfare should be animal and system-orientated, and scientifically based (Averos et al. 2013).

As an alternative to costly, routine inspections of farms, Knage-Rasmussen et al. (2014) designed an animal welfare index utilizing central farm database information of meat inspection, medicine records and mortality (DBWI). The DBWI measured six out of 12 Welfare Quality® criteria. Testing the DBWI against an on-farm animal welfare index of only animal-based measures (AWI) collected from 63 Danish sow herds found no linear association between the indices for any of the herds. This discrepancy may be because the study utilized data that did not cover the same animals in the same environment. The AWI was developed from data collected from each sow herd on one day, and the DBWI from data from each sow herd over a large period of time; 365 days prior to the AWI data collection. However, Knage-Rasmussen et al. (2014), had expected better agreement between the two indexes as the two protocols were measuring near the same Welfare Quality criteria, and expected that herd specific data related to housing and management could lead to similar results. ***Based on the data collected at meat inspection, medicine and mortality records for this study, the DBWI could not reliably replace the on-farm animal-based welfare measures (Knage-Rasmussen et al. 2014).***

On-farm animal welfare assessments typically include animal-, resource- and management-based measures. However, exactly which measures are used, and how many measures are used can vary widely. The inter-observer reliability (inter-OR) of assessment schemes, measures within assessment schemes, and the degree of agreement between three swine welfare assessment programs (Animal Care Assessment™ - Canada, Pork Quality Assurance Plus® - USA and Welfare Quality® - EU), to identify farms with welfare concerns has been assessed by Roberts et al., 2013 (unpublished). Training 10 observers in each of the three welfare assessment programs on five grow/finish farms (4-5 observers/farm), resulted in consistently high inter-observer reliability. The highest level of agreement between observers was for the Animal Care Assessment™ (ACA™), followed by Pork Quality Assurance Plus® (PQA Plus®) and then Welfare Quality®. Similarly, all three types of measures (animal, resource and management-based) had moderate to high inter-observer reliability. Management-based measures had the highest inter-observer reliability, followed by animal-based, then resource-based measures. Resource-based measures tended to be more open to interpretation; Roberts (2013) noted that assessments that ask whether a barn is in a 'good state of repair,' for example, are subjective and may differ in interpretation. In this trial, resource-based measures also had a higher non-response rate than other questions in the assessments. Certain animal-based measures had high reliability between assessment methods, farms and observers, including body condition scoring and measures of thermal comfort. While animal-based measures were found to have a high overall reliability (consistency), the animal based measures of the Welfare Quality® program (Qualitative Behaviour Assessment, QBA) were tested separately, and found to have a negative effect on the reliability of the assessment protocol; in particular, there was a high level of disagreement on measures of 'appropriate behaviour.' However, other animal-based measures may give a better picture of the actual welfare status of the animals than resource-based or management-base measures, which should be considered alongside the reliability and feasibility of assessments.

Roberts et al. (2013) went on to assess 20 Canadian farms with each of the three assessment programs and identified only a moderate level of concordance among the rankings of farms. There was no evidence of concordance in the highest ranked farms for grow-finish measures, and a moderate agreement between the three assessments in the lowest ranked farms. The moderate concordance values were higher than would be expected by chance (Kendell's coefficient of concordance = 0.5), but were below the acceptable threshold of 0.7. ***Farms that were deemed compliant by ACA and PQA Plus, were not deemed so by Welfare Quality, and vice versa. This may be related to the different areas of focus in the assessment programs. The results suggest that correctly trained, there can be high level of inter-observer reliability between assessors in the scoring of farms. Wording of resource-based measures needs to be precise and descriptive to support better reliability in assessment of these measures. Yet, an assessment can be reliable, valid and feasible, but not accurately assessing animal welfare. The ACA and PQA Plus were easily performed on farm, but composed of many measures that did not look at the animal.***

Future work should validate welfare assessment protocols to ensure they can actually assess welfare, and include a combination of animal, resource and management-based measures.

Behaviour is an important component in the assessment of animal welfare. The expression of normal behaviour is important for the welfare of pigs and deviations in behaviour provide indications of the animal responding to stressors within its environment. For these reasons, behaviour should be considered in the assessment of animal-welfare. To date, methods for assessing behaviour have been subjective. Temple et al. (2011) assessed the fourth Welfare Quality® principle, 'Appropriate Behaviour,' using 12 independent criteria that included: measures of social and exploratory behaviour, human-animal relationship and a qualitative behaviour assessment (QBA) rating scale, on 25,856 pigs over 21 Iberian pig farms (11 extensive and 10 intensive), to evaluate the occurrence of and difference in behaviour measures between pigs raised in intensive and extensive systems. From this data evaluations of the validity of such measures can be understood. Negative and positive social behaviours were significantly more frequent on intensive farms, but exploratory behaviours and frequency of a panic response to the human-animal relationship test did not differ. Extensively reared pigs scored significantly higher on the QBA rating scale; a higher score corresponds to more animals assessed as "happy, content, enjoying, positively occupied and lively" than in intensive rearing. Lower scores in intensive rearing resulted from animal assessments including "boredom, frustration and tension". ***The authors concluded that while the behavioural assessments relied on subjective interpretation, collection of behavioural measures was able to discriminate between farms on the basis of the assessment of behaviours. Interpreting the frequencies of the various behaviours (i.e. frequency of positive behaviours), in terms of animal welfare must be done so with caution, especially when scoring farms with diverse rearing systems, as these behaviours are sensitive to changes in housing conditions, and observers may also be bias in different systems.***

Precision livestock monitoring tools are being developed to detect deviations in behaviour, including a study by Diana et al. (2019) to measure increases in biting behaviour. There is potential that extraction of such data could be used for farm welfare assessments.

The Welfare Quality® assessment protocol contains the greatest number of behavioural indicators for pigs of any assessment tool. The inter-observer reliability of the Welfare Quality® assessment program was evaluated by three trained assessors, evaluating 24 German farms in pairs, completing 29 total assessments (Czycholl et al. 2016). Measurements of 'Individual Parameters' such as coughing, wounds, tail biting and lameness were generally reliable, except for the parameter 'bursitis,' which was found to be inadequately defined in the protocol and not a good measure of comfort around resting. The overall QBA scores assigned on each farm were deemed to have "acceptable" inter-observer reliability, but no direct agreement was found for any of the descriptive adjectives scored (e.g. happy, relaxed, lively). The interobserver reliability of behavioural observations (social behaviours, exploration) was acceptable, with moderate to good agreement between observers (Czycholl et al. 2016). ***The Welfare Quality® assessment was found to be useful, with good reliability on most observation parameters, but not for the parameters bursitis and QBA.***

The Common Swine Industry Audit (CSIA), a comprehensive animal welfare assessment protocol was developed by the National Pork Board in 2015 to address the need for a standardized audit platform in the U.S. swine industry (Pairis-Garcia and Moeller, 2017). The CSIA is the first nationally recognized audit for American swine producers. The audit uses a three-point score system for 27 key aspects of animal-based, resource-based and food safety measures, with five critical failure criteria assigned either pass or fail (animal abuse and the processes: equipment, timeliness and effectiveness of euthanasia). Readers should refer to the article for a full description of CSIA welfare measurements, scoring and acceptability thresholds for animal-based measures.

Conte et al. (2014) conducted an experiment to evaluate quantitative animal-based measures of sow welfare, and to understand how housing, parity and stage of gestation influenced the outcome of these measures. Sows (n = 311) from across 10 farms in Canada were examined over a two-day period on each farm for measures of lameness, oral stereotypies and reactivity to humans. Housing variations included, pens, stalls, partially vs fully slated flooring, and floor or trough feeding. The reliability of common welfare assessment categories (gait score, approach test, handling test, stereotypy observation) was measured against behavioural observations. Lameness (gait score of 2 or 3) was accurately predicted for stall-housed sows by measuring walking speed and stride length; the probabilities of lameness for sows with a stride length shorter than 83 cm or walking speed less than 1 m/s were 69% and 72% respectively. However, these measures did not hold true for pen-housed sows. Saliva foam around the mouth was a moderately accurate (63%) method of detecting sham chewing and fixture biting but was only present in 41% of sows engaging in oral stereotypies. A discrimination index was calculated for approach and handling tests to evaluate the ability of these measures to identify sow reactivity as high or low. Latency to exit the stall and the number of handler interventions required to make the sow exit were reliable indicators of reactivity. In pens, reactivity was predicted by exploration, vocalization during approach, isolation, and escape attempts after isolation. ***The outcome of several welfare measures was influenced by sow parity, stage of gestation and housing/feeding system, and these factors should be considered for the interpretation of the measures. No measures accurately predicted lameness, stereotypies or reactivity in all sows. Continued work is necessary to determine objective measures that can be used consistently in a variety of housing systems, and the establishment of threshold values (Conte et al. 2014).***

Inter-observer reliability (inter-OR) and intra- observer reliability (intra-OR) plays an important role in the accuracy of assessing animal-based measures. An evaluation of observer reliability was performed by Pfeifer et al. (2019) during mandatory on-farm self-assessments of animal welfare indicators in Germany. Three observers assigned scores for tail length, skin, ear and tail lesions, lameness and fecal soiling, using the welfare indicator recommendations of The Association for Technology and Structures in Agriculture, Germany, (n=537 finishing pigs/repetition x 8 repetitions, total n=4,292). Scores for each pig were assessed separately for inter-OR and intra-OR using intra-class correlation coefficients (ICC); and a ranking scheme applied to classify reliability of an ICC as poor, fair, good or excellent. Inter-OR was ranked as ‘excellent’ for tail length, skin lesions and ear lesions, ‘fair’ for fecal soiling and tail lesions, and ‘poor’ for lameness. In contrast, intra-OR was ranked as ‘excellent’ for fecal soiling and ear lesions, ‘good’ for skin lesions, tail length and lameness, and ‘fair’ for tail lesions – which was considered unsatisfactory for its use as an assessment measure (Pfeifer et al. 2019). ***The use of such indicators within farm was suitable for making farmers aware of the implications for the welfare of their livestock. However, due to the variability in inter and intra-OR, the use of such indicators can only be recommended when evaluated by the same observer. Therefore, their use for benchmarking between farms should be viewed critically. Based on this, Pfeifer et al. (2019) suggest on-farm welfare assessments using these animal-based measures are likely reliable when measured by a single observer but vary more widely in accuracy between observers.***

Munsterhjelm et al. (2015a) assessed the accuracy of the animal-based measures in the Welfare Quality® program to identify distinct welfare problems on 158 Finnish pig farms (95 grow-finish and 103 farms with suckling piglets). No significant inter-item correlations were found for suckling piglets, so subsequent Principal Component Analysis (PCA) was performed only for grow-finish pigs. The highest inter-item correlations were: i) severe wounds and skin condition with pneumonia and pleurisy condemnations, ii) moderate bursitis and exploratory behaviour towards pen fittings, and iii) liver and pneumonia condemnations. Three welfare problems were extracted by PCA: fighting, lack of bedding and disease; animal-based measures strongly correlated with each welfare problem; wounds to fighting, exploring pen fittings and bursitis to lack of bedding, and negative social behaviours to disease. QBA descriptors were also grouped based on correlation with three mood types: active positive behaviour, passive positive behaviour and passive negative behaviour. Secondary analysis was then performed (Munsterhjelm et al., 2015b) to investigate the linear association of the environment on the assessed farms (space allowance, group size, feeding arrangement, floor type and use of enrichment or bedding) with welfare problems and mood. The most important environmental effects identified were bedding, space allowance for fattening pigs, group size for sows. Thick bedding (>50% of the floor covered) was associated with a decrease in tail wounds and signs of fighting in fattening pigs and reduced measures of frustration and bursitis in sows. Increasing space allowance up to 1.5 m^2/pig in fattening pigs decreased tail lesions and improved mood; however, fighting increased in bedded pens over 1.5 m^2/pig. Signs of 'lack of resources' in sows (vulva lesions, poor skin and body condition, wounds) increased with increasing group sizes. ***The results of these two studies identify that associations between environmental conditions and the animal-based welfare measures exist. This information can be used to identify environmental hazards for certain types of welfare problems (Munsterhjelm et al. 2015b).***

Identification of novel, practical indicators continues. Tear-staining, the accumulation of dark, red-brown staining under the inside corner of the eye, has long been used as an indicator of distress and poor welfare in lab rats (Baumans, 2004). The value of tear staining to assess welfare in pigs is now being assessed. The relationship between tear staining and three production stressors, docked or undocked tails, barren vs enriched (straw) and low (1.2 m^2/pig) or high (0.73m^2/pig) stocking density), was assessed over 80 pigs by Larson et al. (2019). Measuring tear-staining on a five point scale, the probably of a tear-stain >1 was higher in pens with evidence of tail-damage, than in those with no damage, and tear-staining scores of four increased the week before a tail-damage event, but this occurred in pens that did and did not have a tail-biting event. Over the trial period, and with higher average daily gain, the probability of a tear-staining score of 1 or 2 decreased while scores of four increased, indicating a relationship between tear-staining and age/growth. Straw and stocking density did not affect tear-staining, but pens with docked pigs had more pigs with tear-staining of one. ***The results indicate that tear-staining may not accurately reflect pen-level stress, but more research may clarify the use of tear staining as a welfare assessment tool.***

5.3 References

Averos, X., M.A. Aparicio, P. Ferrari, J.H. Guy, C. Hubbard, O. Schmid, V. Ilieski and H.A.M. Spoolder. 2013. The Effect of Steps to Promote Higher Levels of Farm Animal Welfare across the EU. Societal versus Animal Scientists' Perceptions of Animal Welfare. Animals. **3:**786-807.

Baumans, V. 2004. Methods for evaluation of laboratory animal well-being. Alternatives to Laboratory Animals. **32**: 161–162.

Conte, S., R. Bergeron, J. Grégoire, M. Gète, S. D'Allaire, M.-C. Meunier-Salaün, and N. Devillers. 2014. On-farm evaluation of methods to assess welfare of gestating sows. Animal **8**:1153–1161.

Czycholl, I., C. Kniese, K. Büttner, E. grosse Beilage, L. Schrader and J. Krieter. 2016. Interobserver reliability of the 'Welfare Quality® Animal Welfare Assessment Protocol for Growing Pigs.' SpringerPlus. **5**:1114.

Dianaa, A., L. Carpentierc, D. Piettec, L.A. Boyle, D. Berckmans, and T. Norton. 2019. An ethogram of biter and bitten pigs during an ear biting event: first step in the development of a Precision Livestock Farming tool. Appl. Ani. Behav. Sci. **215**: 26-36.

Knage-Rasmussen, K. M., T. Rousing, J. T. Sørensen, and H. Houe. 2014. Assessing animal welfare in sow herds using data on meat inspection, medication and mortality. Animal **9:**509–515.

Larsen, M. L. V., A. Gustafsson, J. N. Marchant-Forde, and A. Valros. 2019. Tear staining in finisher pigs and its relation to age, growth, sex and potential pen level stressors. Animal:1–8.

Munsterhjelm, C., M. Heinonen, and A. Valros. 2015a. Application of the Welfare Quality® animal welfare assessment system in Finnish pig production, part I: Identification of principal components. Anim. Welfare **24**(2):151-160.

Munsterhjelm, C., M. Heinonen, and A. Valros. 2015b. Application of the Welfare Quality® animal welfare assessment system in Finnish pig production, part II: Associations between animal-based and environmental measures of welfare. Anim. Welfare **24**(2):161–172.

Pairis-Garcia, M., and S. J. Moeller. 2017. ANIMAL BEHAVIOR AND WELL-BEING SYMPOSIUM: The Common Swine Industry Audit: Future steps to assure positive on-farm animal welfare utilizing validated, repeatable and feasible animal-based measures. J. Anim. Sci. **95**:1372.

Pfeifer, M., L. Eggemann, J. Kransmann, A. O. Schmitt, and E. F. Hessel. 2019. Inter- and intra-observer reliability of animal welfare indicators for the on-farm self-assessment of fattening pigs. Animal: **1**–9.

Renggaman, A., H. L. Choi, S. I. Sudiarto, L. Alasaarela, and O. S. Nam. 2015. Development of pig welfare assessment protocol integrating animal-, environment-, and management-based measures. J. Anim. Sci. Technol. **57**.

Roberts, A.N. 2013. A Comparison of Three Animal Welfare Assessment Programs on Canadian Swine Farms. M.Sc. thesis, University of Guelph, Guelph, ON. pp. 58-130.

Temple, D., X. Mantecaa, A. Velarde, and A. Dalmau. 2011. Assessment of animal welfare through behavioural parameters in Iberian pigs in intensive and extensive conditions. App. Ani. Behav. Sci. 131: 29-39.

6.0 Implications of high welfare systems on stockpersons

6.1.1 Conclusions

1. **Stockpeople play a critical role, and influence animal welfare and productivity. Understanding the factors that influence attitudes and providing the appropriate training, based on this knowledge, is required to improve stockpersonship and animal welfare.**

2. **Improving the workplace environment may help improve animal husbandry.**

3. **Longer-term strategies to develop a work force of highly skilled stockpeople should be considered. Daigle and Ridge (2018) propose an approach.**

4. **The implications of high welfare systems for stockpersons is under-researched.**

6.1.2 Knowledge gaps

This area is under-researched, and thus lots could be done. Two examples are given.

- Understand how attitudes and job satisfaction differ in stockpeople working in conventional vs higher welfare systems.
- Benefits to stockpeople from improving the human-animal relationship/implementation of management practices to confer improved welfare to pigs.

6.2 How to improve stockmanship

A review by Zulkifi (2013) reviewed the existing knowledge on how human-animal interactions influence animal physiology, productivity and welfare and highlights important role that the quality of stockmanship plays in animal welfare and productivity. This presents opportunities to improve performance and animal welfare through appropriate training. ***The attitude a stockperson has towards animals will strongly influence their behaviour towards the animals in their care. Recognizing this and understanding how to affect beliefs and change attitudes is important when developing training programs for stockpeople.***

The major factors that contribute to a stockpersons work performance have been identified as: capacity (skills, health, ability, knowledge), willingness (motivation, job satisfaction, attitude to the animals and work) and opportunity (working conditions, policy, actions of co-workers), (Coleman and Hemsworth, 2014). Recommendations for improving stockmanship posed by Coleman and Hemsworth (2014) consider the Theory of Planned Behaviour, and suggest that cognitive-behavioural training (or re-training) of stockpersons is recommended based on studies demonstrating improvement in attitudes and behaviour of workers when problematic beliefs, attitudes and behaviours are addressed. Cognitive-behavioural training includes provision of information on the proper handling of livestock and the benefit of fear reduction, and the adverse effects associated with negative stockperson behaviour. ***The role of the stockperson to impact animal welfare and productivity should not be underestimated, and specific stockperson training is required to improve key aspects of stockpersonship related to welfare.***

Daigle (2016) suggests that incorporating stockmanship into agriculture and animal science- based higher education curricula could have a sizeable impact on improving animal husbandry. As urbanization expands, fewer students entering agricultural university programs have hands-on animal experience. Education on animal behaviour and livestock handling may remove barriers to entry into the industry for inexperienced students by providing them with knowledge on how to work with animals confidently, safely and humanely. ***Including stockmanship in higher education could improve the quality and skill of the livestock industry workforce.***

Daigle and Ridge (2018) identify factors contributing to the shortage of good stockpersons including urbanization, lack of skill/experience and training, low wages, high turnover and the emotional valence and attitude of individual stockpersons towards animals. Occupational psychology research indicates that respect, promoting self-confidence and a positive emotional workplace culture contribute to job satisfaction and well-being; improving the workplace environment may improve stockperson attitude and job performance, thereby improving animal husbandry. Daigle and Ridge (2018) recommend exploring whether the provision of higher salaries and education influence stockperson behaviours, retention, animal welfare, applicant pools. Greater value should be placed on the profession of stockperson; they are key to the success of swine production and animal welfare, and the profession requires expertise, empathy and endurance (Daigle and Ridge, 2018). ***A longer-term strategy may be required to support the development of highly-skilled stockpersons. Daigle and Ridge (2018) propose that promoting a greater awareness of the profession, defining expectations, emphasizing the importance of the profession to animal welfare and agriculture, and providing the right education, which may involve inclusion of animal husbandry in the university curricula, are valuable strategies (Daigle and Ridge, 2018).***

6.3 Implications of high welfare systems on stockpersons

Despite extensive research on improving animal welfare in intensive production systems, no research was found on the implications of high welfare systems on stockpersons. Anecdotal discussions are available, such as that by Levis and Connor (2013).

6.4 References

Coleman, G. J., and P. H. Hemsworth. 2014. Training to improve stockperson beliefs and behaviour towards livestock enhances welfare and productivity. Rev. Sci. Tech. **33**:131–137.

Daigle, C. L. 2016. In search of the urban cowboy: the need to incorporate animal husbandry into the united states higher education curriculum and its implications for production animal welfare. Front. Vet. Sci. **3**:84.

Daigle, C. L., and E. E. Ridge. 2018. Investing in stockpeople is an investment in animal welfare and agricultural sustainability. Animal Frontiers **8**:53–59.

Levis D.G., and L. Connor 2013. Group Housing Systems: Choices and Designs. National Pork Board: Des Moines, IA, USA.

Zulkifli, I. 2013. Review of human-animal interactions and their impact on animal productivity and welfare. J. Anim. Sci. Biotechno. **4.**

7.0 Enrichment

7.1.1 Conclusions

1. **Straw is one of the most effective materials for reducing tail biting in pigs.**
2. **The position of point-source (fixed) enrichments within the pen affects enrichment use and pig behaviour.**
3. **A range of practical applications for slatted systems has been explored. Offering several objects that have properties known to be attractive to pigs is most effective at reducing behavioural vices. However, the cost-benefit of implementing an effective enrichment routine has not been evaluated.**
4. **In slatted systems, enrichment interaction may be increased when a variety of slat-compatible, pig appropriate, enrichments are provided. An olfactory stimulus can increase interaction with enrichment, but its effectiveness may depend on the olfactory stimulus, and pig age.**
5. **Effective enrichment (a combination of social, and physical – rooting substrates) can reduce disease susceptibility to PRRSv and co-infection with APP. Research concerning whether point-source enrichments can influence disease susceptibility is in progress.**
6. **The development of pig appropriate, slat compatible enrichments is being explored (i.e foraging towers and foraging blocks), but more research is required in this area.**
7. **Producers who raise undocked pigs provide manipulable materials for enrichment. One study provides evidence that a combination of slat-compatible, manipulable materials can be used to raise undocked pigs in slatted systems. More trials of longer duration must be performed to confirm prolonged ability of such enrichment to reduce tail biting.**
8. **Provision of manipulable, chewable materials early in life (pre-weaning) provides more pronounced benefits to influence pig physiology and reduce behavioural vices.**

9. **Sows show a preference for enrichment properties; chewable, deformable, rootable, ingestible, manipulable. When presented, straw is most preferred, followed by cotton rope over wood and plastic items.**
10. **Point-source enrichment does not reduce aggression in sows, and may increase aggression if the resource is valued.**
11. **Nutritional enrichment (a foraging block) modified the behaviour of sows at mixing, with evidence suggesting a reduction in aggression. However, the relationship between competition for a nutritional enrichment vs the effects of the ingestion of the enrichment to influence sow behaviour needs to be explored.**
12. **Provision of a burlap strips to sows prior to farrowing resulted in a reduction in stillborn piglets.**
13. **The role of human enrichment has good potential. Initial studies have found changes in a neurotransmitter associated with increased stress resilience in gestating sows receiving human enrichment.**

7.1.2 Knowledge gaps

- Slat compatible, practical and effective enrichment options for all ages of pigs, including cost-benefit analysis.
- How do different types of enrichment (auditory, positive human-animal interactions, social) influence pig welfare and productivity, and what is the mechanism of action.
- The role of nutritional (ingestible) enrichments on sow aggression, and disease resilience in growing pigs.
- Automation of enrichment strategies.
- Improving the human-animal relationship to enhance quality of life in pigs (and stockpeople).
- Use of enrichment as a production tool. How can enrichment be used to help various production challenges?
- Enrichment for sows in group housing – interaction with housing system to tailor management.

Section 1.8 of the Code of Practice (NFACC, 2014, pp.19) requires that ‘pigs must be provided with multiple forms of enrichment that aim to improve the welfare of the animals through enhancement of their physical and social environments.’

It is widely accepted that to be effective, enrichment should improve the biological functioning of the animal (Newberry, 1995).

Mkwanzi et al. (2019) identified that enrichment is successful when it:

1) Increases the frequency and/or range of natural behaviours performed;
2) Prevents or reduces the frequency or intensity of abnormal behaviours;
3) Improves quality or frequency of utilization of the environment;

4) Improve the pigs' abilities to cope with and respond to behavioural and physiological challenges.

The vast majority of research has focused on application of occupational, physical, sensory and nutritional enrichment.

7.2 Practical applications

Within fully slatted systems, point source enrichment (objects that are suspended or in a fixed position within the pen), is typically provided. The location of enrichment within the pen has been found to influence the amount of interaction with the enrichment. Growing gilts, penned in groups of three (n=48, 2m^2/pen), studied over seven weeks, and provided with pine wood enrichment secured to the wall 30-40 cm from the feeder, or secured on the opposite wall (Fig. 1, treatments split 50/50) were studied by Dalmau et al. (2019). Pens of gilts spent an average of 29% of observations performing exploratory behaviours, of which 25.2% was directed towards the pen, and only 4.4% towards the enrichment material. Pigs interacted more frequently (6.3% of observations) with wood located close to the feeder than opposite the feeder (2.5% of observations). Pens with wood close to the feeder also rested less and engaged in more social behaviours, both positive (sniffing, nosing, licking, no flight reaction or aggression) and negative (biting, fighting). Exploratory behaviour in all pens was significantly higher in week one than any subsequent weeks, indicating the importance of maintaining novelty to support pigs sustaining interest in the enrichment (Dalmau et al. 2019).

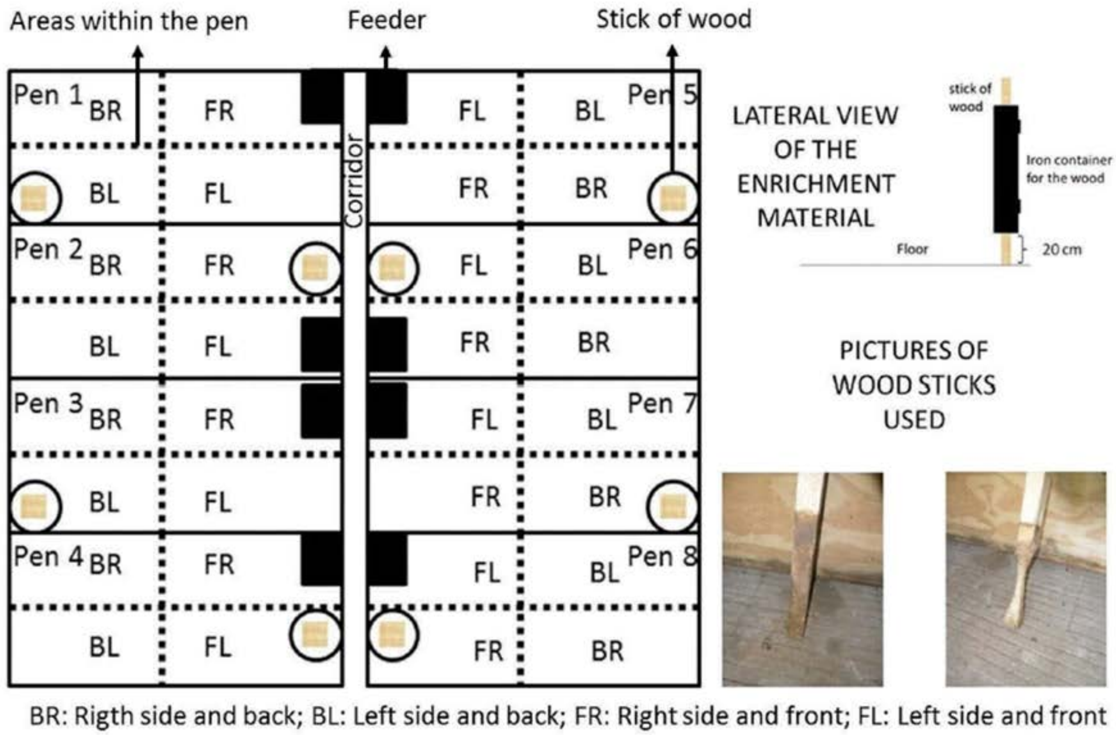


Figure 1. Distribution of the pens in Room 1 and Room 2 (both exactly the same) according to the location of the feeder and the enrichment material. The black box represents the feeder, and the square in the circle represents the wood. For focal sampling, the pen was divided with two imaginary lines into four areas: front left and right (FL and FR, respectively) and back left and right (BL and BR, respectively).

Figure 1. Image from: Dalmau et al. (2019).

Dalmau et al. (2019) identified that position of enrichment placement will affect use, and influence pen activity and social behaviours, however, further work to refine placement should be performed. For example, enrichment by the feeder may increase competition, and thus placement of enrichment more towards the centre of the pen may be of use, but has not been studied. Given that placement affects use and behaviours within the pen, understanding how placement can maximize enrichment benefits would be of value. Concentrating point source close to the feeder may also interfere with feeder use in larger group sizes.

As noted by Dalmau et al. (2019), enrichment use tends to decline over time, particularly if enrichment is static and/or of low biological relevance. The level of interest maintained in enrichment objects is dependent on the properties of the objects (Beaudoin et al. 2019). Habituation to the object(s) will therefore reduce the efficacy of enrichment provision on health and welfare. However, frequent rotation and/or replacement of objects increases cost and labour. Cotton rope has been found as a useful enrichment for pigs, with interaction levels similar to that found with straw provision (Trickett et al. 2009). However, novelty value needs to be maintained. Rotation of point source objects and provision of new material temporarily increases interaction with objects (Trickett et al. 2009). Combining two objects with different properties into one item (i.e. rope and wood in one point-source point), has been found to be additive, rather than provision of the two items in two separate point source areas (Tricket et al. 2009). However, interaction overall still remains low.

A study by Blackie and da Sousa (2019) is the first to report high levels of renewed interest in enrichment. Blackie and da Sousa (2019) tested whether the provision of an olfactory stimulus, ropes flavoured with garlic oil (30 mL oil: 1L water, dried overnight), increased interaction with enrichment for weaned pigs. Weaned pigs (n=146) were divided into groups of 25 pigs/pen; each pen had one plain cotton rope (control) and one rope dipped in garlic oil attached by chains on opposite ends of the pen. Garlic oil (10 mL oil: 500 mL water) was reapplied on day eight of the two-week trial. Daily focal sampling of 10 pigs/pen revealed significant differences in the frequency and duration of interactions with each rope. A greater number of pigs interacted with the garlic rope (84% of observed rope interactions), and more time was spent interacting with the garlic rope (17.2% of daily activity budget) than with other pigs (14%) or the control rope (4.3%). Reapplication of garlic oil on day eight increased interactions with that rope by 17.5%; this also corresponded with a 73% increase in total activity from day seven to day eight. ***This study suggests a preference for olfactory over non-olfactory enrichment in pigs and, demonstrates the use of garlic oil for this purpose. Use of food grade essential oils to stimulate interaction with enrichment is a potential area of research worth investigating. There may be a role of improving animal wellbeing and productivity through use of olfactory enrichment, to retain novelty, whilst also having the benefits of the olfactory molecules acting on their physiology.***

Enrichment provision can be complicated in fully slatted pens where loose foraging materials like straw are not an option. This is especially problematic when using enrichment to prevent tail biting in undocked pigs; Chou et al. (2019) designed a study to test practical applications of multiple 'slat-compatible' enrichments and their effectiveness to support raising undocked pigs (n=96) in a fully-slatted system. Four combinations of eight different items with various properties known to be attractive to pigs (Table 1) were used. To investigate the role of novelty, pigs were either given the same combination of items continuously from weaning to finishing (SAME) or received a new combination every two weeks (SWITCH). Across all treatments, tail lesions increased, and ear lesions decreased from weaning to finishing. However, all average tail scores were low with only one pig (SAME treatment) receiving severe tail lesions (a partially amputated tail); ear lesions and tear staining were also low and not significantly correlated with any treatment. Additionally, no differences in behaviour were observed between treatments. Weaner pigs interacted with all enrichment more frequently than finishers, but finisher pigs interacted with loose material in a container more often than weaners. Across all ages, material in a rack was interacted with significantly more than any other object; wood posts and hanging blocks were the least preferred items. Notably, interaction with all enrichment did not decrease over time with any treatment combination. ***The results from this study suggest it is possible to rear pigs in fully-slatted system undocked, when provided with a large number and variety of slat-comparable enrichment items. The enrichment objects and combinations tested by Chou et al. (2019) contained the properties known to be attractive to pigs and were effective at maintaining novelty and minimizing tail biting in undocked pigs raised in a conventional fully slatted system. However, this study did not evaluate a negative control of no, or little enrichment. Therefore, it is not possible to be sure if the tail biting was low in this barn during the period of study, or whether it truly was related to***

the enrichment use. The enrichment combinations for this study are complex, and readers should refer to Chou et al. (2019) for further details. Given that tail biting is multifactorial, and this is a one-time study on a limited number of pigs, longer-term studies would be needed to confirm if this approach can maintain a reduced level of tail-biting over seasons. The cost-benefit to maintaining this level of enrichment would also need to be explored. Given that there are farms raising pigs undocked in partially slatted systems through provision of straw in a rack, how to altering the design of the slurry system to manage a quantity of fiberous material may be of interest in the longer-term.

Table 1. Enrichment categories used by Chou et al. (2019).

	Properties [19]					
Categories	**Rootability**	**Durability**	**Edibility**	**Presentation**	**Texture**	**Location**
1. Common item *	-	-	-	-	-	-
2. Floor toy	Yes	Deformable	Chewable	Movable	Soft	Floor
3. Wood post	Yes	Destructible	Edible	Attached	Hard	Floor
4. Hanging wood	No	Destructible	Edible	Suspended	Hard	Eye level
5. Loose material (long rack)	No	Renewed	Edible	Attached	Loose	Eye level
6. Fabric	No	Destructible	Chewable	Suspended	Soft	Eye level
7. Hanging chewtoy	No	Deformable	Chewable	Suspended	Soft	Eye level
8. Loose material (container)	No	Renewed	Edible	Suspended	Loose	Eye level

* The same item was present in all pens (an Easyfix® floor toy for weaners and a Piglyx® lick block for finishers).

A limited number of companies have developed commercially available foraging blocks as swine enrichment for unbedded systems. Rault et al. (2018) measured brain-derived neurotrophic factor (BDNF) in blood serum to identify the effectiveness of enrichment provision. It is believed that BDNF mediates the effect of environmental enrichment on the brain (Chourbaji et al. 2011), and hence BDNF could act as a marker of effective enrichment. Higher concentrations of BDNF are linked to greater stress resilience, learning and memory (Rault et al. 2018). Pigs were raised in either barren pens or ones enriched with a foraging block (moveable, malleable, chewable) before and/or after weaning, creating four treatment combinations. The concentration of BDNF tended to be higher in pigs enriched before weaning, while enrichment provided after weaning did not change BDNF concentrations. ***While the interaction with the foraging block was not measured in this study, the results of Rault et al. (2018) indicate that peripheral BDNF concentrations may accurately reflect a physiological response to enrichment. Thus, BDNF may be an indicator of physiological change that results in improved stress resilience. From this, BDNF could have value as a marker of effective enrichment. This study also shows that the timing of enrichment influences physiological changes in pigs, with early life exposure having a greater effect, corresponding to a period of intense brain development (Rault et al. 2018).***

There is evidence that complex enriched environments influence disease susceptibility: Van Dixhoorn et al. (2016) compared two groups (n=28/treatment) of piglets raised from birth in either a barren pen (5 m^2, 100% slatted floor and a 100x45cm solid rubber mat with two blocks on chains for enrichment) or an enriched pen (10 m^2, 40% slatted and 60% solid floor). Enriched pens were given 1 kg straw, 160 L of moist peat and 180 L of wood shavings (with 0.5kg of straw and 23L of wood shavings replenished daily) as rooting substrate, and two jute bags, branches of a broom, and two chains with blocks of wood. Jute, peat and broom branches were replaced weekly. From day 13 post birth, enriched litters were co-mingled with the adjacent litter by removing the central divider between pens, creating a total area of 20m^2. Barren pens contained two blocks of wood on chains permanently present, to meet EU enrichment legislation. On day 39 of life, piglets were weaned and moved to pens with the same group structure and environmental conditions they were raised in, with piglets mixed within treatment. On day 44, two barren and two enriched groups (7 pigs/group) were co-infected with Porcine Reproductive and Respiratory Virus (PRRSv) and *Actinobacillus pleuropneumoniae*. Four control groups (two barren and two enriched) were not inoculated; one group of each housing type were maintained as negative controls and the other groups received the same handling as the infected pigs (mock control) but were not inoculated. Enriched pigs had a significantly reduced disease susceptibility: they cleared PRRSv faster in blood serum, developed fewer lung lesions, had lower pathologic lung tissue damage, and had 2.8-fold less interstitial pneumonia signs in the lungs than positive controls. Stress-related behaviours including mounting and oral manipulation of other pigs and pen fittings were significantly more frequent in barren-housed pigs during infection. Aggression, skin lesions, social behaviour and play did not differ between treatments. ***Van Dixhoorn et al. (2016) subsequently concluded that the enrichment protocol significantly improved the immunological response to PRRSv and co-infection with A. pleuropneumoniae infection while improving clinical outcome and behavioural indicators of stress. However, this study tested a complex enrichment protocol involving increased space allowance and multiple rooting substrates and point-source materials; this application may not be practical on commercial farms, but demonstrates the important role that housing and social conditions play to influence the stress and disease susceptibility of swine.***

An ongoing study is being conducted by Seddon et al. (2019) on the effect of point-source enrichment on the immune response, disease resilience and measures of welfare in pigs. This study tests the practical application of inexpensive and readily available materials (PVC pipe, cotton rope, jute, rubber rooting mats, tarpaulin and commercially available pig ‘toys’), rotated three times weekly, during a multi-pathogen PRRSv disease challenge in young pigs (beginning at 40 days of age).

7.3 The use of enrichment to manage behavioural vices

Two recent studies have explored daily straw provision to manage tail biting in grow-finish pigs. Wallgren et al. (2016) surveyed how pigs with intact-tails are raised, and how tail-biting is handled in Sweden, where tail-docking is banned through national legislation. A phone survey regarding tail biting prevalence and related management practices was conducted on 60 farms raising undocked nursery and/or finishing pigs in Sweden. Ninety-eight percent of farmers reported straw use, of which the median quantities provided daily were 29 g/nursery pig and 50 g/finisher pig in systems with partially slatted flooring. The two farms that did not provide straw provided sawdust or wood shavings. Additional manipulable rooting materials (sawdust, wood shavings, peat, meal) were provided in 39% of nursery barns and 33% of finisher units. Concern over manure system management was the most commonly expressed reason that farmers stuck to restricted straw rations, but a large percentage did not report having manure handling issues with their present straw ration (56% of nurseries and 81% of finisher units). Seventy-six percent of farmers provided chopped straw, which could contribute to the low occurrence of problems with manure handling. The most common manure handling system was also a roe/cable and arm scraper, while only one farmer had slurry, but reported never having problems. Tail biting was reported in 50% of nurseries, a max of two outbreaks per year (mean of 1.6 pens affected/outbreak) and 88% of finisher units, with a range of 3-6 outbreaks per year (mean 1.5 pens affected/outbreak and 1.6% of pigs bitten/batch at slaughter). ***While it should be considered that all answers were self-reported by the farmers interviewed, results of the survey indicate that where pigs are raised undocked, all farms report supplying manipulable material. The majority provide a limited quantity of straw daily, reporting few manure handling problems and low incidence of tail biting. How cost of production is influenced by this quantity of straw use, compared to the benefit to production has not been explored.***

As previously mentioned, ***Chou et al. (2019) propose it is possible to rear pigs in fully-slatted systems undocked, when provided with a large number and variety of slat-compatible enrichment items.*** The enrichment items must contain properties known to be attractive to pigs, and be effective at maintaining novelty, or be rotated to do so. ***However, given the sporadic nature of tail-biting, long-term evaluations of such a strategy are needed.***

Methods to provide more pig appropriate enrichment that can encourage foraging behaviours in fully slatted systems has been explored, including the use of a foraging block by Rault et al. (2018). However, the use of these blocks to reduce tail biting has not been explored.

Because straw is one of the most effective materials at reducing tail biting in pigs, methods to incorporate straw use into fully slatted systems with liquid manure handling are being explored. Holling et al. (2017) evaluated the effect of a 'foraging tower' on the prevalence of tail biting in fully-slatted raised pigs. The foraging tower (Fig. 2) is designed to provide a continuous supply of straw through an adjustable gap at the base of a moveable plastic tower; delivering small amounts at a time, reducing wastage and contamination of slurry pits. On a commercial farm, 640 pigs were raised from weaning to slaughter, in four batches, with either a foraging tower of chopped wheat straw or a similarly-shaped immobile structure without straw (control), divided 50/50 in pens. Average daily straw consumption was 3.5 g/pig in the nursery and 31.9 g/pig in the finishing period. Tail lesion scores were not significantly different between treatments, but tail biting prevalence overall was very low with scores of ≥ 2 (on a six point scale) observed in 104 out of a total 12,032 single time-point observations. A ventilation system failure during one replicate was correlated with a large portion of the tail wounds occurring over the experiment (Holling et al. 2017). ***While the foraging tower has desirable traits for use with slatted flooring, further investigation is needed to validate its efficacy in the prevention or reduction of tail biting.***

Figure 2. Foraging tower as tested by Holling et al. (2017).

Alternatives to straw for slatted-floor systems are being explored. Testing three low cost objects: fresh wood, branching metal chains and polythene pipe as enrichment for undocked growing pigs, Telkänranta et al. (2014) found fresh wood to be effective at reducing tail and ear biting in undocked finisher pigs (n=780). Control pens were fitted with a straw rack, metal chain and wood shavings on a solid-floor section of the pen. Treatment pens were the same as controls, with addition of either: i) suspended pieces of freshly cut birch wood, ii) polythene pipes, iii) vertically-suspended branching metal chains or iv) a combination of all three enrichments. Over a 2.5 month observation period, the researchers found that branching chains were used the least compared to all other enrichments; within the combination pens, wooden blocks were manipulated most frequently. While pig-directed oral-nasal manipulation was not different between treatments, the incidence of tail and ear damage was lowest in pens with either wooden blocks or a combination of all three enrichments. ***Notably, the frequency of manipulation of wood was not different from that of polythene pipes, but the pipes did not significantly reduce ear or tail damage. Fresh wood was therefore found to be successful at reducing likelihood of tail and ear biting. The wood being of ingestible matter is considered to play a role in why this material was successful in reducing likelihood of biting damage, and sustaining interest.***

Evidence suggests provision of enrichment in the early rearing environment (pre-weaning), is important to have lasting beneficial effects on the pigs. The weeks following birth to weaning is a period of intense development of the stress response and neural plasticity. A growing number of studies are reporting greatest effects of enrichment on the developmental physiology of the pig when presented pre-weaning, such as higher concentrations of BDNF (Rault et al. 2018), and that substrate enrichment (straw) provided in weeks 0-4 (preweaning) supports the formation of a circadian cortisol rhythm at 21 weeks of age, whereas a barren environment pre-weaning leads to an blunting of the rhythm by 21 weeks of age (Musterhjelm et al. 2010), the biological significance of which remains to be determined in pigs.

Undocked piglets raised in standard commercial farrowing pens and given sisal rope (10 pieces/pen) and shredded paper (1-2m^2/litter) in the period from birth to weaning showed less oral-nasal behaviour towards pen mates in the pre-weaning period. Upon weaning to a standard environment (part-slatted pens, standard enrichment of sisal rope, a commercial chew toy and wood shavings thrown on the solid floor 2 x/day, 2-3L at a time), undocked piglets that had received rope and paper pre-weaning inflicted less severe tail damage, than control pigs (Severe tail damage prevalence – part of tail missing: Enriched: 9.8% vs Control: 32.1%). In this trial, by Telkänranta et al. (2014b) pre-weaning, control pigs had a small amount of sawdust added daily to the heat mat, and a ball on a chain in the pre-weaning environment – as is required as minimum enrichment in Finland. Enriched pigs had this, plus the addition of the rope (given from birth) and paper (given from day 4-5 of age). ***This study indicates that chewable materials given in the pre-weaning environment have beneficial effects, reducing tail biting damage later in life. That this material was additional to the standard required enrichment could indicate the benefit of a) multiple types of enrichment, and b) chewable properties of the enrichment.***

The provision of jute sacks to litters pre-weaning and post-weaning, has also been found to reduce tail-biting damage at weaning and longer-term, with a five-fold reduction of mild tail wounds in pens provided with jute sacks at 13 weeks of age (Ursinus et al. 2014).

7.4 Enrichment options for sows

Providing flavoured cotton ropes, as olfactory/gustation enrichment to 24 stall-housed breeding gilts did not result in a substantial increase in interaction with the ropes (Colpoys et al. 2018). Flavouring the ropes with sugar water increased interaction with the rope, compared to when flavoured with apple juice or salt water, but no flavor treatment differed in the level of interaction achieved from a plain rope dipped in water. On day of presentation, interaction with the rope was seen in 3.5% of observations, reducing on day two, to around 1.5% of observations. However, overall rope provision increased stall-housed gilt active behaviours, with gilts observed standing and sitting in a greater percentage of observations when provided with the ropes, compared to their baseline activity (Colpoys et al. 2018). However, the study of Colpoys et al. (2018) only studied gilts with ropes for two days, so the influence of the rope for longer periods of time is not known.

Greenwood et al. (2019) evaluated the effect of point-source materials on levels of aggression in 144 group-housed sows (12 sows/pen) over days 0, 1, 4, 7 and 20 after mixing. Point-source materials were flexible rubber mats, sisal rope and yellow plastic discs, all suspended from the roof. Treatment had no effect on aggression (displacements, bites, knocks) and number of injuries sustained, salivary cortisol concentration and sow performance. Treatment sows spent 1.7% of their total time budget across all days interacting with the point-source materials (play and exploration), with significantly more time spent playing (running, shaking head, shaking head whilst holding object in mouth) on days 4, 7 and 20 than on days 0 and 1. Control sows were not observed playing at any time point. ***While the point-source materials were ineffective at reducing aggression, the presence of materials generated play behaviour in sows, possibly indicating a more positive welfare state in the sows. While sows showed interest in the materials, their presence did not cause increased aggression, so they were not seen as a limiting resource (Greenwood et al. 2019). However, whether play in adult animals is an indicator of positive welfare has been questioned, because there is a relationship between the amount of play performed by adults and measures of chronic stress (Hausberger et al. 2012). This areas requires further research to uncover the relationship of play in adults. It can be concluded that, while sows showed interest in the materials, their presence did not cause increased aggression, so they were not seen as a limiting resource (Greenwood et al 2019).***

Providing one of three, point-source enrichments to 18 pens of ESF-fed group-housed sows, (75 sows/pen, 6 pens/treatment), Horback et al. (2016) identified a greater amount of interaction with the suspended rope, than suspended rubber sticks, or a piece of wood. However, severity of skin lesions, nor sow activity differed between treatments. Sow interaction increased from days 1 -3, but declined thereafter, to day 14 (final day of observation), for wood, but remained at a higher, with increased levels of interaction for rope and rubber items (Horback et al. 2016). The portion of time objects were used in this study is higher than typically reported elsewhere, i.e. 80% of observed time, sows were interacting with enrichment. However, with only one point source object provided per pen of 75 sows, this may be a result of other sows in the pen that have not previously interacted with the items taking their turn. ***Results indicate sows will show a preference for items used for enrichment, with rope, being the most preferred, having the characteristics known to be attractive to pigs – chewable, deformable, rootable, ingestible, manipulable.***

Muller et al. (2015) determined provision of either a nutritional foraging block, or increased quantities of feed (4kg/sow/day) reduced aggressive chasing behaviour, increased lying and decreased foraging behaviour in the four day period following regrouping in gestating sows (Muller et al. 2015). However, other types of aggressive behaviour that could cause injury, such as attacking, biting, and pushing were not reduced by these treatments. This short study, did not collect productivity data, nor measure how sow behaviour changed over the course of gestation. ***It can be concluded that the provision of more food, or a foraging block are methods to modify the behaviour of sows at mixing. However, the true benefit of this method on sow wellbeing, injury level and productivity is not known from this study.***

Silva et al. (2017) found stall and group-housed sows played 12-compilations of classical music on two days per week, reduced their frequency of stereotypic behaviour, showed no aggressive interactions to human presence and showed a higher percentage of relaxation behaviours (deduced from lower activity), than those without. Further work into the role of music as environmental enrichment is warranted.

Roy et al. (2019) explored four enrichment treatments on 120 group-housed sows fed via ESF, (20 sows/pen, over six replicates, $3m^2$/sow). Treatments included constant access to wood on a chain, a rotation of three enrichments (rope, straw and wood on a chain), a rotation of the three enrichments with an associative stimulus to announce the arrival of the enrichment (bell or whistle), and a control of no enrichment. Each treatment was rotated over six pens of sows, with each treatment lasting 12 days, and order of treatment randomized. Per pen of 20 sows, three point source enrichments were given. Results found enrichment type, and how the enrichment is presented influenced the number of sows in contact with the enrichment. Provision of straw resulted in the greatest number of sows interacting with the enrichment, followed by rope, with wood on chain the lowest. Rotating enrichments increased sow interaction with the enrichments, but rotation with an associative stimulus resulted in greater aggression as determined from skin lesions. ***Novelty and type of enrichment play an important role in attracting and maintaining interest in sows. The ratio of animals to enrichment needs to also be considered to minimize competition over access where enrichment becomes valued.***

Enrichment type and number of enrichment items was explored by Connor (2018, unpublished), comparing wood and fibre (chopped hay) given in a fibre dispenser, testing whether one of three of each influenced sow use. The fibre dispenser increased the percentage of sows in contact, or close contact with the feeder over the wood. However, a greater amount of fibre was consumed when only one dispenser was given. Dominance hierarchy influenced use, and the dispensers kept jamming, and different dispensers should be explored (Connor, 2018).

Fynn et al. (2019, unpublished) identified sows provided with a strip of burlap in their farrowing crate to use for nest building prior to farrowing, had lower stillborns than sows farrowed without a strip of burlap (n = 277 sows/treatment, burlap: 6.5%; control 8.3%). The results suggest that the provision of burlap to sows prior to farrowing could result in one extra piglet produced for every four litters. Fynn et al. (2019) calculated that assuming that extra piglet is weaned, the return on investment for the burlap is around 200%, i.e. for every \$1 spent on burlap, the producer will receive \$3 in piglet value. Considering that effective enrichment should result in a biological improvement in the animal (Newberry, 1995), enrichment could, and should be viewed positively to support pig welfare and enhance productivity, as championed by Fynn et al. (2019).

Provision of enrichment through human-animal interaction is infrequently discussed as an enrichment option enriching because the majority of focus is on the application of biologically relevant enrichments for pigs. However, the human-animal interaction, when positive, may be very important for improving animal welfare and the biological functioning.

Hemsworth et al. (2018) applied a human enrichment approach to 360 mixed parity, group-housed sows over two replicates. The human enrichment treatment involved the stockperson slowly walking through the group pens for two minutes daily, and stopping at 30 second intervals for 10 seconds, squatting and talking, and if the sows approached, patting them. The rationale for this treatment was that such minimal, but routine positive human contact would provide a difference in environmental stimulation, and be practical to implement. Results found no effect of the human enrichment treatment on stress resilience, gestational stress, sow aggression or productivity.

However, sows in replicate one had higher serum levels of BDNF at week five of gestation, than control sows. Additionally, sows receiving human enrichment showed fewer fear responses to vaccination and pregnancy testing. ***The role of human enrichment to offer positive emotional wellbeing and promote improved biological functioning of the sow from having lower stress, an improved human-animal relationship is worthy for further research. It is recognized that a good human-animal relationship between caretaker and pig could be one of the most important areas for improving animal welfare (Zulkifi, 2013).***

7.5 References

Beaudoin, J-M., R. Bergeron, N. Devillers, and J-P, Laforest (2019) Growing pigs interest in enrichment objects with different characteristics and cleanliness. Animals. 9, 85. Doi: 10.3390/ani9030085

Blackie, N., and M. de Sousa. 2019. The Use of Garlic Oil for Olfactory Enrichment Increases the Use of Ropes in Weaned Pigs. Animals (Basel).**9**(4).

Chou, J.-Y., C. Drique, D. Sandercock, R. D'Eath, and K. O'Driscoll. 2019. Rearing Undocked Pigs on Fully Slatted Floors Using Multiple Types and Variations of Enrichment. Animals **9**:139.

Chourbaji, S., C. Brandwein, and P. Gass. 2011. Altering BDNF expression by genetics and/or environment: Impact for emotional and depression-like behaviour in laboratory mice. Neurosci. Biobehav. Rev. **35**: 599-611.

Connor, L. 2018. Optimizing Flooring and Social Management of Group Housed Gestating Sows (# 1231). Annual performance report to Canadian Swine Research and Development Cluster.

Colpoys, J. D., A. Johnson, and N. K. Gabler, and A. Johnson. 2018. The efficacy of novel rope flavours as environmental enrichment for stalled gilts. Ani. Welfare. **27**: 351-356.

Dalmau, A., B. Areal, S. Machado, J. Pallisera, and A. Velarde. 2018. Does the location of enrichment material affect behavior and dirtiness in growing female pigs? J. Appl. Anim. Welf. Sci. **22**:116–126.

Fynn, M., L. Connor and G. Crow. 2019. Suspended Burlap Strip for Sow Enrichment in Farrowing: Effect on Sow Behaviour and Piglet Performance. Manitoba Pork Council, Ag Action Manitoba research project # 1000210417.

Greenwood, E., W. V. Wettere, J. Rayner, P. Hughes, and K. Plush. 2019. Provision Point-Source Materials Stimulates Play in Sows but Does Not Affect Aggression at Regrouping. Animals **9**:8.

Hausberger, M., C. Fureix, M. Bourjade, S. Wessel-Robert and M-A. Richard-Yris. 2012. On the significance of adult play: what does social play tell us about horse welfare? Naturwissenschaften. **99**. 291-302.

Hemsworth, P., L. Hemsworth, R. Morrison, M. Rice, J-L., Rault, K, Butler, and M. Heyes. 2018. Human enrichment program for breeding sows: Proof of concept – 1C-120. Final Report for the Co-operative Centre for High Integrity Australian Pork.

Holling, C., E. G. Beilage, B. Vidondo, and C. Nathues. 2017. Provision of straw by a foraging tower –effect on tail biting in weaners and fattening pigs. Porcine Health Manag. **3**.

Horback, K., M. Pierdon, and T.D. Parsons, 2016. Behavioural preference for different enrichment objects in a commercial sow herd. Appl. Ani. Behav. Sci. **184**: 7-15.

Mkwanazi, M.V., C.N. Ncobela, A.T. Kanengoni, M. Chimonyo. 2019. Effects of environmental enrichment on behaviour, physiology and performance of pigs — A review. Asian-Australas J Anim Sci. **32**(1):1-13

Muller, T., M.J. Callaghan, R.J.E. Hewitt, and R.J. van Barneveld, 2015. Use of a nutritional lick block and higher feeding levels to reduce aggression and provide enrichment for sows in groups. Ani. Prod. Sci. **55** (12): 1498-1498.

Musterhjelm, C., A. Valros, M. Heinonen, O. Hälli, H. Siljander-Rasi, and O.A.T. Peltoniemi. 2010. Environmental enrichment in early life affects cortisol patterns in growing pigs. Animal. **4** (2), 242-249.

National Farm Animal Care Council (NFACC). 2014. Code of Practice for the Care and Handling of Pigs. A Canadian Pork Council, NFACC publication. Available at: https://www.nfacc.ca/pdfs/codes/pig_code_of_practice.pdf. [Date Accessed: May 6, 2019].

Newberry, N. 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Appl. Ani. Behav. Sci. **44**: 229-243.

Rault, J.-L., A. Lawrence, and C. Ralph. 2018. Brain-derived neurotrophic factor in serum as an animal welfare indicator of environmental enrichment in pigs. Domest. Anim. Endocrinol. **65**:67–70.

Roy, C. L. Lippens, V. Kyeiwaa, Y.M. Seddon, L.M. Connor and J.A. Brown. *Accepted.* Effects of enrichment type, presentation and social status on enrichment use and behaviour of sows with electronic sow feeding.

Seddon, Y.M., M.K., Pedersen-Macnab, J.C.S. Harding, F. Fortin, J. Dekkers, M.K. Dyck, and G.S. Plastow. N.d. The effect of environmental enrichment on immune response and measures of disease resilience and welfare in pigs. A project funded by the Alberta Agriculture and Forestry. [In progress].

Silva, F.R.S., K O.DA.S. Miranda, S.M.D.S. Piedade, D. D'Alessandro Salgado. 2017. Effect of auditory enrichment (music) in pregnant sows welfare. Eng. Agríc., Jaboticabal, **37**: 215-225.

Telkänranta, H., M. B. Bracke, and A. Valros. 2014a. Fresh wood reduces tail and ear biting and increases exploratory behaviour in finishing pigs. Appl. Anim. Behav. Sci. **161**:51–59.

Telkänranta, H., K. Swana, H. Hirvonen, and A. Valros. 2014b. Chewable materials before weaning reduce tail biting in growing pigs. Appl. Ani. Behav. Sci. **157**: 14-22.

Trickett, S.L., J.H. Guy, and S.A. Edwards. 2009. The role of novelty in environmental enrichment for the weaned pig. Appl. Anim. Behav. Sci. **116**:45-51.

Ursinus, W.W., H.J. Wijnen, A.C. Bartels, N.Dijvesteijn, C.G. van Reenen, and J.E. Bolhuis, 2014. Damaging biting behaviours in intensively kept rearing gilts: The effect of jute sacks and relations with production characteristics. J. Ani. Sci. 92: 5193-5202.

Wallgren, T., R. Westin, and S. Gunnarsson. 2016. A survey of straw use and tail biting in Swedish pig farms rearing undocked pigs. Acta Veterinaria Scandinavica **58.**

Van Dixhoorn, I. D. E. V., I. Reimert, J. Middelkoop, J. E. Bolhuis, H. J. Wisselink, P. W. G. G. Koerkamp, B. Kemp, and N. Stockhofe-Zurwieden. 2016. Enriched Housing Reduces Disease Susceptibility to Co-Infection with Porcine Reproductive and Respiratory Virus (PRRSV) and Actinobacillus pleuropneumoniae (A. pleuropneumoniae) in Young Pigs. Plos One. 11.

Zulkifli, I. 2013. Review of human-animal interactions and their impact on animal productivity and welfare. J. Anim. Sci. Biotechno. **4.**

8.0 Floor space allowances for weaned/nursery pigs

8.1.1 Conclusions

1. **While young pigs tend to overlie early in the nursery, this does not reduce their space requirement, and young pigs reduce their overlying over increasing weeks in the nursery.**
2. **Pigs will adjust their behaviour to accommodate reductions in space below *k* =0.0335, with some behaviours suggesting increased stress, although the full significance of these changes is unknown.**
3. **Results from commercial trials suggest providing space allowances greater than *k*=0.0335 will improve ADG.**
4. **That pigs are adjusting their behaviour in response to reductions in space, and that trial results show growth is reduced before *k* = 0.0335, suggests the Code allowance for a short term 15-20% reduction in space should be revaluated. Further research is needed to improve understanding on appropriate minimum space for productivity and welfare.**
5. **The productivity of grower and finisher pigs is reduced to a greater extent than that of small pigs when penned at low space allowances.**

8.1.2 Knowledge gaps

- The effect of space provision above a *k* value of 0.0335 on productivity and measures of welfare; understand at which *k* value does growth become a plateau.
- Understanding the effect of temporary space restriction on productivity and welfare.

The Code of Practice (2014) uses a *k* value of 0.0335, representing the floor space allowance coefficient in the allometric formula: $A = k * BW^{0.667}$ to calculate the required minimum space allowance for nursery and grow-finish pigs. This *k* value was determined from a meta-analysis by Gonyou et al. (2006), which identified 0.0335 to be the critical value below which productivity is reduced. The Code further permits that space allowance can be temporarily decreased by 15-20%

at the end of the nursery phase, providing that no adverse effects on productivity or measures of welfare (e.g. tail biting) can be demonstrated.

It has been proposed that weaned nursery pigs may require less space (relative to body size) than grow-finish pigs without impacting productivity, because of their propensity to overlie which reduces the total area required for lying (Brown, 2018, unpublished). The productivity and welfare implications of raising nursery pigs penned at six space allowances (k= 0.023, 0.0265, 0.0300, 0.0335, 0.0370 and 0.0390) was examined in two studies conducted by Brown et al. (2018, unpublished); Phase 1 exploring the interaction between space allowance and group-size; and Phase 2 replicating the space allowances on two commercial farms.

Phase 1: At all space allowances, as piglets grew older, overlying behaviour reduced and lateral lying (on their side) increased. However, overlying was greater at lower space allowances, suggesting it was a response to stress or overcrowding. Temperatures were controlled throughout and did not influence lying behaiour. At a space allowance of k = 0.023 there was an increased frequency of sitting compared to higher space allowances (Brown et al. 2018). Sitting is a posture which requires less space, and has previously been associated with crowding in pigs (Pearce and Patterson, 1993).

There was an effect of space allowance on ADG and feed efficiency in Phase 1, but it was not a clear effect, with a tendency for ADG in week 5 (near nursery exit) to be greatest at a k of 0.023, and lowest at 0.037. Feed efficiency was greatest at a k of 0.0335. Pigs at lower space allowances (0.0335 and below) spent less time feeding, but tended to compensate by having more feeding bouts per day than those at larger space allowances. There was no interaction between group size and space allowance on piglet productivity or behaviour (Brown et al, 2018).

Phase 2: When the six space allowances were studied in commercial nursery facilities, there was a linear effect of space allowance on ADG. Pig ADG was greatest at the greatest space allowance (k = 0.039), with space allowances of 0.0339 and 0.0337 being no different. ADG was lowest at the lowest space allowance (k = 0.023), with the ADG at space allowances with k 0.023 and 0.026 being no different. ADG at space allowances with a k of 0.030 and 0.035 were intermediate, and no different from one another (Brown et al, 2018). These results suggest that the ADG will be reduced at a k of 0.0335, and will be improved at spaces above. Behavioural differences on commercial farms were similar to those identified in Phase 1, with a greater percentage of pigs sitting at lower space allowances. Body injury score, ear necrosis and tail biting scores were not significantly affected by space allowance, however, piglet age and season (summer vs winter) did affect these measures. No morbidity and mortality data for these trials are presented.

The initial results of Phase 2 suggest that under commercial conditions, penning weaned piglets at the current space recommendation of k= 0.0335, could be reducing ADG, and that piglets will alter their behaviours, to adjust to the reduced space (phase 1 & 2). The tendency for young piglets to overlie is largely related to thermal comfort, and based on maintaining appropriate room temperatures for the age of the pigs, does not reduce their need for space.

The linear reductions in ADG observed in the commercial trials suggest that space allowances below 0.0337 will decrease ADG. The Code currently permits short term, 15-20% reduction in

space allowance, providing such a higher density does not compromise welfare as determined by "ADG, mortality, morbidity, and treatment records, or an increase in injurious behaviour such as tail-biting," NFACC (2014, point 1.2.2, pp. 66). However, data from commercial trials suggest that a 20% reduction in space will compromise pig growth rate. For phase 2, the growth over weeks on trial is not captured in the report by Brown, (2018, unpublished), so it is not possible to determine how the ADG reduced as the space restriction increased. It may be of interest and value for the industry to explore this further, including understanding the effect of temporary space restriction on ADG.

Callahan et al. (2017) explored the combined effects of group-size and floor space allowance in the nursery phase. Space allowances of 0.15, 0.19 & 0.27m^2/pig were explored, with space adjusted by group size (groups of 8, 11 or 14 pigs respectively). There was a linear reduction in ADG with decreasing space allowance, and an interaction with pig size and space allowance. Medium and large pigs were more affected by space restriction; those at the lowest space allowance had a lower ADG than those at the largest space allowance. Space allowances of 0.15, 0.19 and 0.27m^2/pig represent k values of 0.018, 0.023 and 0.033 respectively. Callahan et al. (2017) did not measure pig behaviour, but did report a range of blood analytes, finding subtle changes in some measures. Callahan et al. (2017) interpreted this to be evidence of mild stress, or reduced feed and water intake in pigs held at lower space allowances, but not as indicators of seriously compromised health or wellbeing.

8.2 References

Brown, J. (2018) Determining the Optimum Space Allowance for Nursery Pigs (#1234). 2017 - 2018 Annual Performance report for the Canadian Swine Research and Development Cluster, Swine Innovation Porc.

Callahan, R., A. J. Cross, A. E. DeDecker, M. D. Lindemann, and M. J. Estienne (2017) Effects of group-size-floor space allowance during the nursery phase of production on growth, physiology, and hematology in replacement gilts. J. Anim. Sci. **95**:201–211.

Gonyou, H.W., M. C. Brumm, E. Bush, J. Deen, S. A. Edwards, T. Fangman, J. J. McGlone, M. Meunier-Salaun, R. B. Morrison, H. Spoolder, P. L. Sundberg and A. K. Johnson (2006) Application of broken-line analysis to assess floor space requirements of nursery and grower-finisher pigs expressed on an allometric basis. J. Anim. Sci. **84**:229–235

National Farm Animal Care Council (NFACC). 2014. Code of Practice for the Care and Handling of Pigs. A Canadian Pork Council, NFACC publication. Available at: https://www.nfacc.ca/pdfs/codes/pig_code_of_practice.pdf. [Date Accessed: April 13, 2019]

Pearce, G.P. and A.M. Paterson, (1993) The effect of space restriction and provision of toys during rearing on the behaviour, productivity and physiology of male pigs. Appl. Ani. Behav. Sci. **36**, 11-28.

9.0 Exercise frequency, strategies, etc. for sows and boars housed in stalls

9.1.1 Conclusions

1. **Exercise at a regular frequency (several times per week) for at least 10 minutes has been shown to confer health benefits to the sow, and may influence her productivity. How exercise at a lower frequencies affects the sow and her piglets remains to be determined.**
2. **Forced exercise of sows provides a greater freedom of movement, but, even when given at a regular frequency, may provide less exercise than when sows are housed in groups.**
3. **Strategies explored to provide a greater freedom of movement to stall housed sows include: forced exercise in the alleyway between stalls, exercise on a treadmill, and the use of turnaround stalls; each method has its advantages and disadvantages.**
4. **Sow individual differences should be taken into account: not all sows will accept forced exercise on a regular basis. Depending on the quality of flooring/facilities, exercise may cause injury to sows.**
5. **Sows have a level of motivation for time out of their stalls, but this motivation is reduced with provision of high fibre feed in addition to the sow's standard ration.**
6. **Considering the results of studies of turnaround stalls and motivation tests, sows will take advantage of greater freedom of movement if given the chance. However, it is unlikely that the implementation of turn-around gestation stalls will significantly enhance sow welfare, and it is not comparable to the movement a sow will receive in groups.**
7. **Knowledge on the effects of exercise in stall-housed boars is limited to studies of leg health. The results indicate that exercise benefits boar leg health.**
8. **Sows value enrichment provided in the stall, with compost being the most valued, followed by straw. Access to a rope and rubber mat were less valued, based on operant test results for these materials being no different from an empty trough.**

9.1.2 Knowledge gaps

- Explore the feasibility of providing periodic access to greater freedom of movement under commercial conditions, versus provision of enrichment in the stall.
- Examine the effects of periodic turnout of groups of stall-housed sows into a group pen. However, considering the knowledge on sow injury resulting from mixing, it is advised that matted, or bedded pens be used. Considering knowledge on sow recognition, turnout of the same individuals would be required.

9.2 Stall-housed sow exercise

Sections 1.1.2 (Housing systems –gestating gilts and sows) and 1.1.6 (Housing systems – boars) of the Code of Practice for the Care and Handling of Pigs, require that boars, mated gilts and mated sows may be housed in stalls providing, "they are provided with the opportunity to turn around, or exercise periodically, or by other means that allow a greater freedom of movement," (NFACC, 2014, pg. 11 & 13). Suitable options are to be clarified by stakeholders, by July 2019, as informed by scientific evidence (NFACC, 2014). Provision of greater opportunities for freedom of movement for stall-housed sows was not covered in the Pig Code of Practice scientific committee review of research priorities (NFACC, 2012), therefore, this report will include studies conducted prior to and post 2012.

Any discussion concerning the frequency and strategy by which to exercise stall-housed pigs must consider what benefits the exercise will provide to the animals, the labour involved, and the practicality of implementing the strategy on farms.

9.2.1 Exercise frequency

Schenck et al. (2008) evaluated the impact of periodic exercise between day 35 and 110 of gestation on lameness, the musculo-skeletal system, production and behaviour in stall-housed gilts. Exercise consisted of encouraging a gilt with light taps and vocal signals to walk/run for a preset number of laps (61m/lap) around the gestation room (Figure 3). Animals (n = 51) were studied in one of three treatments: Control (n =17, no exercise); Low exercise (n = 19, 122 m/day [2 x laps], five days/week); High exercise: (n = 15, ascending exercise schedule of 122 m/day [2 x laps] for two days and gradually increasing to 427 m/day [7 x laps] three days per week by the third week and for the remaining nine weeks). High exercise resulted in a greater live litter birth weight, and a greater number of piglets weaned than control and low exercise treatments. Exercise reduced preweaning mortality in comparison to the control treatment. Bone density of the radius and tibia was greater in the exercise groups, with the density of the humerus being greater in the low exercise group than the high exercise and control groups. Breaking force of the femur, tibia and humerus was greater in the low exercise group than the control, with only the breaking force of the tibia greater in the high exercise group than the control. Bone shear force did not differ between treatments.

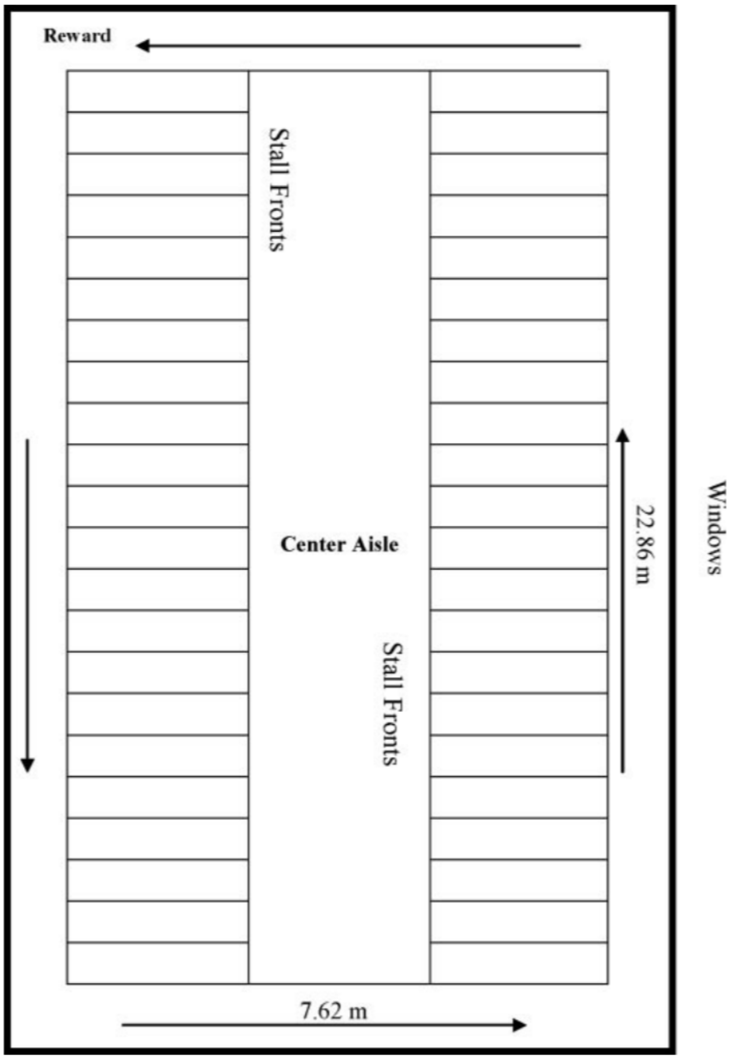


Figure 3. Room layout for sows and gilts in an exercise trial (Schenck et al. 2008). For exercise, each animal was backed out of the stall and encouraged to walk/run following the direction of the arrows. Entry to the centre aisle was blocked by wooden boards during exercise periods. Animals were rewarded with sugar lumps each lap at the reward corner, to encourage positive association with the routine.

There was no difference between treatments in muscle weights, lameness and articular cartilage. Front hooves of the high exercise group had higher lesion scores than the control group. Lying down speed (duration of time for the gilt to move from standing to lying) was different between each treatment group, with high exercise gilts lying down faster than the low exercise and control groups, and low exercise gilts lying down faster than controls. Whether the reduced time to lie down in high exercise sows influenced their lower preweaning mortality rate is not clear from the work of Schenck et al. (2008), because the cause of preweaning mortality is not reported. The relationship between lying time and crushing is not yet clear; a reduced lying time may suggest better muscular control in the sow and provide piglets time to move away and not return under the sow.

The study does not report how lameness was evaluated. Schenck et al. (2008, pg. 3170) state that "lameness may be numerically less in the control treatment due to the fact that it is harder to identify lameness problems…when the sow is in a confined space and unable to move freely," suggesting that control animals remained in stalls for the evaluation. For this reason, the lameness results may not be reliable.

For the behavior data, there were no differences in the mean avoidance score among treatments in the human avoidance test. The purpose of the test was to ensure that the gilts did not exercise because of fear of the handlers, and it consisted of an unfamiliar person approaching the gilts and attempting to touch her. Considering that Schenck et al. (2008) also reported nine cases of refusal to exercise in gilts from the high exercise treatment, these cases were probably caused not by fear of the handlers, but individual differences. Schenck et al. (2008) also conducted behavioural observations to compare the distance travelled by the low and high treatment groups, compared to group-housed sows at different stocking densities (4.46 m^2/sow, 3.56 m^2/sow and 2.74 m^2/sow). It was found that at the lowest space allowance – i.e. the most comparable to industry norms – sows in pens moved a greater distance in an eight hour period, than sows in the maximum exercise treatment.

To sum up, this study showed that: weight bearing exercise in stall-housed gilts from days 35 – 110 of gestation at low (19 laps over five days/week) or high (maximum of 25 laps over five days/week) levels:

- Increased bone density, but not bone quality (macro-architecture).
- Reduced preweaning mortality
- Reduced the total time taken for gilts to move from standing to lying down.
- High levels of exercise increased live piglet, litter birth weights and weaning weights.
- Gilts provided high levels of exercise had greater hoof lesions scores on front hooves.

Multiple studies on impact of periodic exercise on leg health/bone strength in pigs were conducted in the second half of the 20th century. Considering that pigs have typically been given limited space to exercise, these studies have largely been conducted to evaluate how the provision of exercise could improve leg health and carcass characteristics. For example, Murray et al. (1974) exercised four gilts from a liveweight of 12 to 60 kg on a treadmill three times a week for 60 min at a speed of 2 km/h. Among other measures, the authors looked at the distribution of carcass muscle, fat and bone, and did not find any effect of treatment. In contrast, Petersen et al. (1998) compared growing pigs housed in individual pens (2.5 m^2/pig) and not exercised, pigs housed in individual pens and exercised on a treadmill for 15 min/day at a speed of 4 km/h, 5 x days/week for a period of 70 days, and group-housed pigs (0.9 m^2/pig), and found that group-housed pigs had a higher total carcass bone mass in comparison to the two groups of individually housed pigs. Leg weakness and osteochondrosis did not differ across the treatments, whereas the locomotory ability was improved by housing in groups, but not by individually-penning animals and exercising them. ***The differences between the results of Murray et al. (1974) and Petersen et al. (1998) may indicate that group-housed pigs perform activity that imposes more physical demands on the skeleton than when pigs are given time-limited treadmill sessions.***

Enfalt et al. (1993) explored the effect of exercising growing pigs on production and carcass traits. Pigs (n = 40) were penned in groups of 10, during the fattening period (from 22 kg to 103 kg of liveweight), and exercised by running/walking as a group, 5 x days/week in a narrow passage, gradually increasing the distance from 105 m/day to 735 m/day. Among other measures, the authors looked at the presence and severity of osteochondritic joint lesions for both knee and elbow joints, and did not find any difference between exercised and non-exercised pigs. These results suggest that forced additional exercise of group-housed pigs does not lead to an increased degree of osteochondrosis. However, the authors did not present the speed of exercising pigs, calling it 'moderate,' and thus it is not possible to evaluate the exercise intensity.

Weiss et al. (1975) exercised growing and finishing pigs by walking them on a treadmill at a speed 1.6 km/h for 1 h 5 days/week, and found that bone breaking strength of the left fourth metatarsal was greater for exercised pigs, than those not exercised. However, not all bones were influenced this way, suggesting uneven involvement of the pig musculo-skeletal system when exercising pigs on a treadmill.

Perrin and Bowland (1977) looked at the effects of exercise on a treadmill on the incidence of leg weakness in growing boars. Four boars, exercised three times a week at a speed of 2 km/h and four boars, exercised with the same frequency at a speed of 4 km/h, were compared to four non-exercised boars. All the boars were housed in individual pens. The authors reported that non-exercised boars had more foreleg abnormalities on visual appraisal than exercised boars, and the degree of unsoundness in the non-exercised animals increased from week 6 to week 10, but not in the exercised boars. Abnormalities of forelegs based on visual appraisal were significantly correlated with cartilage appraisal of both of the proximal radius-ulna and the distal humerus. Exercise had no influence on bone mineralization. Overall, these results are not strong due to the small sample size used.

Fredeen and Sather (1978) studying boars housed at space allowances of 3.6 m^2/pig, 2.3 m^2/pig, 1.7 m^2/pig and 1.0 m^2/pig, found the degree of cartilage damage in the joints of growing pigs was related to their degree of confinement, rather than liveweight, and that pigs confined individually had greater cartilage damage than those housed in groups. Interestingly, after transferring the animals from confinement to pasture at 90 kg liveweight, a substantial degree of cartilage repair was indicated. It suggests that providing a greater freedom of movement may help to improve the joint condition. Conversely, Morrison et al. (1968) found evidence to suggest that body weight could contribute to lameness when periodic exercise is provided. In their study, gilts that averaged 60 kg and were exercised twice a day by running/walking 400 m in the alleyway, had a higher incidence of lameness than lighter gilts (averaging 50 kg) exercised on the same schedule.

Hale et al. (1984) exercised gilts on a treadmill 6 x days a week for 15 min or 30 min/day (n =24) and compared them to the littermate gilts that were not exercised. All the animals were housed in individual pens. It was reported that four gilts from the non-exercised control group had severe locomotor problems, while only one gilt from the exercised groups experienced difficulty to walk due to inability to flex the carpus of the right leg. In contrast, three non-exercised gilts could not flex the carpus of either front leg, and the fourth gilt had a sickle leg condition that caused severe difficulty in walking and standing. These results are in agreement with the findings of Perrin and Bowland (1977), that exercise helps to reduce leg problems and increase the soundness of animals. Additionally, Hale et al. (1984) did not find any effect of exercise on age at puberty or conception rate.

To summarize, early studies looked at the effects of frequent exercise (3-7 times/week, 1 or 2 times/day), and the results indicate that periodic exercise has the potential to increase pig leg health/bone strength. However, consideration of other factors, such as pig body weight, flooring type (higher chance of injury), exercise type (treadmill or free movement), and handler skill is required.

Ferket and Hacker (1985) studied 48 stall-housed gilts from day 35 to day 108 of gestation, that either received exercise (2 km daily on a concrete track; about 1.25h/day), or not. Farrowing time and piglet birth intervals in exercised gilts tended to be shorter than in control gilts. More piglets were born to exercised gilts in the first 2 h of farrowing than to control gilts, a result that may be due to hypertrophy of the muscle tissue involved in piglet expulsion. The litter sizes and stillbirth rates did not differ between the two groups, but a higher percentage of piglets from control gilts died before suckling. Higher neonatal mortality in non-exercised sows may be related to intrauterine hypoxia resulting from the protracted farrowing, and the piglets were consequently too weak at birth to survive. Prepartum levels of cortisol started to increase earlier in non-exercised gilts than in exercised gilts. The authors explain it by adaptation of the adrenal gland to chronic exercise, resulting in lower basal levels of plasma corticosteroids than found in untrained individuals. ***It was concluded that exercise during gestation can reduce farrowing duration and increase piglet viability.***

Harris et al. (2013) studied stall-housed gilts (total =8), either control, (n = 4) or exercised (n = 4) for 30 min, 3 x/week over two parities for behaviour and body condition (1st parity, n = 8), fetal growth, umbilical blood flow, and parturition (1st and 2nd parity, n=6, divided equally between treatment and control). Gilts were individually walked by two handlers; one person in front of, and one person following behind the gilt. Exercised gilts sat less, stood more, and had fewer postural changes compared with the control gilts. The ability of exercised gilts to sit less and stand longer may be due to higher bone density in radius, tibia and humerus. Additionally, the reduction in postural changes and increased time standing may indicate greater ease of movement in animals due to higher bone density.

Umbilical blood flow increased in the exercise treatment compared with the control treatment. Higher umbilical blood flow may increase litter size and decrease stillborn numbers due to higher supply of oxygen and nutrients to the developing fetuses. Indices of vascular resistance were not affected by maternal treatment, but gilts from the exercise treatment reached peak pulsatility index earlier than control gilts. The authors hypothesized that the earlier decline of vascular resistance could be due to earlier vasodilation within the uteroplacental vasculature, ultimately increasing blood flow and/or nutrient exchange. Body condition, fetal weights, piglet birth weights, placental weight, the interval between piglet births, and blood lactate of newborn piglets (measure of oxygen deprivation and predictor of fetal viability in pigs) were unaffected by maternal treatment. Interestingly, the authors observed a decrease in the number of steps in the parity 2 sows but increased distance, which was attributed to experienced sows exploring less of their surroundings and anticipating a reward for completion of their activity. ***It can be concluded from this study that provision of exercise reduced maternal restlessness and increased umbilical blood flow, but did not influence productivity.***

In sows, as the number of piglets per litter increases, blood flow to each fetus decreases, which can have detrimental effects on fetal development. However, exercise can enhance umbilical blood flow in pigs. The influence of exercise in stall-housed gestating gilts on offspring body, uterine and ovarian weight, and ovarian cell proliferation at fetal, neonatal and adolescent stages of development was assessed by Kaminski et al. (2014), utilizing the same animals and experimental design as described by Harris et al. (2013). Exercise resulted in increased cell proliferation in fetal ovaries and ovarian weight in the group of lightest neonates. Offspring body weight and uterine weight were not affected by the treatment.

Evaluated together, these studies show that periodic exercising of gestating sows has a potential to improve sow musculo-skeletal system, productivity and reproductive performance, as well as piglet development and survivability. However, productivity was not consistently shown to be better: i.e. Schenck et al. (2008) showed increased litter birth weights, and lower preweaning mortality, but Harris et al. (2013) did not, and, Harris et al. (2013) exercised sows 2.6 times the distances per day of exercise, than the high exercise group of Schneck et al. (2008). However, this lack of effect observed by Haris et al. (2013) may be due to the much smaller sample size used. Also, Schneck et al. (2008) found that high exercise gilts were lying down faster than the low exercise and control groups, and low exercise gilts lying down faster than controls, which indicates that exercise helps to improve sow locomotory ability and potentially decrease piglet crushing.

Harris et al. (2013) discovered that the exercised gilts could stand longer and sit less, which may be due to greater bone density, as shown by Schenck et al. (2008). The frequency of exercise in the above-described experiments was very regular, which could be hard to achieve in the commercial barn environment. Also, if the quality of flooring is bad, frequent exercise can have detrimental effect of hoof condition. Tokareva et al. (2019a, unpublished) exercised stall-housed gestating sows at a lower frequency (once a week) which could be more practical to implement. However, given that in previous studies pigs were exercised at higher frequencies, it needs to be determined if exercising at a low frequency can provide health benefits.

On the other hand, in the studies of Tokareva et al. (2018, 2019b) stall-housed gilts and sows in early gestation had the opportunity to ask for time out of the stall by interacting with an operant panel. Results of the study suggest there is a moderate level of motivation to exit the stall (as measured by comparison to their motivation to receive a food reward). This suggests that, given the opportunity, female pigs are motivated to access greater freedom of movement, and on a daily basis, given that sows presented with the panel on consecutive days continued to interact with it upon presentation. This is not surprising given that the behavioural repertoire of the pig is to be active and foraging for at least 50% of the day. Typically, sows in stalls have not received environmental enrichment. The provision of the operant panel each day, and opportunity to exit the stall likely provided a source of enrichment for the sow.

9.2.2 Exercise strategy

Studies conducted in the second half of the 20th century mostly looked on the impact of forced exercise (walking/running in an alleyway or treadmill) on pigs housed in individual or group pens, where they had a greater freedom of movement than stall-housed sows. Tokareva et al. (2019a, unpublished) is the first to evaluate the influence of a low frequency exercise strategy (2 x laps around the gestation room, once per week), which may be more practical to implement under commercial conditions. Studies providing exercise to space-restricted pigs have either opted to walk/run the animals one at a time around the perimeter of the gestation room (Schenck et al. 2008; Harris et al. 2013; Tokareva et al. 2019a), or trained pigs to walk on a treadmill (Murray et al. 1974; Weiss et al. 1975; Perrin and Bowland, 1977; Hale et al. 1984; Petersen et al. 1998). If walking in the alleyway, over the course of time sows decrease the number of steps taken, but increase the distance travelled, which attributes to experienced sows exploring less of their surroundings (Harris et al., 2013). However, sows that are naïve to exercise in the alleyway, can make multiple stops to investigate floor and other sows. Walking on a treadmill eliminates these distracting factors and helps an animal to concentrate on exercise. On the other hand, exercising in the alleyway offers a wider range of movement than the treadmill, which imposes a more pronounced physical demand on the skeleton and can lead to higher bone strength and improved locomotory ability. Additionally, if exercised in the alleyway, sows have a greater opportunity to express their natural behaviours, which is important for sow welfare (NFACC, 2012).

In the study of Schenck et al. (2008), the authors reported cases of refusal to exercise in gilts from the high exercise treatment, which indicates evident individual differences, and potentially poor pig handling. The right strategy for the animals that are unwilling to move may be to not exercise them at all. Another fact that needs to be considered is that both Schenck et al. (2008) and Harris et al. (2013) offered sows rewards for exercise. Schenck et al. (2008) provided sugar cubes once per lap in the same corner to encourage sows and reduce time exploring and sniffing. Harris et al. (2013) rewarded sows with a treat (i.e., a cookie) at the completion of exercise. Hence, the motivation of sows to exercise is not clear from these studies, as some animals may exercise only to get the reward. Although, it is likely a more positive experience for the sow when each lap is rewarded.

Harris et al. (2013) exercised sows at 2.6 times the maximum distance covered per day by Schenck et al. (2008): 940 – 1229 m/day vs. 427 m/day. The total time to exercise a sow per day was up to 14 min in the study of Schenck et al. (2008), and 30 min in the study of Harris et al. (2103). However, group-housed sows have been observed to move a greater distance in eight hours, than sows in a maximum exercise treatment (Schenck et al. 2008). This calls into question the sufficiency of exercising stall-housed sows to be comparable to groups. The type of exercise in group-housing and periodic exercising also differs, and this may influence the benefits of providing a greater freedom of movement.

Providing sows with 30-minute exercise sessions (Harris et al., 2013) with the participation of two handlers would significantly increase labour costs. Implementation of 10-minute exercise sessions, which involve only one handler (Tokareva et al., 2019a), would require less additional funds.

In the above-mentioned studies, sows were exercised individually which reduced negative social encounters and encouraged them to move forward. This ensured that the animals were getting the required amount of exercise and received similar physical benefits. However, sows have other behavioural needs than exercise– such as exploring the surroundings and social contact.

9.3 Motivation for a greater freedom of movement, or presentation of resources in the stall

Tokareva et al. (2018) tested the motivation of stall-housed sows (n = 12) and gilts (n = 12) to access three min of exercise in the alleyway between stalls, in comparison to their motivation to receive additional feed in their stall (30% of daily ration). Sows showed a greater motivation for feed than for movement, but gilts showed similar levels of motivation for the two rewards. Sows had a greater motivation to access feed than gilts. However, gilts and sows did not differ in their motivation to access movement. It can be concluded that there is a level of motivation by sows and gilts to have a greater freedom of movement.

In a second study, Tokareva et al. (2019b) compared the motivation of stall-housed gestating sows (n = 42) to access time out of their stall for three min in the alleyway, when maintained movement at different levels of satiety. Sows were assigned to one of three treatments: control (n = 14), fed a standard gestation ration; moderately satiated (n = 14), receiving 50% of their ad-lib high fibre intake once per day in addition to their standard ration; and fully satiated (n = 14), given unlimited access to high fibre in addition to their ration. Control sows showed a greater motivation for movement than fully satiated sows. Moderately satiated sows were intermediate between control and fully satiated sows for their motivation to access movement. ***This study indicates that the motivation of sows to exit their stall is influenced by feeding level, with feed restriction increasing sows' motivation to exit the stall.***

Elmore et al. (2012a) measured the motivation of stall-housed sows to access a trough behind their stall gate containing enrichment. A total of 32 sows (8 sows/treatment) were trained to interact with an operant panel to access the following enrichments: compost in a trough, straw in a rack, additional food (positive control) or an empty trough (negative control). To get access to the resource upon completion of the testing, an animal had to walk forward out of the stall into a short alleyway. Sows showed shorter latency to press the operant panel and higher levels of interaction with the panel when access to food or compost was the reward, compared to an empty trough. There was no difference between sows' motivation to access straw and an empty trough. However, upon exiting the stall, sows spent a greater percentage of time interacting with straw. It was concluded that both compost (as indicated by operant responses), and straw (as indicated by interaction time), are valued by sows, and their provision should be considered to improve welfare. Considering the fact that the reward in this study consisted of gaining access to the resource and exiting the stall, these results may indicate an element of sow motivation to access more space. This was proposed by Elmore et al. (2012a) by the fact that levels of interaction with the panel for an access to the empty trough were relatively high: 59.9 ± 12.1 button presses within one hour.

A second study by Elmore et al. (2012b) replicated the approach of Elmore et al. (2012a), but compared the motivation of stall housed sows to access a new stall containing a cotton rope, a rubber stall mat, an empty trough (negative control) or food (positive control). Sows showed the highest level of motivation to access food, with the motivation to access rope, a mat or an empty trough being lower, and no different. It was concluded that the motivation was low for the enrichment options, and that the ability to walk into a new stall to access the items was the main reward, which would explain why the motivation to access the rope and mat was no different from the motivation to access an empty trough.

The above-mentioned studies show that stall-housed gestating sows have a level of motivation for movement outside of their stalls, and given an opportunity, will work to achieve this on a daily basis. However, this motivation can be reduced with provision of high fibre feed additional to the sow standard ration. Stall-housed sows value access to certain enrichment items (compost,

straw), and less some for items such as rope and rubber matting. There is evidence that interacting with the operant panel and walking to an empty stall is enriching in itself.

9.4 Other options for providing a greater freedom of movement

McFarlane et al. (1988) studied behavior of mated gilts in turn-around crates. Crate width in the center was 56 or 61 cm depending on treatment, and the crates widened to 112 and 122 cm, respectively, which allowed the gilt to turn around. The authors found that gilts housed in the narrower turn-around stalls had reduced turning frequency by more than 30% (12.9 turns/day for the wide stalls vs. 8.9 turns/day for the narrow stalls). The authors concluded that the need to turn around in pregnant gilts may be not particularly strong, due to the observed relationship between the level of space reduction and frequency of turning around. However, turning around may have been more difficult in the narrower stalls, and was not considered.

Boe et al. (2011) also looked at the turning around behaviour, but this research was focused on the effects of reducing individual pen width in pregnant sows. The findings were in agreement with the results of McFarlane et al. (1988): the frequency of turning movements decreased from almost 200 times per 24 h in a 2.4 m wide pen, to less than 36 times at a pen width 60% of sow length, and less than twice at 50% of sow length. All sows turned around several times daily, even when pen width was reduced to 60% of sow length. However, when pen width was reduced to 50%, only seven of 16 sows turned around. ***Within this study, turning occurred irrespective of the location of food and water in the pen, which implies that the sow's desire to move around reflects the need for a greater freedom of movement or the need to orientate and explore.***

The behavioural and physiological (immune and cortisol) responses of Meishan (MM, n = 12), Yorkshire (YY, n = 12) and crossbred (YM, n = 12 and MY, n = 12) gilts to confinement in conventional and turn-around gestation stalls was studied Bergeron et al. (1996). Animals were assigned equally by genotype to either a conventional, or a turn-around stall after breeding and studied for 36 days. Animals housed in the turn-around stall could increase their available floor space by pushing on one or both sides of the stall. All of the animals had continuous access to environmental enrichment (chains). Gilts in turn-around stalls stood more frequently, performed more manipulative behaviours (nosing/licking of the stall bars, and chain manipulation) and had lower plasma-cortisol levels than gilts in conventional stalls. Treatment did not influence immune system functioning. Bergeron et al. (1996) concluded that gilts housed in turn-around stalls utilized the greater freedom of movement afforded to them by turning frequently. The authors also stated that manipulative behaviours (such as interaction with chains and drinkers), may be involved in stereotypy development, but could also be associated with the greater frequency of standing and turning observed in turn-around stalls. The findings may be confounded by the effect of the specific stall design, which allows the animal to increase its available floor space only at the expense of its neighbour's space, so each of the animals was constantly disturbed by its neighbour's movements.

There is no work exploring providing a greater freedom of movement to stall-housed sows through temporary provision of access to a group pen.

9.5 Stall-housed boar exercise

No recent published work was located on exercising boars. However, a body of research on exercising boars was conducted in the second half of the 20th century.

Section 9.2.1, on exercise frequency, includes studies that have explored the effect of exercise on boars, including those of Petersen et al. (1998), Enfalt et al. (1993), Perrin and Bowland (1977).

Nowadays it is a common practice to remove adult boars from the stall several times a week for heat detection or mating purposes, and they receive social enrichment and a greater freedom of movement from this activity, as described in the Code of Practice (NFACC, 2014, pg.13). However, if the farm uses a boar cart - then the boar does not receive as much freedom of movement, which should be considered.

9.6 References

Bergeron, R., H.W. Gonyou, and T.E. Eurell. 1996. Behavioral and physiological responses of Meishan, Yorkshire and crossbred gilts to conventional and turn-around gestation stalls. Can. J. Ani. Sci. **76**:289–297.

Boe, K.E., G.M. Cronin, and I.L. Andersen. 2011. Turning around by pregnant sows. Appl.Ani. Behav. Sci.**133**:164–168.

Elmore, M.R.P., J.P. Garner, A.K. Johnson, R.D. Kirkden, E.G. Patterson-Kane, B.T. Richert, and E.A. Pajor. 2012a. Differing results for motivation tests and measures of resource use: The value of environmental enrichment to gestating sows housed in stalls. Appl. Ani. Behav. Sci. **141**:9-19.

Elmore, M.R.P., J.P. Garner, A.K. Johnson, R.D. Kirkden, B.T. Richert, and E.A. Pajor. 2012b. If You Knew What Was Good For You! The Value of Environmental Enrichments With Known Welfare Benefits Is Not Demonstrated by Sows Using Operant Techniques. J. Appl. Ani. Wel. Sci. **15**: 254-271.

Enfalt, A.C., K. Lundstrom, I. Hansson, A. Karlsson, B. Essen-Gustavsson, and J. Hakansson. 1993. Moderate indoor exercise: Effect on production and carcass traits, muscle enzyme activities and meat quality in pigs. Ani. Prod. **57**:127–135.

Ferket, S.L. and R.R. Hacker. 1985. Effect of forced exercise during gestation on reproductive performance of sows. Can. J. Ani. Sci. **65**:851–859.

Fredeen, H.T. and A.P. Sather. 1978. Joint damage in pigs reared under confinement. Can. J. Ani. Sci. **58**:759-773.

Hale, O.M., G.L. Newton, and E.R. Cleveland. 1984. Effects of exercise during the growing-finishing period on performance, age at puberty and conception rate of gilts. J. Ani. Sci. **58**:541–544.

Harris, E.K., E.P. Berg, E.L. Berg, and K.A. Vonnahme. 2013. Effect of maternal activity during gestation on maternal behavior, fetal growth, umbilical blood flow, and farrowing characteristics in pigs. J. Ani. Sci. **91**:734–744.

Kaminski, S.L., A.T. Grazul-Bilska, E.K. Harris, E.P. Berg, and K.A. Vonnahme. 2014. Impact of maternal physical activity during gestation on porcine fetal, neonatal, and adolescent ovarian development. Dom. Ani. Endocrin. **48**:56–61.

McFarlane, J.M., K.E. Boe, and S.E. Curtis. 1988. Turning and walking by gilts in modified gestation crates. J. Ani. Sci. **66**:326–333.

Morrison, S.R., H.F. Hintz, and R.L. Givens. 1968. A note on effect of exercise on behaviour and performance of confined swine. Ani. Prod. **10**:341–344.

Murray, D.M., J.P. Bowland, R.T. Berg, and B.A. Young. 1973. Effects of Enforced Exercise on Growing Pigs: Feed Intake, Rate of Gain, Feed Conversion, Dissected Carcass Composition, and Muscle Weight Distribution. Can. J. Ani. Sci. **54**:91–96.

National Farm Animal Care Council. 2014. Code of Practice for the Care and Handling of Pigs. Available at: https://www.nfacc.ca/pdfs/codes/pig_code_of_practice.pdf

National Farm Animal Care Council. Pig Code of Practice Scientific Committee. 2012. Code of Practice for the Care and Handling of Pigs: Review of Scientific Research on Priority Issues. Available at: https://www.nfacc.ca/resources/codes-of-practice/pig/Pig_Scientists_Committee_report.pdf

Perrin, W.R. and J.P. Bowland. 1977. Effects of enforced exercise on the incidence of leg weakness in growing boars. Can. J. Ani. Sci. **57**:245-253.

Petersen, J.S., N. Oksbjerg, B. Jorgensen, and M.T. Sorensen. 1998. Growth performance, carcass composition and leg weakness in pigs exposed to different levels of physical activity. Ani. Sci. **66**:725–732.

Schenck, E.L., K.A. McMunn, D.S. Rosenstein, R.L. Stroshine, B.D. Nielsen, B.T. Richert, J.N. Marchant-Forde, and D.C. Lay. 2008. Exercising stall-housed gestating gilts: Effects on lameness, the musculo-skeletal system, production, and behavior. J. Ani. Sci. **86**:3166–3180.

Tokareva, M., J.A. Brown, A. Woodward, E.A. Pajor, and Y.M. Seddon. 2018. Movement or more food? A comparison of motivation for exercise and food in stall-housed sows and gilts. In: Proceedings of the 52nd International Society for Applied Ethology Congress, Charlottetown, PEI, Canada, 30th July-3rd August, pp. 232.

Tokareva, M., J.A. Brown, E.A. Pajor, D. MacPhee, D. Beaulieu, G, Adams, D, Janz, and Y.M. Seddon. 2019a. Motivated for movement? Exercise and the gestation environment on sow performance and welfare (Project# 20160021). Report No. 2 produced for the Saskatchewan Agriculture Development Fund. Unpublished data.

Tokareva, M., J.A. Brown, A. Woodward, E.A. Pajor, and Y.M. Seddon. 2019b. Influence of satiety on the motivation of stall-housed gestating sows to exit their stall. Accepted for: 53rd International Society for Applied Ethology Congress, Bergen, Norway, 5th-9th August.

Weiss, G.M., E.R. Peo Jr, R.W. Mandigo, and B.D. Moser, 1975. Influence of exercise on performance and carcass parameters of confinement reared swine. J. Ani. Sci. **40**:457-462.

10.0 Evaluating the efficacy of knowledge transfer for on-farm application

10.1.1 <u>Conclusions</u>

1. **Human behaviour is dynamic and influenced by demographics, prior experience, and knowledge. Knowledge transfer must also be dynamic, and consider the factors that influence decision-making of individuals and groups.**
2. **Mass media is an extension tool that can deliver information to the greatest number individuals at once, but has a lower likelihood of influencing change. Knowledge transfer using individual communication is more effective because it takes individual circumstances into account. However, it delivers information to only one or few individuals at a time.**
3. **Livestock owners and operators are more likely to adopt new practices when they are aware of a problem, perceive a risk to themselves or their farm, and believe they are capable of making the necessary management changes.**

10.1.2 Knowledge gaps

- Understand barriers to adoption of on-farm application of improved management practices.

- Information on the efficacy of different knowledge transfer approaches in the swine industry.

Ritter et al. (2017) reviewed literature on factors affecting farmer behaviour and decisions to adopt recommended management strategies. The Theory of Planned Behaviour (Ajzen, 1991), is considered a relevant model for socio-psychological influences on farmer adoption of management practices, in combination with the 'Health Belief Model' summarized in Figure 4. Factors influencing decision making include: farmer demographics, problem awareness, perceived responsibility and ability to make changes, combined with the perceived benefits and disadvantages (including laws and regulations, market prices, cost of implementing a program). ***Ritter et al. (2017) proposes that effective knowledge transfer must therefore address all factors that affect decision making.*** The importance of a policy or management strategy, in context of the producer's socio-psychological influences, must be communicated. Evidence-based recommendations and case studies may assist in enhancing a producer's belief in the effectiveness of the proposed best management strategy, and the strategy must be within their perceived ability to implement.

Knowledge transfer or extension tools can include mass media, seminars and conferences, participatory group learning (workshops, farm tours) and individual communication. However, each tool will vary in its ability to deliver information to large groups and to take individual circumstances into account (Figure 5).

Animal disease management is a well-studied model for the efficacy of knowledge transfer and the behavioural influences associated with adoption of disease management practices (Hidano et al., 2018). In a review of dynamic human behavioural changes in response to animal disease outbreaks, Hidano et al. (2018) found that three key factors influence livestock owners to change on-farm biosecurity and disease management practices: i) prevalence-based factors, ii) belief-based factors, and iii) knowledge gaps and limitations.

Specifically, local prevalence of a disease is more likely to induce behavioural change in farmers than global prevalence, due to a perceived increase in personal risk. Belief-based factors include prior disease experience (and subsequent risk perception), perception of social norms, and perceived efficacy and safety of disease control measures. Farmers are more likely to respond to disease risk if they believe that they are at a high risk, that they will benefit economically or personally from management changes, and that the proposed changes are within their capabilities. A farmer's knowledge of, and response to, social norms will also influence their adoption of a management strategy; pressure from peers, industry and society will affect behaviour. Response to social norms is also partially dictated by a person's prior experience and their relationships with peers. Finally, education on disease control such as knowledge of disease and biosecurity and comprehension of cost-benefit analysis of adopting new practices will likely impact behavioural changes.

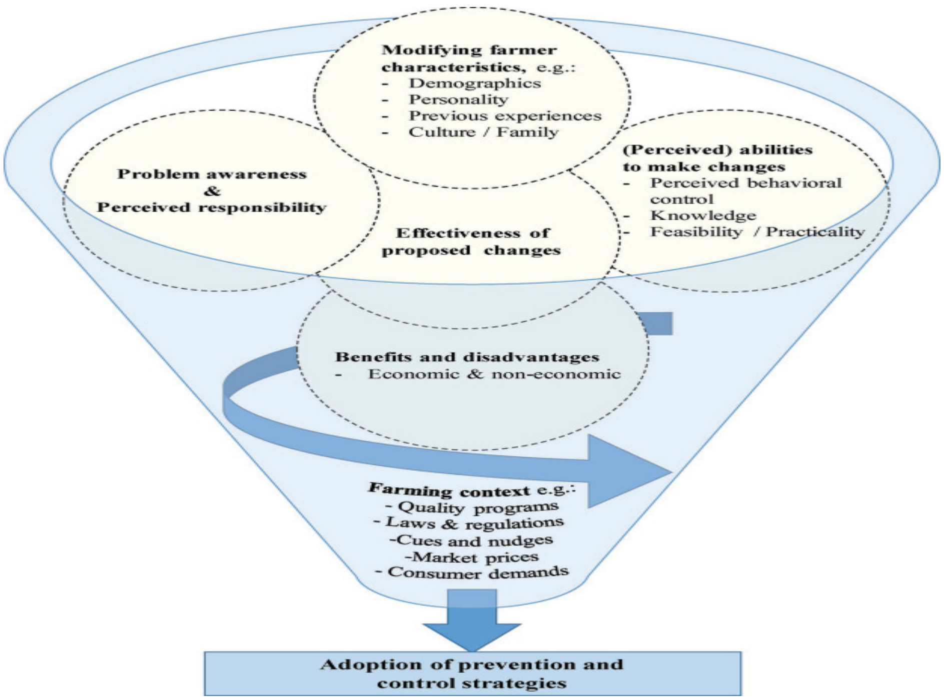


Figure 4. Socio-psychological factors that influence the adoption of on-farm management strategies for improved infectious disease prevention and control, from Ritter et al. (2017).

Figure 5. Potential of agricultural extension tools to deliver information simultaneously to many farmers and tailor communication according to individual circumstances. From Ritter et al. (2017).

10.2 References

Ajen, I. 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50, (2), 179-211.

Hidano, A., G. Enticott, R. M. Christley, and M. C. Gates. 2018. Modeling Dynamic Human Behavioral Changes in Animal Disease Models: Challenges and Opportunities for Addressing Bias. Front. Vet. Sci. **5**.

Ritter, C., J. Jansen, S. Roche, D. F. Kelton, C. L. Adams, K. Orsel, R. J. Erskine, G. Benedictus, T. J. Lam, and H. W. Barkema. 2017. Invited review: Determinants of farmers adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. **100**:3329–3347.