Research Summaries

Project summaries from CRC
for High Integrity Australian Pork

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PORK CRC Research Summaries

Mission Statement

The CRC for High Integrity Australian Pork aimed to differentiate Australian pork as a 'high integrity' meat that is welfare-optimal, premium quality, nutritious, in high demand nationally and internationally, and which is produced while conserving energy and water, minimising greenhouse gas emissions and maintaining efficiency and cost of production at levels which encourage investment, growth and sustainability.

Outcomes

A key challenge for Australia's pork industry is to produce high quality food for sale at a reasonable price, and with a satisfactory return on production capital invested, without negatively impacting pig welfare, the environment or the health of the consumer.

Through innovative, collaborative, whole value chain research, development and education programs within a CRC, the Australian pork industry can meet this challenge and has unique potential compared with other foods, meats and sources of pork by facilitating production that:

1. Is efficient and ethical with reduced need for sow confinement and judicious use of antibiotic medications.
2. Safely delivers key nutrients, enhancing the health and well-being of consumers.
3. Utilises innovative feed sources and effluent management systems, resulting in emissions of less than 1kg of CO_2 per kg of pork produced.
4. Contributes significantly to Australia's economic growth and food security without drawing on the ecological capital of other parts of the world.

Executive Summary

The CRC for High Integrity Australian Pork (Pork CRC) has completed all its research projects and its Education program. The agreement with the Australian Government concludes on June 30, 2019.

Delivering research outcomes to industry, participants and consumers of pork will be ongoing and where appropriate this publication provides summaries of all Pork CRC projects. The full reports can be accessed through the Pork CRC web site (www.porkcrc.com.au).

Research across the six programs within Pork CRC has helped change the Australian pork industry. Compared to even six years ago the Australian pork industry is more competitive than ever and leads the world in understanding and implementing housing and management systems which enhance animal welfare and wellbeing. Most of the information, which allowed this transition, was generated by Pork CRC in Program 1 (Reducing the Confinement of Sows and Piglets).

Tremendous strides have been made through Pork CRC research in the eating quality of Australian pork. Since 2011, our researchers in Program 3 (Healthy Pork Consumption) took meat science out of the laboratory and across the supply chain resulting in processing innovations, which markedly enhanced the eating quality of Australian pork. The research efforts culminated in the development of an interactive eating quality model, which should ensure participants across the supply chain, can assess their best strategies for further enhancing the eating quality of Australian pork.

Pork CRC researchers in Program 2 (Herd Health Management) developed new diagnostics for all major pathogens, established genetic indictors for disease resilience and robustness and alternatives to antibiotics for preventing some diseases and ameliorating the impacts on animal performance and the heath of others.

In Program 4 (Carbon Conscious Nutrient Inputs and Outputs), we saw the tremendous uptake of Biogas capture and use for generating power and heat led largely by Pork CRCs Bioenergy Support Project. Two Life Cycle Assessments on greenhouse gas emissions conducted by Pork CRC showed the $C0_2$ equivalents have fallen from near 3.6 kg/kg pork produced in 2010 to closer to 2kg/kg in 2015 and will approach 1.0:1.0 in 2020. This tremendous reduction in greenhouse gas emissions (44% reduction between 2010 and 2015 and 66% reduction projected between 2010 and 2020) has been achieved by improvements in the efficiency of pork production and the capture of methane from covered ponds, other digester systems, and the use of the methane to generate power and heat. Researchers in Subprogram 4B refined/enhanced Pork CRCs AusScan calibrations for rapidly determining the energy value of grains and the total amino acid and reactive lysine content of soybean meal and canola meal. The calibrations are used globally and AusScan is a major generator of revenue for APRIL. Researchers in the same subprogram also investigated the impacts of processing and grain particle size and fibre on rate of passage through the intestinal tract and the impacts of changes in these factors on pig growth performance.

In Programs 5 and 6 we completed projects on reproduction and nutrition respectively started in the CRC for an Internationally Competitive Pork Industry. The outcomes changed our thinking on how gestating sows should be fed to maximise reproduction and provided new information on ingredients that can stimulate intake in weaner pigs and reduce the chance of nutrient asynchrony occurring in grower-finisher pigs.

The Pork CRC has been integral in the transformation of the Australian pork industry and whilst our higher feed costs and relatively low, carcass weight may prevent us becoming the lowest cost producers in the world there is a good chance we produce the best value pork in the world.

CRC for High Integrity Australian Pork

PROGRAM 1	REDUCED CONFINEMENT OF SOWS AND PIGLETS
PROGRAM 2	HERD HEALTH MANAGEMENT
PROGRAM 3	HEALTHY PORK CONSUMPTION
PROGRAM 4	CARBON CONSCIOUS NUTRIENT INPUTS AND OUTPUTS
PROGRAM 5	IMPROVING SOW REPRODUCTION
PROGRAM 6	NUTRITIONAL MANIPULATIONS TO ENHANCE THE PERFORMANCE AND FEED EFFICIENCY OF GROWING PIGS

CRC for High Integrity Australian Pork

PROGRAMS

Investment across programs and subprograms are summarised in the following tables and where appropriate, a summary of each project including the key findings and industry relevance are provided.

1 **Reduced confinement of sows and piglets**

2 **Herd Health Management**

3 **Healthy Pork Consumption**

4 **Carbon Conscious Nutrient Inputs and Outputs**

5 **Improving Sow Reproduction**

6 **Nutritional manipulations to enhance the performance and feed efficiency of growing pigs**

PROGRAM

1 Reduced confinement of sows and piglets

Program 1 supported research to develop innovative sow and piglet management and housing systems that progressively rely upon less confinement to optimise sow and piglet welfare while maintaining production efficiency and profitability of pork production.

SUBPROGRAM 1A	**MATING AND LACTATING INNOVATIONS**
SUBPROGRAM 1B	**INNOVATIVE WEANING SYSTEMS**
SUBPROGRAM 1C	**MANAGEMENT OF SOWS IN GROUPS**

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Subprogram 1A: Mating and Lactating Innovations

The development of effective and efficient strategies to stimulate ovulation by lactating sows within conventional lactation accommodation as well as low confinement housing systems.

PROJECT ID	TITLE
1A–101	Strategies to enhance oestrous induction in lactating sows
1A–102	Managing the sow to stimulate lactational ovulation
1A–103	Optimising the time of mating in easy-to-manage lactation systems to improve pregnancy outcomes and weaning
1A–104	Maximising fertility and fecundity of sows mated during lactation
1A–105	Developing commercially-viable, confinement-free farrowing and lactation systems
1A–106	Development of a lactational oestrus induction protocol that can be implemented in confinement free sow housing systems
1A–107	Reducing early embryonic loss in the pig
1A–108	Reducing the labour costs and increasing synchrony and predictability of lactation oestrus
1A–109	Innovative refinements of existing lactation pen systems to better suit Australian environmental and management systems
1A–110	Reducing confinement of peri-parturient and lactating sows
1A–111	Developing ways to measure and increase sow contentment
1A–112	Commercial evaluation of lactational oestrus
1A–113	Welfare implications of group lactation at various ages
1A–114	Can oxytocin nasal spray improve gilt behaviour during the peri-partum period and increase the weaning weight of piglets
1A–115	The feeding behaviour of sows and its relationships to sow welfare and reproduction
1A–116	Managing light and mat surface temperature in creep areas to minimise dangerous piglet behaviour associated with crushing
1A–117	A meta-analysis of farrowing pens: factors responsible for high performance
1A–118	Fenceline boar exposure at the end of lactation to improve reproductive performance of group-housed sows
1A–119	Using an anti-inflammatory to increase piglet survival and growth in crates and pens

Research Summaries for Subprogram 1A

PROJECT 1A–101: STRATEGIES TO ENHANCE OESTRUS INDUCTION IN LACTATING SOWS

Project Leader:
Dr Jeff Downing

Project Participants:
University of Sydney
and Rivalea Australia

Aims and Objectives

Results from Pork CRC project 2D–113 'Induction of oestrus in lactating sows' confirmed it was possible to induce oestrus in lactating sows at 24–25 days after farrowing with an injection of PG 600 at 20 days post-partum combined with boar exposure and overnight (16 h) piglet separation each day until mating by AI. While this protocol was successful there remained no clear understanding of the relevance of each of the individual components. The objective of the current research was to refine the original induction protocol by investigating the roles of PG600 injection, boar exposure and the period of piglet separation needed to get successful level of mating and pregnancy in lactating sows.

The project involved 4 experiments to determine:

1] The earliest time in lactation that oestrus can be induced.

2] The role of PG600 injection and the days of piglet separation needed.

3] The period of piglet separation (hours/day) needed.

4] The role of fenceline boar exposure and rate of spontaneous ovulation in lactating sows.

All experiments were undertaken at the Research and Innovation unit, Rivalea, Corowa NSW, using the PrimeGro™ genotype.

Key Findings

1] Around 15% of sows were found to spontaneously ovulate during lactation.

2] The oestrus induction protocol can be initiated as early as day 14 of lactation but would be best limited to day 16 and later of lactation to ensure good pregnancy rates and litter size.

3] The use of PG600 does not seem critical to oestrus induction.

4] With fenceline boar exposure, the piglet separation period can be limited to overnight (16h) for 3 days.

5] With fenceline boar exposure, separation for 8h for 3 days while giving good mating results may have negative effects on return to oestrus rate and subsequent litter size.

6] Using PG600, piglet separation and fenceline boar exposure resulted in similar lactational mating rates for primiparous as for multiparous sows.

7] Fenceline boar exposure alone is not sufficient to induce lactational oestrus in a high percentage of sows.

Application to Industry

Induction of oestrus in lactation eliminates the weaning to oestrus interval and provides the industry with increased management options for sows and piglets. These include confinement free housing options for lactating and gestating sows, reducing 'weaner setback' by increasing weaning age and increased farrowing frequency.

PROJECT 1A–102: MANAGING THE SOW TO STIMULATE LACTATION OVULATION

Project Leader:
Dr William van Wettere

Project Participant:
University of Adelaide

Aims and Objectives

The development of commercially viable and natural methods of stimulating lactation oestrus. Specifically:

- Determining the effects of split weaning (permanent removal of a portion of the litter) on lactation oestrus expression in boar exposed sows.
- Determining the optimal day of lactation on which to commence boar stimulation.

Key Findings

The current data is the first to demonstrate that boar contact on its own, when conducted in a detection mating area, can be used to stimulate a high proportion of sows to exhibit a rapid and synchronous oestrus and ovulation during lactation.

The use of daily boar contact from day 18 of lactation onwards represents an efficient and "natural" method of inducing lactation oestrus, thus maintaining commercially viable farrowing to conception intervals and allowing piglet age at weaning to be increased.

Research Summaries for Subprogram 1A continued

Providing multiparous sows with 15–20 minutes of daily, physical boar contact in a detection mating area from day 18 of lactation onwards is an effective method of stimulating a rapid and synchronous lactation oestrus, and appears to negate the need to reduce the suckling intensity by removing piglets.

79% of multiparous sows suckling 11 piglets, and receiving physical boar exposure in a DMA exhibited a lactation oestrus and a subsequent total born of 11.0.

A rapid and synchronous lactation oestrus was also obtained when suckled litter size was reduced to 7 piglets on day 18 of lactation and sows received fence line contact with a mature boar in a detection mating area.

More specifically, split weaning in conjunction with fence line boar exposure in a DMA resulted in high incidences of lactation oestrus (83.3–94.4 %, and subsequent total born of 11.6–13.5 piglets).

Application to Industry

The ability to extend sow lactation length without compromising the efficiency of the breeding herd allows piglet weaning ages to be based on piglet needs rather than the need to maximise farrowing frequency. Considering increased retailer and consumer interest and awareness of management practices, the ability to use natural methods (namely boar exposure) to stimulate sows to express oestrus, ovulate and conceive during lactation, as well as produce commercially viable farrowing rates and litter sizes is an important outcome for the pig industry.

Boar exposure is a process that most stock persons are familiar with, and therefore little additional training would be required if this strategy was adopted.

The use of physical boar contact, in a DMA, appears to negate the need to modify suckled litter size (split weaning) and may mean that temporary separation of the piglet from the sow is unnecessary to achieve high incidences of lactation oestrus, along with good sow fertility and fecundity.

PROJECT 1A–103: OPTIMISING THE TIME OF MATING IN EASY-TO-MANAGE LACTATION SYSTEMS TO IMPROVE PREGNANCY OUTCOMES AND WEANING, FOR FIRST LITTER SOWS

Project Leader:
Dr Pieter Langendijk

Project Participants:
George Foxcroft, Michael Dyck, Jennifer Patterson (all University of Alberta), Rebecca Athorn (Rivalea), Ellen McDonald (University of Sydney), Tai Yuan Chen (SARDI Livestock) Diana Turpin and John Pluske (both Murdoch University)

Aims and Objectives

This project was a collaborative approach involving resources from SARDI, Rivalea, Murdoch University, University of Sydney and University of Alberta. The overall objective of this Project was to stimulate ovulation and a fertile pregnancy in lactating, first litter sows, using a combination of limited nursing and boar contact stimuli, imposed at different times of lactation. These treatments also enabled a more gradual weaning process, so the effect of these treatments on the development of gut physiology and piglet performance was also monitored.

Key Findings

Removal of the litter from the sow for 8 hours per day for the last 7 days of lactation, combined with daily fenceline contact with a boar was sufficient to stimulate up to 70% first litter sows to ovulate and exhibit oestrus during lactation. In some cases, the proportion of sows that responded to this protocol was lower, possibly because of less effective boar stimulation. Other key observations from this project were:

- The subsequent reproductive performance of those sows mated during lactation was often no less than those conventionally weaned and mated after weaning.
- Delaying the start of the stimulation protocol from day 21 to day 28 of lactation tended to provide a greater oestrus response and better piglet performance and gut development during the immediate periods prior to and after weaning.
- Limited nursing may temporarily reduce growth performance of piglets, but provided a more gradual transition to weaning and long term growth was unaffected.
- Delaying the mating of stimulated sows until the next oestrus (“skip-a-heat”) failed to improve subsequent reproductive performance of first litter sows.

- Those sows that responded to the oestrus stimulation protocols appeared to be heavier and less catabolic at the start of stimulation than “non-responders”.

The split suckling protocol, where the largest piglets were removed for 16 hrs each day for the last 7 days of lactation and were alternated with the remaining piglets for the remainder of the day, failed to improve the oestrus response of sows and furthermore had a negative impact on piglet growth rate, compared to the litter separation protocol.

Application to Industry

It appears that up to about 70% first litter sows may respond to a stimulation protocol of litter separation and boar exposure during the last week of lactation, by exhibiting a fertile oestrus during late lactation. The response rate in older sows is often in excess of 80–85%. However the lower and often less predictable response rate in first litter sows may be acceptable in most commercial piggeries where there are weekly matings, as those sows that don’t respond to the stimulation protocol usually exhibit oestrus within 7 days of weaning and have acceptable subsequent reproductive performance.

The protocol of litter separation for 8 hours per day from at least day 21 of lactation accompanied by daily fenceline and nose to nose boar contact should be sufficient to stimulate an acceptable proportion of sows exhibiting oestrus during lactation, particularly in multiparous sows. Any short term reduction in piglet preweaning growth resulting from piglet separation in later lactation is more than likely to be compensated by lower post weaning growth check and more acceptable post weaning performance of piglets.

PROJECT 1A–104: USE OF NATURAL STIMULI TO INDUCE OVULATION AND MAXIMISE FERTILITY IN LACTATING SOWS

Project Leader:
Dr Will van Wettere
(University of Adelaide)

Project Participants:
Alice Weaver
and Roy Kirkwood
(University of Adelaide),
David Lines
(Sun Pork Farms SA)

Aims and Objectives

A total of four experiments were conducted as part of this project. The overall aim of these experiments was to optimise lactation oestrus expression and reproductive output of sows induced to ovulate using natural stimuli. The natural stimuli investigated included various forms of boar contact, manipulations of suckling load by temporary separation of litters and split weaning as well as shifting to group housing of sows in late lactation.

Key Findings

The main findings from these four experiments were:

1] The oestrus response to stimulation strategies in lactation in first litter sows is often 20-30% lower than in older sows. Daily full physical boar exposure in a DMA area from about day 18 of lactation can result in at least 70% response. Further stimulation by weaning up to half the litter at day 18 may lift the response to almost 90% in multiparous sows. However the litter size of those sows that were mated during lactation was about 0.7 piglets less than those mated after weaning. In addition, the farrowing rate of stimulated sows mated during lactation was about 10 percentage units lower than sows mated after weaning.

2] Ten minutes of physical nose-to-nose contact with a mature boar at the front of the farrowing crate each day wasn’t sufficient to stimulate oestrus in more than 20% lactating sows. However, combining litter separation for either 7 or 16 hours per day, in addition to this boar contact, increased oestrus response in lactation to 50% and 81%, respectively. Litter separation for 16 hrs for 3 days had little effect on the welfare of the piglet (as measured by cortisol levels), but piglet weaning weight was reduced by about 0.8 kg.

3] In the third experiment, 15 minutes of daily physical contact with a boar in the DMA resulted in at least 80% response. There was less opportunity for the additional stimuli of split weaning to improve this already good response. However the split weaning treatments improved pregnancy rates and subsequent embryo number.

4] In the final study, grouping 3 sows and their litters together from day 18 of lactation wasn’t sufficient to stimulate a reliable oestrus in lactating sows. Providing further stimulation of these group housed sows with 20 minutes of fenceline contact with a mature boar resulted in a lactation oestrus response rate in excess of 80%. However, the weaning weight of piglets in litters from group housed sows was reduced by about 0.6 kg.

Application to Industry

Conducting daily physical boar exposure in a DMA from day 18 of lactation is an effective method of stimulating lactating sows to exhibit oestrus and ovulate during lactation. Less stringent boar exposure protocols, such as physical nose-to-nose contact for about 10 minutes in the farrowing crate will require further stimulation, such as some type of piglet separation (split weaning or litter separation) to achieve an acceptable proportion of multiparous sows exhibiting oestrus during lactation. Piglet separation protocols may not necessarily affect piglet weaning weights, but may also assist in restoring subsequent farrowing rates and litter sizes to levels comparable to conventionally weaned sows. Group housing of sows from day 18 in combination with fenceline boar exposure may be an alternative and effective method of stimulating oestrus during lactation. However, piglet weaning weights may be adversely affected with these changes to the sow housing systems during lactation.

Research Summaries for Subprogram 1A continued

PROJECT 1A–105: DEVELOPING COMMERCIALLY-VIABLE, CONFINEMENT-FREE FARROWING AND LACTATION SYSTEMS. PART 1: THE PIGSAFE SYSTEM

Project Leader:
Dr Rebecca Morrison
and Dr Emma Baxter

Project Participants:
Dr Greg Cronin
(University of Sydney),
A/Professor Inger Lise
Andersen (Norwegian
University of Life Sciences),
Professor Sandra Edwards
(Newcastle University),
Professor Lee Johnston
(University of Minnesota),
Dr Vivi Moustsen (Danish
Agriculture and Food Council),
Dr Pieter Langendijk (SARDI)
and Dr Jeff Downing
(University of Sydney)

Aims and Objectives

The use of farrowing crates can improve the welfare of neonatal pigs by providing warmth and limit the risk that piglets become chilled and die from either starvation or being overlain by the sow. Farrowing crates and the lack of straw bedding, however, restrict the ability of the sow to move around and perform "normal" pre-farrowing behaviours such as nest-site selection, nest-building activity and bonding with the piglets, and thus have been criticised on welfare grounds. Recently loose farrowing pens have been developed with specific farrowing pen design criteria to meet those biological needs of the sow and piglet and the needs of the stockperson. Two of these farrowing pens are the PigSAFE and UMB farrowing pens. The objective of this component of the project was to assess the PigSAFE loose farrowing system compared to a farrowing crate system under Australian conditions. The other part of this project investigated UMB farrowing pens and a two-stage farrowing systems (PigSAFE farrowing pen to group housing of sows during lactation).

Key Findings

- Piglet survival and number of piglets weaned per sow in the PigSAFE system were comparable to a farrowing crate system under Australian conditions. The majority of piglet deaths in the PigSAFE and farrowing crate system were caused by being overlain by the sow and occurred within 2 days post-partum, regardless of season.
- There was a tendency for piglets to grow faster in the PigSAFE system. Piglet growth may be improved further in the PigSAFE system if creep feeding can be provided.
- Sows in the PigSAFE system tended to eat more in lactation.
- Sows in the PigSAFE system had a better locomotion score and ease of movement score at weaning, compared to sows in farrowing crates.
- The PigSAFE system met the "biological needs" of the sow. The sows were not constrained at all, they were able to move around, the majority of sows exhibited maternal behaviours such as nest building and the sows were able to farrow in an isolated nest area. The current nest design in the PigSAFE pen was successful at promoting at least 90% of the sows to farrow in the designated nest area, regardless of season.
- In the PigSAFE system, piglets and sows spent significantly more time in the dunging area over summer, compared to winter, and as a result piglets were more like to get overlaid in this area. Further research is required to investigate pen modifications that discourage piglets from spending substantial time in the dunging area and/or protect them while they are in the dunging area and thus reduce the risk of piglets being overlain, particularly during summer.

Application to Industry

- The PigSAFE loose farrowing system meets the biological needs of the sow.
- Piglet survival was comparable to farrowing crate system under Australian conditions.
- Due to higher construction costs of the PigSAFE system, piglet survival (or other factors such as piglet growth rate, sow performance etc) will need to improve to increase the commercial viability of the PigSAFE system.
- During the experiment, new management routines were developed and the stockpeople became more confident and skilled working in the PigSAFE system.

PROJECT 1A–105: DEVELOPING COMMERCIALLY-VIABLE, CONFINEMENT-FREE FARROWING AND LACTATION SYSTEMS. PART 2: NORWEGIAN UMB FARROWING PEN SYSTEM

Project Leader:
Dr Greg Cronin
(University of Sydney)

Project Participants:
Professor Inger Lise Andersen (Norwegian University of Life Sciences), Dr Rebecca Morrison (Rivalea)

Aims and Objectives

The use of farrowing crates can improve the welfare of neonatal pigs by providing warmth and limit the risk that piglets become chilled and die from either starvation or being overlain by the sow. Farrowing crates and the lack of straw bedding, however, restrict the ability of the sow to move around and perform "normal" pre-farrowing behaviours such as nest-site selection, nest-building activity and bonding with the piglets, and thus have been criticised on welfare grounds. Recently loose farrowing pens have been developed with specific farrowing pen design criteria to meet those biological needs of the sow and piglet and the needs of the stockperson. Two of these farrowing pens are the PigSAFE and UMB farrowing pens.

The objective of this component of the project was to assess the UMB farrowing pen (2.4 m wide by 3.3 m long) compared to the conventional farrowing crate system (1.7 m x 2.2 m), under Australian conditions.

Key Findings

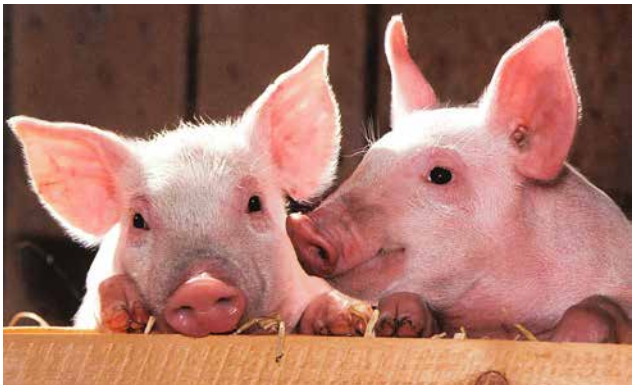
- The early results from the project identified high piglet mortality in both the conventional farrowing crate and the prototype UMB farrowing pen systems, with piglet mortality considered unacceptably high in the prototype UMB farrowing pen system, particularly during the colder winter months. Piglet mortality in farrowing crates and the prototype UMB pens was different (P=0.03) and was 15.4% and 25.0% of live born, respectively (n=36 for each treatment). In addition, 30.6% of the sows in the UMB pens lost more than 4 piglets in their litters, compared to only 8.3% of the sows kept in the farrowing crates.
- Subsequently, additional piglet heaters were installed in the UMB pens to assist in reducing piglet mortality for the remaining 5 replicates (20 sows per treatment). Piglet mortality for these replicates was 19.8% and 22.6%, for farrowing crates and the modified UMB farrowing pens, respectively. Although piglet mortality was similar, the absolute level is considerably higher than expected in commercial production.
- Sows in the UMB pens ate more feed (8.6 vs 7.8 kg/day, P=0.002) between day 7 and day 21 of lactation.
- Sows in farrowing crates had 1.7 more suckling bouts each day (P<0.05), but there was no significant difference between the crates and the UMB pens in piglet pre-weaning growth.
- Only 7.1% of the sows in the UMB pen system began farrowing outside the designated nesting area, but each of these sows moved to the nesting area for the births of the remaining piglets in the litter.
- Sows allocated to the UMB pens that performed more root/nose straw activity had lower pre-weaning mortality (P<0.05). Similarly, those that spent more time in the nest in the 24 h pre-partum had a lower pre-weaning mortality.

Application to Industry

These findings suggest that the prototype UMB pen did not provide an acceptable farrowing/lactation environment for adequate piglet survival, when installed in a retro-fitted, non-heated and poorly insulated shed.

The UMB pen and other farrowing/lactation pen systems may require installation in more climate controlled facilities to ensure adequate piglet survival and welfare.

Sows did have a strong preference to farrow in designated nesting areas of the UMB pens.



Research Summaries for Subprogram 1A continued

PROJECT 1A–106: DEVELOPMENT OF A LACTATIONAL OESTRUS INDUCTION PROTOCOL THAT CAN BE IMPLEMENTED IN CONFINEMENT FREE SOW HOUSING SYSTEMS

Project Leader:
Dr Jeff Downing

Project Participants:
Ellen McDonald, Hannah Lyons and Josephine Wilkinson (all University of Sydney)

Aims and Objectives

1] To examine oestrus induction protocols in lactating sows that involve different protocols of piglet separation and direct boar exposure.

2] To investigate the significance that sow metabolic status could have on the success of oestrus induction in lactation.

3] To investigate the behaviour and welfare of sows and piglets during periods of separation as part of an oestrus induction protocol.

4] To monitor follicle development in lactating sows to identify the levels of spontaneous ovulation during lactation.

Key Findings

- Daily piglet separation for 16 hrs for 3 consecutive days starting on day 21 of lactation was a successful oestrus induction protocol, although there were obvious adverse effects on piglet growth. For this protocol, 82% of sows were mated during lactation and 92% of these sows farrowed successfully with an acceptable litter size.
- Either a shorter separation period of 8 h/d, or temporarily removing sows from their farrowing crate and providing 30 min of full boar contact, were not sufficient by themselves to achieve adequate oestrus responses or adequate subsequent farrowing rates.
- There did not appear to be any effect of the metabolic status of sows during lactation on their ability to respond to oestrus induction protocols.
- An 8-hr daily piglet separation protocol for 7 consecutive days had little adverse effect on the welfare of sows and their piglets. Sow udder injury or cortisol levels were unaffected by the separation protocol. There were no consistent effects on piglet cortisol and there appeared to be no long term adverse effects on the welfare and behaviour of piglets during the daily 8-hr separation protocol.
- Examination of follicle size during lactation and weaning to oestrus interval data revealed that about 8-9% of the sows that were monitored, potentially ovulated during lactation. Oestrus induction protocols during lactation would identify these sows allowing them to be mated at this lactational oestrus.

Application to Industry

Daily piglet separation for 16 hrs for at least 3 consecutive days from day 18 to 21 of lactation can result in acceptable oestrus response rates and fertility. However shorter separation periods would be more acceptable to industry and the community because of possible adverse effects on piglet growth and welfare.

It is likely that a combination of less intrusive separation protocols, combined with boar exposure and even group housing in late lactation may be more acceptable for commercial pork production systems. These combined strategies could result in acceptable oestrus response rates and subsequent fertility, which would enable mating during lactation to be a real option.

Mating during lactation may allow more flexibility in grouping sows after insemination. Furthermore it may allow piglets to be weaned at a later age or in a more gradual process with benefits to their welfare and growth, without compromising overall sow reproduction rate.

PROJECT 1A–107: REDUCING EARLY EMBRYONIC LOSS IN THE PIG

Project Leader:
A/Professor Mark Nottle (School of Paediatrics and Reproductive Health, University of Adelaide)

Project Participant:
Dr Pieter Langendijk (Research Scientist, SARDI)

Aims and Objectives

The Australian sow ovulates on average 22 oocytes per cycle yet the number of pigs born live is around 11. A recent study by us showed that 33% of embryos (7 potential piglets) were lost by day 35 of gestation, with 23% (5 potential piglets) lost by day 21 (Langendijk et al., Pork CRC project 5A–105). Apparent differences in embryo survival between Australian and overseas herds suggest that further studies in this area are warranted. Previous studies in mice have demonstrated that the number of cells in the inner cell mass of blastocysts is correlated with implantation rate and fetal development and that this can be influenced by nutrition (Lane and Gardener 1997). As a first step in understanding the reasons for this loss in Australian Herds the present study examined the relationship between nutrition and inner cell mass number in gilts and sows using the known effect of feed restriction to increase early embryonic loss.

Key Findings

The present study confirmed previous studies that gilts fed at recommended levels for at least two weeks prior to ovulation (control) have a higher ovulation rate and as a consequence numbers of embryos, compared with those fed at maintenance (restricted). Interestingly blastocysts from the restricted group tended to have higher total, trophectoderm and inner cell mass cell numbers. Similar trends in ovulation rate and blastocyst total, trophectoderm and inner cell mass cell number were also seen in the sow study.

Application to Industry

This is the first time to our knowledge that the effect of feed restriction on blastocyst inner cell number has been examined in gilts and sows. The apparent increase in cell number with restricted feeding was an unexpected finding which we have interpreted to mean that under normal management conditions gilts and sows produce a proportion of embryos which are less viable (as indicated by inner cell mass cell number) which is a major contrbutor to early embryonic loss. Alternatively cell number may not be a good predictor of early embryonic loss in the pig. Given the potential to increase the number of piglets born by up to five the present study needs to be extended to confirm which hypothesis is correct. If confirmed that a proportion of embryos ovulated under normal management conditions are non-viable, the current approach will not only have identifed a major source of early embryonic loss but also provide a model whereby strategies to improve embryo survival can be evaluated.

The immediate message to Australian pork industry is that the results of this project confirm the adverse effects of restricted feeding prior to ovulation and insemination on ovulation rate and litter size. Every attempt should be made to ensure satisfactory feed levels are achieved for the 1–2 weeks prior to insemination.

PROJECT 1A–108: REDUCED LABOUR COSTS AND INCREASING SYNCHRONY AND PREDICTABILITY OF LACTATION OESTRUS

Project Leader:
Roy Kirkwood (University of Adelaide)

Project Participants:
Emmy Bouwman and Pieter Langendijk (SARDI), Jessica Zemitis and Will van Wettere (University of Adelaide)

Aims and Objectives

To determine whether an injection of hCG 1 or 2 days post-partum will induce ovulation and whether this is followed by normal cyclicity during the later lactation period.

Key Findings

Most sows had medium sized follicles at farrowing and injection of hCG at either 24 or 48 hours after farrowing resulted in follicular growth. However, the incidence of hCG-induced ovulation was low at about 26% and unaffected by injection timing. The reason for a lack of ovulation is unknown. However, although speculative, it is possible that the high circulating concentrations of luteinizing hormone (LH) occurring in the immediate post-partum period resulted in a down-regulation of follicular LH receptors, making them unresponsive to an ovulatory LH signal. If true, then the timing of hCG injection becomes even more critical and would possibly need to be administered immediately post-partum.

In addition, none of the hCG responsive sows appeared to exhibit oestrus and ovulate at the expected 21 days after their first post-farrowing, induced ovulation. Minimal boar stimulation may have contributed to the lack of the subsequent and predictable second oestrus and ovulation during late lactation.

Overall, these results indicate that post-partum administration of hCG is not an effective means to stimulate an ovulation and consistent oestrus cyclicity during the later lactation period.

Application to Industry

The data from this Project, together with the results from other studies, indicate that post-partum administration of hCG is not an effective means to consistently stimulate ovulation and subsequent cyclicity in lactating sows.

Research Summaries for Subprogram 1A continued

PROJECT 1A–109: INNOVATIVE REFINEMENTS OF EXISTING LACTATION PEN SYSTEMS TO BETTER SUIT AUSTRALIAN ENVIRONMENTAL AND MANAGEMENT SYSTEMS

Project Leader:
Dr Rebecca Morrison

Project Participants:

Rivalea Australia,
Dr Emma Baxter
(Scotland's Rural College),
Dr Vivi Moustsen (Danish
Agriculture and Food Council)
and Dr Janni Hales
(University of Copenhagen)

Aims and Objectives

To investigate sow welfare, piglet and sow lying behaviour, piglet growth and survival in the PigSAFE and SWAP loose farrowing system – which included cooling innovations for summer.

Key Findings

The pen cooling innovations in the PigSAFE experiment included cooled tiles in the creep area and an additional fan over the nest area. The SWAP experiment included cooling tiles in the creep area, a slatted nest area and an additional fan over the nest area.

- The experiments were conducted in different periods (different seasonal effects etc.), therefore caution is required when comparing the two farrowing systems.
- In the PigSAFE Experiment, more piglets were observed in the creep in the Cooled treatment when temperatures were between 24 and 35°C. There was a trend for higher feed intake of sows in the Cooled treatment; however, this did not translate into improved survival or growth performance of the piglets. Furthermore, there were significant benefits of the Cooled treatment for improving pen hygiene in the nest and creep area. Further research is warranted to assess the impact of the Cooled treatment on sow feed intake and piglet survival and growth performance in the PigSAFE system.

SWAP:

- There appears to be no benefit of providing additional cooling modifications to the SWAP system.
- Piglets in the Cooled treatment spent a greater proportion of their time lying on the cooled tiles in the creep areas compared to the Control treatments when the shed temperature was greater than 36°C. However, this change in behaviour did not significantly affect piglet survival, piglet rate of gain or weaning weight.
- There was a trend for a negative impact on growth performance and weaning weight in the Cooled treatments.
- The inclusion of a slatted nest area with the SWAP pen design remains controversial. The slatted nest area pens were cleaner and there was a trend for higher number of pigs weaned.

Application to Industry

These experiments were conducted over Australian summer in buildings where environment was managed by natural ventilation, dripper systems and overhead fans.

- There may be benefits of providing additional cooling (cooled tiles in creep and fan in nest area) in the PigSAFE design. This requires further investigation.
- There were no benefits of providing additional cooling (i.e. cooled tiles in creep area and fan in nest area) in the SWAP design.
- There may be benefits of including a slatted nest area in SWAP design (hygiene and number of pigs weaned) however the use of a slatted floor remains controversial.
- Further research is warranted to assess further cooling strategies in the PigSAFE and SWAP systems over the Australian summer. This could include micro-control within pens or assessment of systems that allow greater control of shed environment over the summer conditions (e.g. climate control sheds).

PROJECT 1A–110: REDUCING THE CONFINEMENT OF PERI-PARTURIENT AND LACTATING SOWS

Project Leader:
Dr William van Wettere
(University of Adelaide)

Project Participants:
Dr Kate Plush
and Dr Dave Lines
(Sunpork Farms Group South)

Aims and Objectives

The aim of this project was to determine how, under commercial conditions and across summer and winter, different periods of reduced confinement during and after parturition affected sow and piglet performance and sow welfare. This was achieved by comparing five housing treatments: 1) sows housed in farrowing crates until weaning (n = 145); 2) sows housed in farrowing crates, with sows and litters then housed in a simple pen from day seven of lactation until weaning (n = 121); 3–5; sows housed in swing sided crates which were either shut from farrowing shed entry until day seven of lactation (n = 112), shut from the day before farrowing until day seven of lactation (n = 118), or open throughout (n = 112). This study was conducted in summer and winter, with the following measures collected: piglet survival and growth, sow body composition, cortisol and sow subsequent reproduction.

Key Findings

Housing sows in an open swing sided pen during parturition and for the first seven days of lactation did not reduce still birth rates, and resulted in significantly higher mortality of live born piglets

Removing sow confinement from day seven of lactation, either by opening the swing-sided pen or movement to a simple pen, did not increase piglet mortalities when compared with conventional crate housing during the equivalent time period.

Incidences of live born piglet mortality were lowest for sows and litters housed in conventional farrowing crates during parturition and for the first seven days post-partum.

Cortisol levels were slightly lower in sows, which farrowed in open pens and regardless, of housing treatment, cortisol level reduced as lactation progressed.

Season did not affect piglet survival within housing treatment; however, stillbirths and early (24 hour) mortality of live born piglets was higher during summer, with piglet mortality from day 3 of lactation to weaning tending to be higher during summer than winter.

Application to Industry

This current project provides strong evidence that confinement of sows during lactation can be reduced to the period immediately before farrowing and the first seven days of lactation without reducing the weaned litter size and weight.

These data also demonstrate that incidences of piglet mortalities are lowest when sows (and their litters) are housed in conventional farrowing crates during, and for the seven days after, parturition. Based on this study, it is suggested that a two stage farrowing / lactation housing system is viable, with sows (and their litters) housed in crates from entry until day 7 of lactation) and then moved to simple, cheap pens until weaning.

Based on these data, two areas of future research are proposed:

1] Develop strategies to enrich the farrowing crate, such that sow welfare and capacity to express natural behaviours are enhanced / optimised.

2] Develop a larger, nationwide data set (encompassing different types of non- or reduced- confinement housing systems) to confirm the current outcomes and provide industry confidence.

PROJECT 1A–111: DEVELOPING WAYS TO MEASURE AND INCREASE SOW CONTENTMENT

Project Leader:
Dr Rebecca Doyle
(Animal Welfare Science Centre, University of Melbourne)

Project Participants:
Dr Rebecca Morrison (Rivalea), Dr Cameron Ralph (SARDI), Kate Plush (Sun Pork Farms SA), Lauren Edwards (AWSC)

Aims and Objectives

The project aimed to identify indicators of contentment in sows, test their practicality in production settings, and assess how the provision of enrichment affects sow contentment, behaviour and performance in farrowing crates. This project involved two experiments. Experiment 1 was conducted in a research piggery. This involved best practice provision of enrichment (~1+ kg lucerne hay daily during farrowing and lactation) to test the effect of enrichment on sow contentment welfare indicators in detail. Experiment 2 took place at a commercial piggery to assess different types of enrichment (lucerne, straw and non-nutritive cotton rope; either only during farrowing or over the course of lactation) on sow contentment and performance and the practicality and robustness of welfare indicators under commercial conditions. A third independent study involved a control and sows offered lucerne chaff during and after farrowing.

Key Findings

In all studies, the provision of enrichment altered sow behaviour and the straw and lucerne treatments reduced still birth rates. In the large commercial study (Experiment 2) control sows exhibited less sham chewing and pain related behaviours that those on the enrichment treatments. There was also an indication in experiment 2 that enriched sows had a higher subsequent farrowing rate (FR) than controls with FR for the control and the hay treatment for two days before farrowing averaging 84% and 93% respectively.

Application to Industry

The findings suggest that enriching the environment of sows housed in farrowing crates before and after farrowing changes sow behaviour and biological function –the latter being expressed as reduced stillbirths and in study 3 increased colostrum intake and preweaning growth performance. Establishing the impacts of enrichment on cognitive behaviour and affective state requires further investigation.

Research Summaries for Subprogram 1A continued

PROJECT 1A–112: COMMERCIAL EVALUATION OF LACTATIONAL OESTRUS

Project Leader:
Dr Rebecca Athorn
(Rivalea Australia)

Project Participant:
Dr Jeff Downing
(University of Sydney)

Aims and Objectives

Mating during lactation can increase weaning age, produce piglets that are more viable post-weaning and eliminate mating stations. For this system to be viable in a conventional farrowing system, 85% of sows need to be mated during lactation with subsequent reproduction as good as that achieved in a conventional mating system, where sows are mated after weaning.

This study used criteria developed through various Pork CRC HIAP supported trials to investigate the production outcomes of a lactational oestrus induction protocol (intermittent suckling and boar exposure) employed for a full 12-month period. The objective of the study was to assess outcomes, in terms of subsequent reproduction, between sows that responded to the induction protocol (mated during lactation) and those that did not (mated after weaning) were compared.

Key Findings

- 40% of sows responded to the protocol and were mated in lactation.
- Sows mated during lactation (responders) had a significantly lower farrowing rate compared to sows mated after weaning (non-responders) (78 vs 88%).
- The number of sows responding to the stimulation protocol dropped during the summer period and those that were mated had a lower farrowing rate and born alive.
- Sows mated during lactation outside the summer period performed similarly to those mated after weaning.

Application to Industry

- Not feasible in a conventional farrowing crate system year round.
- However, a mating in lactation protocol has potential as a management tool employed during periods when an in increase in stale sows (and thus an increase in non-productive days) occurs due to higher incidences of spontaneous lactational oestrus.
- May also be beneficial in systems where the motivation is to reduce the overall confinement of the sow.

PROJECT 1A–113: WELFARE IMPLICATIONS OF GROUP LACTATION AT VARIOUS AGES

Project Leader:
Megan Verdon

Project Participants:
Rebecca Morrison
(Rivalea Australia),
Jeap-Loup Rault
(University of Melbourne)

Aims and Objectives

To compare the welfare implications of grouping sows and their litters during lactation at 7, 10 or 14 days postpartum, in comparison to sows and litters that remained in farrowing crates.

Key Findings

- Compared to farrowing crate housing, sows and piglets in group lactation pens were more active and interacted more frequently, and piglets showed less manipulative harmful behavior towards other piglets.
- Nursing was disrupted in group lactation pens, piglet average daily growth was lower (ADG), cortisol and post-mixing injuries were higher for sows and piglets and piglet mortality was higher, compared to farrowing crates.
- There were positive effects of group lactation housing on piglet aggressive behaviour (i.e., reduced aggression post-weaning), but no effects on growth, FCR or mortalities in the post-weaning period.
- In general, there were no differences in the behaviour of sows and piglets mixed at 7 or 14 days postpartum, but the younger piglets were mixed into group lactation, the higher the mortality. Further, piglets mixed at 7 days of age had reduced ADG than those mixed at 14 days, but there was no difference in the ADG of piglets mixed at 10 or 14 days of age.
- Sows mixed at 14 days postpartum nosed other sows more frequently, but lost more weight and were lighter at weaning than those mixed at 7 days postpartum. The weight of sows mixed at 10 or 14 days postpartum did not differ.

Application to Industry

- Group lactation housing allows for the development and expression of highly motivated maternal behaviours, and supports the development of social behaviour in piglets, resulting in a reduction in the prevalence of harmful manipulative piglet behaviours and lower aggression post-weaning. However, this comes at a cost as cross-suckling disrupts sow nursing resulting in reduced milk intake, and possibly piglet hunger and sow distress. Further, intra-pig aggression leads to injuries and possibly social stress. Finally, piglet mortality is higher in group lactation pens, due to a higher incidence of crushing.
- There do not appear to be any short or long-term benefits for sows or piglets in group lactation housing from 7 rather than 14 days postpartum.
- A reduction in productivity during the transition to multi-litter sow lactation housing may be unavoidable. As stock people and animals become familiar with the housing system, and research that reduces the occurrence of cross-suckling progresses, two-stage group lactation housing from 10-14 days of age may become a viable loose-sow lactation housing option that allows for the expression and development of natural behaviour in sows and piglets.

PROJECT 1A–114: CAN OXYTOCIN NASAL SPRAY IMPROVE GILT BEHAVIOUR DURING THE PERI-PARTUM PERIOD AND INCREASE THE WEANING WEIGHT OF PIGLETS

Project Leader:
Cameron Ralph

Project Participants:
Kate Plush (Sun Pork Farms SA),
Robyn Terry (SARDI),
Jean-Loup Rault
(University of Melbourne)

Aims and Objectives

These experiments aimed to gain a greater understanding of the effects of intranasal oxytocin administration to perinatal sows on their maternal behaviours and effects on piglet weight and mortality. It was hypothesised that administration of intranasal oxytocin would reduce farrowing duration, reduce sow posture changes during farrowing, stimulate greater positive mother-young interactions, greater activity during separation from piglets and improved piglet vigour. In contrast to this, it was hypothesised that the administration of an oxytocin antagonist would stimulate the sow to display greater behaviours of agitation following farrowing and greater negative interactions with her piglets.

Key Findings

- Administration of intranasal oxytocin in Experiment 1 resulted in some changes of maternal behaviour during farrowing however, these effects were not evident during the 24 hours post-partum.
- Piglet weight in Experiment 1 at day 3 of age was higher for piglets from the saline treatment and this effect increased at day 18.
- Administering oxytocin antagonist in Experiment 2 did not have an effect on any aspects of sow behaviour or piglet production.

Application to Industry

As a result of the outcomes in this study the following recommendations are made:

- Administration of intranasal oxytocin to sows during the parturition phase did little to positively affect sow welfare and, negatively impacted on piglet growth performance. The use of oxytocin administered to farrowing sows is therefore not recommended.

PROJECT 1A–115: THE FEEDING BEHAVIOUR OF SOWS AND ITS RELATIONSHIP TO SOW WELFARE AND REPRODUCTION

Project Leader:
Megan Verdon

Project Participants:
Rebecca Morrison
(Rivalea Australia),
Paul Hemsworth
(University of Melbourne)

Aims and Objectives

This project examined the feeding behaviour of sows, fed over multiple feed drops, and how this relates to sow welfare and reproduction. The objective was to study whether feeding sows multiple times per day reduced competition for feed in the later drops, thereby increasing feeding opportunities and improving the productivity and welfare of submissive sows.

Key Findings

Dominant sows (sows that deliver more aggression than they receive) spent the most time feeding in the location of the pen where the majority of feed was distributed. Subdominant (sows that receive more aggression than they deliver) sows spent more time feeding opportunistically, whereas submissive (sows that deliver very little or no aggression) sows spent the most time avoiding aggression and consequently the feeding area. These relationships were true regardless of day post-mixing, gestation, or feed drop number within a day. Floor feeding sows multiple times per day did not increase the time submissive sows spent feeding in the later drops. Sows that fed directly under the feed hopper spent less time showing feeding behaviour on the slatted area at the back of the pen, delivered more aggression, gained more weight and ended up heavier. Sows that frequently fed on the cement floor where there was reduced feed availability had lower cortisol concentrations, but received more aggression. One interpretation of these results is that sows that fed opportunistically were more willing than avoidance feeders to risk receiving aggression from dominant conspecifics in order to gain access to feed. When submissive sows have to compete for access to feed, the motivation to minimise harm and avoid aggression is in direct conflict with the motivation to approach the feeding area. However, these animals sustained an adequate level of intake to maintain pregnancy and some growth. An examination of the relationship between the prevalence of oral stereotypies that reflect frustrated motivation to feed and feeding behaviour may assess variation in sow hunger within groups. However, ethical considerations relating to the price, in terms of fear, stress and injury, competitive feeding systems require submissive sows to pay in order to get access to food are required when feeding systems for group-housed are considered and implemented.

Application to Industry

In addition to food restriction imposed on gestating sows, floor-feeding systems place considerable spatio-temporal restrictions on the availability of feed. Consequently, the space that is available to pigs to feed, and regulate social interactions at feeding, is limited. This system forces low ranking sows to risk receiving aggression by feeding in close proximity to high-ranking sows, or alternatively avoiding feeding. While it is difficult to reduce temporal restrictions on food availability to floor-fed gestating sows, spatial restrictions may be minimised by increasing the spread of feed onto the ground (e.g., by increasing the number of feed hoppers per pen) thereby increasing accessibility for low ranking sows. Although aggression declines over subsequent feed drops, dominant sows nonetheless monopolise the feeding area in each feed drop. Research into methods of promoting and/or prolonging satiety in restively fed group-housed sows is required. A multifactorial approach to reducing hunger in sows, that utilises dietary manipulations, methods to extending meal length and the provision of substrates that allow for the expression of appetitive behaviours, may be most effective.

Research Summaries for Subprogram 1A continued

PROJECT 1A–116: INCREASED LIGHT INTENSITY AND MAT TEMPERATURE ATTRACT PIGLETS TO CREEP AREAS IN FARROWING PENS

Project Leader:
Jean-Loup Rault

Project Participants:
Gabriella Morello, Jeremy Marchant-Forde (all University of Melbourne), Rebecca Morrison (Rivalea Australia), Greg Cronin (University of Sydney)

Aims and Objectives

Evaluate the effects of two light intensities (300 Lx vs. 4 Lx) in creep areas with two mat temperature set points (30°C vs. 35°C), without any source of radiant heat, on piglet behaviour and survivability in farrowing pens.

Key Findings

1] **Lighting in the creep:** Piglets with access to Bright (i.e. illuminated) creeps spent on average 7.2 % more time in the creeps than piglets in pens with Dark creeps. Piglets in pens with Bright creeps spent less time in the pen areas immediately in front of the creep and the least time farthest from the creep. Piglets of Bright creeps tended to take longer to enter the creep for the first time after birth, but the latency for the litter to remain clustered for 10 min in the creep area was shorter in Bright compared to Dark creeps.

2] **Mat surface temperature, and room temperature:** For each degree increase in mat temperature, piglets spent in average 2.1 % more time in the creep. Ambient temperature strongly affected the piglet's use of the creep and remaining pen areas. Generally, for each 1°C increase in ambient temperature, there was an approximate 4.8 % reduction in piglet use of the creep.

3] **Other factors influencing use of the creep:** The number of piglets in the pen had a small, but significant effect on piglet use of pen areas, as the increase of one piglet in the litter led to a 1.2 % decrease in time piglets spent in the creep. The provision of light in the creep or mat temperature did not affect sow use of pen areas or piglet weight gain.

Application to Industry

Illuminating creeps with cool white Light Emitting Diodes (LED´s, 300 Lx) led to increased use of the creep area by the piglets.

Increased mat temperatures led to increased piglet use of creeps, independently of light levels. Noteworthy most (bulb) heating lamps on farm emit both heat and light.

Sow use of pen areas immediately in front and farthest from the creep did not change among treatment combinations. Thus, increasing mat temperature and illuminating the creep seemed not to be attracting or driving sows away from the area closest to the creep.

Sow location was still the main factor contributing to piglet location in the pen.

Research on a larger sample size is needed to evaluate the implications of creep light and mat treatments on piglet survivability in farrowing pens, through increasing the time piglets spend in the creep in an effort to reduce dangerous situations leading to piglet crushing by the sow.

These research findings were obtained in SWAP farrowing pens and in environmentally controlled rooms. Results may vary in other types of farrowing pens, farrowing crates or naturally ventilated environments. Of importance, high ambient (room) temperature significantly reduced use of the creep by the piglet, suggesting that ensuring a gradient in temperature in the creep relative to the rest of the environment (creep warmer than the room) is important to encourage piglets to use the creep, hence attracting them to a safe location.

PROJECT 1A–117: A SYSTEMATIC REVIEW AND META-ANALYSIS ON THE INFLUENCE OF FARROWING PENS ON PIGLET TRAITS

Project Leader:
Kate Plush

Project Participants:
Dannielle Glencorse (Sun Pork Farms SA), Michelle Hebert, Susan Hazel (University of Adelaide)

Aims and Objectives

The aim of this project was to conduct a systematic review into the effects of farrowing pens versus crates on piglet traits. A meta-analysis was then conducted on included studies to determine effects of housing type on farrowing house performance. The design features of the farrowing pen (i.e. confinement length, enrichment provision and pen size) were compared with farrowing crates to determine factors that enhance piglet performance in pen systems.

Key Findings

This is the first systematic review and meta-analysis completed on the performance of farrowing crates versus pens.

- The overall quality of the publications was high with half of these obtaining a score of greater than 70%.
- Relative risk of piglet mortality was 16% greater in farrowing pens when compared with farrowing crates, indicating that farrowing pens do compromise post-natal piglet survival.
- Overall, the number of stillborn piglets was not affected by the type of farrowing accommodation. However, when enrichment was examined, stillborn piglets were less likely in farrowing pens that were not enriched when compared with crates.
- There was no effect of housing accommodation on the number of piglets born alive or weaned.

Application to Industry

Producers should anticipate an increase in mortality when piglets are reared by sows that are unconfined in currently available pen designs. This scientific finding re-enforces the industry belief that crates are successful at reducing pre-weaning piglet mortality.

The number of stillborn piglets however is reduced in farrowing pens when enrichment is not provided compared with farrowing crates. This indicates that the increased freedom of movement provided to sows in pens can reduce the risk of intra-partum piglet death.

PROJECT 1A–118: FENCE-LINE BOAR EXPOSURE AT THE END OF LACTATION TO IMPROVE REPRODUCTIVE PERFORMANCE OF GROUP HOUSED SOWS AND THE IDENTIFICATION OF SOWS THAT SPONTANEOUSLY OVULATE DURING LACTATION

Project Leader:
Dr William van Wettere (University of Adelaide)

Project Participant:
Dr Rebecca Morrison (Rivalea)

Aims and Objectives

The current project had two aims. One, to determine whether four days of fence line boar exposure in the last week of lactation reduces the weaning to mating interval in either farrowing crates or group lactation, and increases subsequent litter sizes, without inducing lactation oestrus. Two, to determine whether changes in vulval temperature accurately identify the timing of oestrus in weaned sows.

Key Findings

- Fenceline boar exposure during the last 4 days of lactation stimulated lactation oestrus in 22% of group housed sows and 8% of crated sows.
- Weaning to re-mating intervals were shorter for sows housed in groups and receiving fenceline boar exposure, compared with sows housed in crates.
- Compared to sows mated after weaning, mating during lactation resulted in lower farrowing rates (67.5% versus 87.8%) and smaller subsequent total litter sizes (12.8 versus 14.1).
- Vulval temperature was higher during oestrus.
- 84% of sows which did not display oestrus prior to day 7 post-weaning had ovulated undetected prior to this time (based on plasma progesterone).
- Gestation lengths shorter than 115 days produced larger litters, but a higher incidence of pre-foster deaths, and resulted in smaller litter sizes post-foster.
- There was a significant, positive correlation between gestation lengths prior to, and after, the imposed treatment.

Application to Industry

The current data demonstrated reduced fertility and fecundity of sows mated during, as opposed to after, weaning. It is, therefore, suggested that protocols focussed on mating sows during lactation should involve a reduction in metabolic demand to the sow (i.e. split-weaning or interrupted suckling). Vulval temperature increased at oestrus; however, its value as a strategy to detect spontaneous lactation ovulation requires further work. It is also evident from the current data that sows with short pregnancies give birth to less viable piglets, which is consistent with previous evidence of extended parturition and increased still births in this population of sows. It is also recommended that heat detection start immediately at weaning for sows with longer lactations.

Based on these data, three areas of future research are proposed:

- Develop commercially applicable protocols for lactation oestrus management which incorporate a reduction in suckling load.
- Approximately 10–15% of sows have pregnancies shorter than 115 days. Therefore the impact of short pregnancy lengths on piglet survival and growth from birth to slaughter should be investigated, and strategies to prevent short pregnancies (premature farrowings) should be investigated.
- The apparent repeatability of gestation length within individual sows requires further investigation, as it may provide a useful tool for either strategic culling of sows or targeted use of interventions which prevent premature farrowing.

PROJECT 1A–119: USING AN ANTI-INFLAMMATORY TO IMPROVE PIGLET SURVIVAL AND GROWTH RATES

Project Leader:
Kate Plush

Project Participants:
John Pluske (Murdoch University), David Lines (Sun Pork Farms SA), Cameron Ralph (SARDI) and Roy Kirkwood (University of Adelaide)

Aims and Objectives

The study aimed to deliver an efficacious and cost-effective method of alleviating sow discomfort during and after farrowing with attendant benefits to sow behaviour and colostrum/milk production.

The objective was to improve neonatal piglet growth and survival leading to the weaning of larger litters of heavier pigs by injecting sows before farrowing with either a non-steroidal (NSAID) or steroidal (SAID) anti-inflammatory drug.

Key Findings

NSAID treated older parity sows (P5+) gave birth to fewer liveborn and more stillborn piglets when compared with the SAID and CONTROL groups. Facial injuries throught to be caused by oral-facial stereotypes were reduced in parity two to four sows by SAID administration. There was no treatment effect on rectal temperature of the sows, or incidence of mastitis, but piglet serum protein levels tended to be reduced in the NSAID litters. None of the plasma markers of inflammation and stress were altered by treatment. Whilst average feed intake was improved by both NSAID and SAID medication, piglet mortality and growth remained unaffected. Farrowing rate after subsequent re-breeding was reduced by almost 40% in the NSAID treatment.

Application to Industry

As a result of the outcomes in this study the following recommendations have been made:

1] Injecting sows with a non-steroidal anti-inflammatory prior to farrowing reduced the number of piglets born alive, and impaired subsequent farrowing rates and so should be avoided.

2] Steroidal anti-inflammatory administration can be used to improve crated sow wellbeing as fewer facial injuries and improved feed intake were observed, but its use does not improve piglet survival and growth.

Subprogram 1B: Innovative Weaning Systems

Subprogram 1B's primary focus was to investigate if gradual weaning of piglets benefits piglet performance before and after weaning and if these systems work within Australian production systems. The premise behind gradual weaning is it encourages the piglet to consume more creep feed before weaning, effectively preparing the gastro-intestinal tract for the complete removal of milk. A secondary benefit may be that gradual separation from the sow could reduce the stress typically associated with abrupt weaning strategies.

PROJECT ID	TITLE
1B–101	Novel strategies to enhance creep attractiveness and reduce piglet mortality
1B–102	Peri-weaning polyamine supplementation: a novel strategy to improve piglet survival and growth post-weaning
1B–103	The effects of alternate lactation housing on piglet welfare and performance around weaning
1B–104	The gradual weaning of piglets: how an intermittent suckling regime can contribute to pigs overcoming nutritional and environmental stressors at weaning
1B–105	Effects of multi-suckling on piglet welfare and performance pre- and post-weaning
1B–106	A novel sow-piglet separation technique in lactation to enhance piglet welfare and production after weaning

Research Summaries for Subprogram 1B

PROJECT 1B–101: NOVEL STRATEGIES TO ENHANCE CREEP ATTRACTIVENESS AND REDUCE PIGLET MORTALITY

Project Leader:
Alex Whittaker
(University of Adelaide)

Project Participants:
Dr Will van Wettere,
Technical Officers
(University of Adelaide)

Aims and Objectives

This project investigated three novel strategies hypothesised to enhance creep attractiveness to piglets, and by so doing encouraging piglets into these areas and reducing the chance of crushing in the early days of life. These strategies included maternal applied scents, the use of sound and the use of temperature gradients. Studies used a preference testing methodology to determine piglet preference for three creep areas arranged radially in a test arena over an observation period of 1 hour on each of days 3, 7, 10 and 14 of lactation. It was hypothesised that piglets would spend the majority of the observation time in an area with their dam's scent, with sounds of the maternal pig and in a location with the greatest heat. These hypotheses were tested in three different pilot trials each using four litters of pigs, replicated over the 4 time periods.

Key Findings

The results showed that there is no one strategy that is convincingly preferred by the piglets above others. In general results showed high variability, and the central or control locations also found favour with piglets on several occasions.

The preference testing model that was used in this Project may be refined and improved if conducted with an improved design and under more controlled environmental conditions.

Application to Industry

None of the strategies that were investigated in this Project showed potential as a strategy to keep piglets away from the sow in low confinement or group housing systems during lactation.

PROJECT 1B–102: PERI-WEANING POLYAMINE SUPPLEMENTATION: EFFECTS ON PIGLET PERFORMANCE PRE- AND POST-WEANING

Project Leader:
Dr Will van Wettere
(University of Adelaide)

Project Participants:
Dr David Lines
and Tracy Kennet
(Sun Pork Farms SA)

Aims and Objectives

The results of Project 2D–124 in the previous Pork CRC demonstrated that polyamine supplementation prior to weaning can significantly improve piglet liveweight gain pre-weaning, and increased intestinal absorptive area at weaning. The current project involved two experiments that had three primary aims.

- To determine whether peri-weaning polyamine supplementation promoted piglet growth and survival pre- and post-weaning.
- To determine when, relative to weaning, polyamine supplementation has the greatest effect on piglet performance.
- To investigate the effectiveness of a commercial application of polyamines.

Key Findings

The first experiment investigated the effect of orally dosing piglets with polyamines prior to and/or after weaning on growth rate to day 36 post-weaning. The results failed to demonstrate any beneficial effects of polyamine supplementation on piglet performance.

The second study involved suckling piglets that had been identified "at risk" and were considered developmentally impaired. Specifically these piglets were gilt progeny suckling first lactation sows during summer This second study investigated the effect of providing polyamines in bowls to piglets prior to and/or after weaning on their growth performance pre and post-weaning. The results of this second study revealed that piglets receiving polyamines were heavier at weaning (6.59 ± 0.04 versus 6.48 ± 0.04 kg), 7 days post-weaning (7.27 ± 0.05 versus 7.11 ± 0.05 kg) and day 36 post weaning (20.1 ± 0.19 versus 19.5 ± 0.19 kg). Furthermore, there was a significant effect of treatment (Polyamine versus control) on liveweight gain during the 7 days prior to weaning (1.46 ± 0.04 versus 1.32 ± 0.04 kg), and on liveweight gain from weaning to day 36 post-weaning (13.6 ± 0.2 versus 12.9 ± 0.2 kg).

Application to Industry

The results of the second experiment in this project, together with previous observations suggest that polyamine supplementation during the last week of lactation can be beneficial for 'at risk' or vulnerable piglets. The most obvious application to industry is to develop strategies to increase the polyamine intake of compromised piglets at and around weaning. The easiest method may be to provide these "at risk" piglets and litters with polyamine delivered in additional drinking bowls towards the end of lactation in the farrowing pen and then during the period immediately after weaning. The benefits of this type of strategy should be demonstrated in larger field studies to identify where the response to polyamine is beneficial and economic.

In the longer term, dietary supplementation of the sow to increase polyamine levels in the colostrum and milk should also be explored to determine whether this mode of supplementation may be beneficial for intestinal and immune development, and subsequent growth and survival of "at risk" piglets.

Research Summaries for Subprogram 1B continued

PROJECT 1B–103: THE EFFECTS OF ALTERNATIVE HOUSING ON PIGLET WELFARE AND PERFORMANCE AROUND WEANING

Project Leader:
Kate Plush (Sun Pork Farms SA)

Project Participants:
Dr William van Wettere (University of Adelaide), Dave Lines (Sun Pork Farms SA)

Aims and Objectives

The aim of this project was to determine if piglets from litters that have reduced sow contact as lactation progresses, experience a reduction in stress typically witnessed at weaning, and if this gradual weaning process has positive effects on the post-weaning performance and welfare of these piglets.

Key Findings

Litters were assigned to two treatments:

- **Control:** Litters remained in constant contact with the sow within the traditional farrowing crate up until weaning at about 28 days.
- **Gradually Weaned:** The sow was transferred to a pen immediately behind the farrowing crate for 5 hrs/day between day 11 and day 16, 7 hrs/day between days 16 and 21 and 9 hrs/day from day 21 to weaning at 28 days. This reduced the period that the litters had contact with the sow, thereby replicating a gradual weaning process.

Piglets that were gradually weaned were lighter at weaning, but continued to grow in the days following the weaning event. Control piglets were 0.8 kg heavier at weaning, but suffered a 'growth check' at weaning. By day 7 after weaning there was no effect of treatment on average body weight of piglets.

Overall, more gradually weaned piglets had a tendency to consume solid/creep feed, potentially explaining some of the improvement in growth performance of these piglets after weaning. Control piglets exhibited agonistic behaviours (such as belly nosing and fighting) for significantly longer on the day following weaning than those piglets that were gradually weaned. Furthermore, injury scores were greater for control piglets than those gradually weaned on almost all of the days examined. Weaning produced an increase in circulating plasma cortisol concentrations in control piglets, whilst inducing little change in piglets that were gradually weaned.

Application to Industry

The findings from this project provide convincing evidence that gradually reducing the amount of sow contact as lactation progresses provides welfare and production benefits to piglets in the days following weaning. The improved growth of piglets from the gradually weaned treatment in the immediate post-weaning period could be attributed to an increase in creep feed consumption, a reduction in agonistic behaviours, fewer injuries and a lower cortisol response to weaning.

The housing design implemented in the current investigation involved a significant amount of labour as the sow was removed daily from the farrowing crate and returned once more after the separation period. Further work on housing design and strategies that facilitate sow-controlled access to her litter, is recommended before gradual weaning is likely to be successfully implemented in the commercial environment.

PROJECT 1B–104: THE GRADUAL WEANING OF PIGLETS: HOW AN INTERMITTENT SUCKLING REGIME CAN CONTRIBUTE TO PIGS OVERCOMING NUTRITIONAL AND ENVIRONMENTAL STRESSORS AT WEANING

Project Leader:
Professor John Pluske (Murdoch University)

Project Participants:
Dr P. Langendijk (SARDI), Ms D. Turpin (PhD student)

Aims and Objectives

1] To determine whether piglets that are separated from the dam for a specified period of time each day with creep feed during lactation will have:

- Better post-weaning performance.
- Enhanced indices of gastrointestinal tract (GIT) structure and function.
- Show less behaviours indicative of compromised welfare, compared to piglets in a conventional weaning regime with or without creep feed.

2] To determine if piglets subject to repeated maternal separation would develop behaviours or GIT changes indicative of compromised welfare compared to piglets in a conventional weaning regime.

Key Findings

1] Piglets that received sow separation (8 h/day for 6 days or 16 h/day for 3 days before weaning) were more likely to consume creep feed during the lactation period, but this did not translate into an increase in solid feed consumption after weaning.

2] In this study, intermittent suckling did not prevent weaning-associated changes, but rather advanced them in an attenuated way with piglets experiencing a growth check at the start of IS rather than at weaning. Furthermore, there was also no evidence to suggest that IS resulted in quicker maturation of the gastrointestinal tract.

3] Intermittent suckling during the last week of lactation did not compromise piglet welfare as determined by selected measures of neuroendocrine, inflammatory, immune and behavioural indices, however some physiological changes such as reduced growth and differences in plasma glycerol were evident before weaning.

Application to Industry

1] Intermittent periods of separation from the sow, long or short (16 hours verses 8 hours), during the last week of lactation did not induce any neuroendocrine, inflammatory or immune changes suggestive of a chronic stress response in piglets. However, there was also little evidence to suggest that intermittent suckling (IS) provides beneficial effects for the piglets with regard to post-weaning performance.

2] Labour associated with moving the piglets away from the sows was significant and for IS to be considered commercially, more research needs to be conducted into farrowing pen design to allow easy separation of sows from their litter.

3] Results from the current project demonstrate the potential of using *in vivo* sugar absorption tests to measure permeability and absorptive function markers in the serum. While markers of GIT function are not necessarily relevant to Industry, other research projects could consider the use of sugar absorption tests as welfare biomarkers, reducing the necessity for terminal experiments.

PROJECT 1B–105: EFFECTS OF MULTI-SUCKLING ON PIGLET WELFARE AND PERFORMANCE PRE- AND POST-WEANING

Project Leader:
Dr David Line,
SunPork Farms SA

Project Participants:
Julia-Sophia Huser, Suzanne Hallett, Anthony Martyniuk, Kate Plush SunPork Farms South, South Australia

Aims and Objectives

The objectives were to investigate the effects grouping sows and their litters 13 days before weaning (at 28 days) on sow and piglet welfare and performance in comparison to sows and litters which remained in farrowing crate to weaning.196 primiparous sows were used in the study. Forty-seven were housed in farrowing crates and 141 were housed in groups of three with their litters commencing 13 days before weaning.

Key Findings

Grouping sows and their litters (groups of three) adversely affected sow and piglet welfare between mixing and weaning and piglet welfare during lactation and performance to and subsequent to weaning. Sows and piglets kept in groups during lactation suffered significantly more scratches/injury than those in farrowing crates. Piglets reared in farrowing crates exhibited significantly higher scratch score seven days after weaning than their group-reared counterparts.

Application to Industry

The results suggest that grouping sows and litters in an attempt to reduce the time they are confined in lactation has negative effects on sow or piglet welfare and reduces the number of piglets weaned because of higher mortality and removals and piglet performance to weaning which persists for at least 30 days after weaning.

Research Summaries for Subprogram 1B continued

PROJECT 1B–106: A NOVEL SOW-PIGLET SEPARATION TECHNIQUE IN LACTATION TO ENHANCE PIGLET WELFARE AND PRODUCTION AFTER WEANING

Project Leader:
Professor John Pluske (Murdoch University)

Project Participants:
Dr D. Turpin (PhD student), Dr P. Langendijk (SARDI), Westpork P/L

Aims and Objectives

The current research project aimed to mimic the natural weaning process as much as possible under commercial indoor conditions by introducing intermittent weaning (IS) and also allowing piglets to socialise with non-littermates (CoM) during lactation, to determine whether IS and/or CoM can promote positive behavior and positively affect post-weaning performance.

Key Findings

1] Piglets that received sow separation consumed more creep feed before weaning and had a better growth and a tendency for a higher feed intake 2 to 7 days after weaning.

2] The improvement in pig performance by IS did not seem to occur through increased familiarisation with creep feed, but rather through the prevention or attenuation of the weaning-associated stress response as evidenced by increased sleeping behaviour and reduced manipulative behaviour immediately after weaning as well as reduced post-weaning Hp levels and reduced plasma cortisol levels on the day of weaning.

3] Piglets that spent 8 hours daily with piglets from a different litter during the last week of lactation did not have a better performance than piglets that were not co-mingled.

4] Co-mingling did reduce aggression, but this did not seem to impact on selected measures of stress, inflammation or immune status.

5] A higher mannitol absorption was evident in CoM pigs 3 days after weaning and galactose absorption was reduced in IS pigs 3 days before weaning and tended to be reduced 3 days after weaning, likely reflecting a GIT adaptive response.

Application to Industry

1] Intermittent suckling was the most effective pre-weaning intervention at improving performance in the first week after weaning, however the labour associated with moving the piglets away from the sows was significant and for IS to be considered commercially, more research needs to be conducted into farrowing pen design to allow easy separation of sows from their litter.

2] There was strong evidence from both experiments that co-mingling does reduce aggression. We achieved this by removing the barrier at the back of two farrowing crates allowing piglets to move between two sows and interact with piglets from another litter. This method was easy to implement and required minimal labour.

3] Results from the current project and 1B–104 demonstrate the potential of using *in vivo* sugar absorption tests to measure permeability and absorptive function markers in the serum. While markers of GIT function are not necessarily relevant to Industry, other research projects could consider the use of sugar absorption tests as welfare biomarkers, reducing the necessity for terminal experiments.

Subprogram 1C: Management of Sows in Groups

This Subprogram investigated the complex and challenging interactions between sows housed in groups. Development of optimum management procedures for group housed sows while accommodating their individual requirements for nutrition, maintenance of health, and well-being is required.

Australian Pork Limited pig producers voted to voluntarily phase out sow stalls by 2017, from five days after mating until they are moved into farrowing crates. However, pressure from retailers and the community accelerated this timetable for some producers, as well as placing further restrictions on the housing of sows during gestation. Investment in Subprogram 1C was directed at improving the welfare and reproductive performance of sows housed in groups during gestation.

PROJECT ID	TITLE
1C–101	Physical and nutritional interventions to reduce sow lameness
1C–102	Effects of aggressive characteristics of individual sows and mixing strategies on the productivity and welfare of group-housed gestating sows
1C–103	Optimising the management of group-housed gestating sows
1C–104	Welfare and productivity of sows and litters housed in farrowing pens compared to farrowing crates
1C–105	Effects of floor space on the welfare of group-housed sows
1C–106	Reducing aggression in group-housed gestating sows through manipulation of dietary water holding capacity and hind-gut fermentation substrates to control gut distension and blood VFA levels
1C–107	Improving behaviour, welfare and commercial performance of group housed sows through development of appropriate selection criteria
1C–108	The sensitivity of sows to stressors throughout gestation
1C–109	Animal welfare monitoring in research settings
1C–110	Stall-free gestation housing
1C–111	Effects of group housing after weaning on sow welfare and sexual behaviour
1C–112	Literature review on effects of group housing, both post-weaning and post-insemination, on sow productivity and welfare
1C–113	Welfare and productivity of sows and litters housed in farrowing pens compared to farrowing crates
1C–114	Reducing sow stress around farrowing
1C–115	Nutritional management strategies to reduce aggression at mixing of unfamiliar sows
1C–116	Enriching the environment of group housed sows using straw / hay in racks
1C–118	Sham-chewing and sow welfare and productivity
1C–119	Brain-derived neurotrophic factor as an indicator of environmental enrichment effectiveness
1C–120	Human enrichment program for breeding sows: proof of concept

Research Summaries for Subprogram 1C

PROJECT 1C–101: PHYSICAL AND NUTRITIONAL INTERVENTIONS TO REDUCE SOW LAMENESS

Project Leader:
Professor Robert van Barneveld (CHM Alliance Pty Ltd)

Project Participants:
Dr Mark Wilson (Zinpro Corporation), Dr John Watling (University of Western Australia), Mr Robert Hewitt (CHM Alliance Pty Ltd), Mrs Tracy Muller (CHM Alliance Pty Ltd)

Aims and Objectives

The aims of this project were to use physical and/or nutritional strategies in gilts and sows as a means of improving longevity and reduce culling. The specific technical objectives of this project included:

- Utilising feet trimming interventions to reduce the incidence of lameness.
- Develop methods for the rapid assessment of sow lameness.
- Utilise trace elemental analysis of hair samples to assess the effectiveness of mineral supplementation programs.

Key Findings

Trimming of gilts feet after they are mated, whilst effective at changing the pattern of foot lesions, did not have a major influence on the reproductive performance of the gilt within this herd, which had a relatively low incidence of inherent lameness. In a herd with significant lameness issues, this procedure may have greater application. It would appear that foot lesions are already established in gilts prior to first mating and that greater selection pressure placed on foot lesions when being selected for breeding is possibly required to influence lesion development.

Thermal imaging does not appear to be a method to identify sows that are likely to go lame in the short term, with hotspots seen in many sows with normal gaits. However, it does appear that thermal imaging is useful in identifying the potential cause of lameness in sows with modified gaits, allowing for more targeted treatments to be undertaken and monitored. Longer term studies may be required to determine whether thermal imaging can detect sows well before they develop a compromised gait and become lame.

Changes in organic mineral supplementation were able to be detected through the analysis of hair samples. This analysis not only showed changes in the pattern of deposition of the trace minerals that were supplemented but also showed an impact on the important bone minerals – calcium, phosphorus and magnesium. Analysis of hair samples may be a useful adjunct in any studies that are designed to investigate the role of trace and macro minerals in bone/foot health and lameness.

Application to Industry

Remedial feet trimming did not have an impact on lameness and had only a minor impact on wean-to-oestrus intervals. The prophylactic feet trimming treatment of mated gilts doesn't appear to be warranted in herds with low levels of lameness. The established foot lesions present at the initial inspection of gilts in this project suggests that lesions begin development earlier in the gilts life, which indicates greater scrutiny for lesions at selection may be required.

Thermography would appear to be a useful tool for targeting treatment in those sows that exhibit lameness. The high incidence of hotspots seen in sows with a normal gait suggests that thermography should be investigated further to determine if this technology can be used to predict the likelihood of lameness later in life.

There also appears to be scope to use hair analysis to better understand the metabolism of dietary organic/inorganic minerals associated with bone health and lameness.

PROJECT 1C–102: EFFECTS OF AGGRESSIVE CHARACTERISTICS OF INDIVIDUAL SOWS AND MIXING STRATEGIES ON THE PRODUCTIVITY AND WELFARE OF GROUP-HOUSED GESTATING SOWS

Principal Investigator:
Professor Paul Hemsworth and Megan Verdon (University of Melbourne)

Project Participant:
Rivalea Australia

Aims and Objectives

Three experiments were conducted to examine:

1] The development of possible predictive tests of aggressive behaviour.

2] Repeatability of aggressive behaviour of group-housed sows within and between parities.

3] Effects of group composition in terms of the aggressive behaviour of individual sows on the welfare and reproductive performance of both the individual and the group as a whole.

Key Findings

- The behavioural response to a fibreglass model sow before mixing was moderately related to the aggressive behaviour of sows displayed in the early period after mixing in groups. This social behaviour test appears to be a useful predictive test of individual aggressive behaviour.
- Individual aggressive behaviour is repeatable within gestations but less so between successive gestations, suggesting that experience and group composition affect the aggressive behaviour of individual sows.
- Aggressive behaviour of individual sows early after mixing was related to the injuries, stress and litter size of the individual sow.
- Mixing females either of predicted high levels of aggression (homogenous groups) or mixing sows randomly (heterogenous groups) had little effect on the welfare and production outcomes at a group level.

Application to Industry

- Highlights to industry the variation that exists in individual sow aggression and consequently the welfare and productivity implications for the individual within a group.

- The social behaviour test was moderately related to aggressive behaviour of sows mixed in groups. The magnitude of the relationships improved with age suggesting that social experience may be important in the predictive value of this test. This social behaviour test may provide a useful measure for selection if animals are scored at least in adulthood after experience of grouping or scored several times to assess their true phenotype and full- or half-sib analyses are utilised.

- Dominant sows tended to gain more weight in gestation and have a larger litter size, perhaps because of increased feed intake through priority access to feed and/or less stress.

PROJECT 1C–103: OPTIMISING THE MANAGEMENT OF GROUP-HOUSED GESTATING SOWS

Project Leader:
Kate Plush (Sun Pork Farms SA)

Project Participants:
Paul Hughes (SARDI), Emma Greenwood, William van Wettere, Roy Kirkwood (all University of Adelaide)

Aims and Objectives

The overall objective of this Project was to develop strategies to ameliorate aggression amongst sows at mixing. This project examined the effects of space allowance and environmental enrichment in a mixing pen on the behavioural and physiological measures associated with sow aggression. Further studies investigated the use of a synthetic olfactory agonist and dietary supplements of magnesium to reduce aggression in sows at the time of mixing. The effects of various times of mixing during late lactation, at weaning and after insemination were studied in a final experiment.

Key Findings

In many of the studies in this Project, the behavioural and physiological measures associated with sow aggression and stress had generally stabilised within a week of mixing, and often within 1–2 days. These observations support the results of earlier Pork CRC projects that suggest that sows habituate to different housing conditions through behavioural adaptation, which often occurs within 1 week of mixing.

- In the space allowance study, although there was little general impact of the higher space allowances, subtle behavioural effects suggest that sows that are lower in social rank within a pen may benefit from higher space allowances.

- The presence of novel materials in the mixing pen were ineffective at reducing aggression levels in sows, but sows exposed to novel materials performed positive aspects of behaviour through spending more time playing with novel materials, particularly rope, in the 2–3 weeks after mixing.

- The delivery of a synthetic olfactory agonist (that behaves like appeasing pheromones) through a diffuser in the mixing pen was sufficient to increase eating duration and frequency as well as reduce aggressive interactions between sows. This could be important to ensure submissive sows improve their daily feed intake in group feeding systems.

- Providing gestating sows with 1.4g MG/day as either, MgSO4 or as a marine algae extract, after mixing into smaller groups failed to have any consistent positive effects on sow aggression, stress measurements or reproductive performance.

- The fifth experiment showed that mixing sows into multi-suckle groups in late lactation resulted in little aggression and tended to improve subsequent litter size.

Application to Industry

Producers may offer more space allowance to sows upon mixing and for the short period of up to 4–5 days after the establishment of the group, to allow sows to better adapt to the mixing process. The introduction of novel materials such as hanging rope may also have positive effects on sow behaviour. Dietary supplements of Mg failed to provide any beneficial effects, but the delivery of a synthetic olfactory agonist through a diffuser in the mixing pen may have some beneficial effects and should be examined further.

Although this Project failed to observe any differences between sows mixed at weaning and those mixed after insemination, previous Pork CRC projects have shown that sows housed in groups at weaning may experience higher stress and a possible lower sexual receptivity than sows housed in individual stalls at weaning and then housed in groups after insemination. Mixing sows during lactation through a multi-suckle system may offer an alternative production system that provides a mixing strategy that is consistent with minimal sow aggression. But greater piglet mortality and reduced piglet weaning weights associated with lactation group housing systems need to be overcome before this type of system is commercially viable.

Research Summaries for Subprogram 1C continued

PROJECT 1C–104: WELFARE AND PRODUCTIVITY OF SOWS AND LITTERS HOUSED IN FARROWING PENS COMPARED TO FARROWING CRATES

Project Leaders:
Ms Clara Singh and
Professor Paul Hemsworth

Project Participants:
University of Melbourne
and Charles Piggery

Aims and Objectives

The aim of the project was to assess the viability (in terms of welfare and production) of replacing the conventional farrowing crate with an alternative system (the farrowing pen) for the lactation period, beginning 3 days post farrowing in a commercial piggery. The farrowing pen trialled had a slightly increased total floor area, standard heated creep area and sloping bars along two walls. The major differences between the two housing systems were the increased floor space in the farrowing pens and that sows were unrestrained and could freely walk and turn around. Assessment of productivity was straightforward and based generally on measurements of litter size, mortality rate, growth rate and sow farrowing rates. In terms of productivity, it was hypothesised that:

1] Piglet survival is unaffected by housing treatment.

2] Piglets housed in pens during lactation gain more weight, producing larger piglets at weaning.

Key Findings

No significant differences were found in piglet survival (P=0.20) or weight gain (P=0.15) between treatments. Sows in farrowing pens obtained significantly more skin injuries than those in crates (P=0.03) but treatment had no effect on incidence of skin injury for piglets (P=0.08). Suckling bout duration (P<0.01) and frequency (P<0.01) decreased with week while intervals between bouts increased (P<0.01) but showed no difference between treatments. Overall, more sow-piglet interaction around suckling was observed in farrowing pens (P<0.01), the frequency of which also decreased with week (<0.01). Farrowing pens were also associated with more displacements (P=0.04), more piglets missing bouts (P<0.01) and fewer bouts terminated by the sow (P=0.05). Piglet time budgets of behaviour revealed significantly more play behaviour (P=0.03) and interaction with the sow (P=0.02) occurring in farrowing pens and more manipulative behaviour (P=0.02) and inactivity (P=0.02) in farrowing crates.

Application to Industry

Farrowing pens appeared to provide more social and environmental stimulation for piglets, resulting in more activity and social interaction, which may be interpreted as an improvement to welfare. The increased incidence of sow skin injuries may indicate a lack of adaptation or experience of sows in the farrowing pen environment. Evaluation of productivity was inconclusive because of the limited sample size. A subsequent study on a larger scale suggested few differences between the systems on sow productivity.

PROJECT 1C–105: EFFECTS OF FLOOR SPACE ON THE WELFARE OF GROUP HOUSED SOWS

Project Leader:
Paul Hemsworth
(AWSC-UoM)

Project Participants:
Rebecca Morrison (Rivalea),
Alan Tilbrook (SARDI),
Kym Butler (AWSC-DPI),
Maxine Rice (AWSC-UoM)
and Steve Moeller (OSU)

Aims and Objectives

This experiment examined the effects of floor space in the range of 1.45 to 2.9 m^2/sow on the aggression, stress and reproduction of sows housed in groups after insemination.

Key Findings

There was a consistent linear effect of floor space on aggression at feeding and plasma cortisol concentrations on day 2 post-mixing, with aggression and cortisol concentrations reducing with increasing space from 1.45 to 2.9 m^2/sow. There was no indication of space effects on aggression or plasma cortisol concentrations at day 26 post-mixing, or on subsequent farrowing rate, litter size (total or alive) or sows removed for non-reproductive reasons.

This current research and recent research by the research team show that reducing floor space for recently-inseminated sows within the range of 1.4 to 3.0 m^2/sow in the first week or so after mixing, increases aggression and stress, as assessed by aggressive behaviour at feeding and plasma cortisol concentrations. These results together with previous results on gilts and sows, particularly those on aggression and stress and reproduction, indicate that a space allowance for gilts and sows of 1.4 m^2/animal is likely too small early after mixing. The current recommended minimum floor space allowance for group-housed gestating sows in the *Australian Model Code of Practice for the Welfare of Animals – Pigs* (Primary Industries Ministerial Council, 2007) is 1.4m^2 per sow and clearly this recommended minimum space allowance in the immediate post-mixing *period* needs to be reviewed.

Application to Industry

A space allowance for gilts and sows of 1.4 m^2/animal is likely too small early after mixing. However, there is evidence that sows may adapt to reduced floor space, albeit with risks to reproductive performance. Thus staged-gestation penning to provide increased floor space for recently-inseminated sows immediately after mixing may be a practical solution to reduce aggression and stress.

Providing more floor space at the top end of the range 1.4 to 3.0 m^2/sow should allow the dominance hierarchy in the group to be established quickly with minimum aggression and stress, and thus minimum risk to reproduction. Further modification to the pen by the use of visual barriers, feeding stalls, and straw or bedding may also assist in reducing aggression amongst newly mixed sows. There is then the opportunity in the remainder of gestation to reduce floor space to levels in excess of 1.8 m^2/sow. Indeed, staged-gestation penning to provide increased space for recently-inseminated sows is one of the common features often recommended in a dedicated mixing pen.

The strategy of staged-gestation penning, with more space immediately after insemination and less space later in gestation, may address both animal welfare and economic considerations.

PROJECT 1C–106: REDUCING AGGRESSION IN GROUP-HOUSED GESTATING SOWS THROUGH MANIPULATION OF DIETARY WATER HOLDING CAPACITY AND HIND-GUT FERMENTATION SUBSTRATES TO CONTROL GUT DISTENSION AND BLOOD VFA LEVELS

Project Leader:
Professor Robert van Barneveld (Sun Pork Farms)

Project Participant:
Sun Pork Farms Queensland

Aims and Objectives

There are a number of dietary sources with potential to induce satiety in sows during gestation. Dietary sources that have shown some satiating effects include Sugar beet Pulp (SBP) Guar gum, Opticell® and Magnesium oxide. The aim of this study was to investigate the ability of these dietary ingredients to induce satiety and thus change the physiological stress and behavioural responses of sows. The inclusion levels of the various ingredients investigated in this study were held at commercially viable levels and diets were isoenergetic to reduce for the energy dilution effects of fibrous ingredients.

Key Findings

There was no significant effect of dietary treatment on behavioural or heart rate measurements. The lack of behavioural responses to the dietary treatments was more likely due to the experimental model being used. The sows were housed in gestation stalls and the behavioural responses were examined over a short period of up to one week. Any subtle treatment effects may have been masked by abnormal behaviour of sows, typical of that observed in stalls. Physiological data measured by blood glucose sampling showed significant effects of dietary inclusions on blood sugar levels. All four dietary inclusions used may play a role in stabilising blood glucose levels but there appeared to be different modes of action of these individual dietary inclusions on digestion and absorption. The most consistent behavioural response from this Project was that SBP appeared to have a positive effect on satiety, as inclusion of 20% SBP in a diet increased meal time and reduced voluntary feed intake to no more than 4 kg/day.

Application to Industry

As there were no consistent and positive effects on the behavioural response of sows to the dietary inclusions studied in this project, there is no immediate application of any of the dietary treatments to industry. However, the project was able to identify that future experiments examining dietary manipulations to improve satiety and reduce aggression amongst sows should be examined under group housing systems where the behavioural responses are more likely to be observed in these types of longer-term studies. In view of the positive effects of SBP on reducing voluntary feed intake, increasing meal time with an apparent improvement in satiety, the use of SBP and similar materials in diets should be further investigated during short term critical times, particularly when sows are mixed into groups.

Research Summaries for Subprogram 1C continued

PROJECT 1C–107: IMPROVING BEHAVIOUR, WELFARE AND COMMERCIAL PERFORMANCE OF GROUP HOUSED SOWS THROUGH DEVELOPMENT OF APPROPRIATE SELECTION CRITERIA

Project Leader:
Kim Bunter (AGBU, UNE)

Project Participants:
Dave Swain (CQU), Jean-Loup Rault (Uni Melb), Craig Lewis & Scott Newman (PIC US), Kristy Tickle (Rivalea)

Aims and Objectives

The project had three primary objectives:

1] To establish whether "competitive" or "social genetic" effects influence sow performance, as assessed using data on reproductive outcomes for sows housed in known groups. The philosophy is that animals which perform better to the detriment of their pen mates could be identified as having a negative social effect only under "competitive effects" BLUP models, and not using conventional BLUP.

2] To provide "proof of concept" that proximity logging networks can provide an effective and efficient way to collect additional behavioural data on group housed sows.

3] To investigate the heritabilities of and associations between some novel behavioural traits (flight time and fight lesion scores) recorded on gilts at selection, 24 hours post-mixing, with their later attributes as group housed sows.

Key Findings

Data from pedigreed nucleus sows that were housed in small groups (4–10 sows) from about day 35 of pregnancy was used to examine social genetic effects on sow performance. This dataset revealed small heritable social genetic effects affecting litter size traits. However, estimates of social genetic effects are likely to be affected by group size, stage of gestation when mixed, space allowance and whether sows are in static or dynamic groups. Thus, the results of this study may currently underestimate the magnitude of social genetic effects compared to some other more challenging production systems.

Proximity loggers were able to automatically record contacts (and duration of contact) between specific sows in small groups. However, numerous technical difficulties including loss of collars, and the need for simultaneous collection of video analysis to link observed data with logger data were encountered during this component of the Project. Consequently, this component was terminated on the basis of an inability to develop a consistent and reliable implementation procedure for the proximity loggers.

Both flight time and lesion score traits were low to moderately heritable behavioural measures. Flight time was lowly heritable (0.07–0.12), uncorrelated with any sow reproductive parameters, and appears to have little value as a potential selection criterion in maternal lines of pigs. In contrast, scoring fight lesions 24 hours post-mixing as gilts was practical, moderately heritable (0.12–0.15) and related to reproductive outcomes of sows. Selected gilts that were considered aggressive (had higher anterior lesion scores) had a higher wastage and were more likely to leave the herd without farrowing. Furthermore, aggressive gilts that entered the herd and went onto farrow produced litters that had lower birthweights, 21 day litter weights and higher pre-weaning piglet losses in their first parity.

Application to Industry

This project has shown that sophisticated genetic models may be used to estimate social genetic effects and to identify sows that perform well in groups, but not to the detriment of other animals in the pen. However, the need for adequate performance data combined with tracking individual animals to groups may be beyond the capability of herd recording systems for many breeding herds at the moment.

In R&D studies, assessment of behaviour and interactions between sows in groups will continue to rely upon video analysis (VIA), until the proximity loggers or GPS technology are developed sufficiently to provide a viable alternative. This technology is likely to be developed and miniaturised in ear tags for larger animals such as dairy cattle, before it may be adapted to further application with sows. For breeding program applications, VIA will not generally provide useful data on a sufficiently large scale.

Overall, this Project demonstrated that the development of meaningful selection criteria based on behavioural attributes which have positive welfare benefits and which are practical to implement in commercial breeding programs, will not be straight forward. However, lesion scoring 24 hours post-mixing showed the most promise as a potential selection criterion. In addition, in dam lines of pigs, with ongoing selection for longevity and maternal attributes, there would be slight downward pressure on fighting post-mixing as a correlated response, which should improve both the welfare and reproductive performance of group housed sows. Strategies to minimise aggression amongst gilts post-mixing is expected to have favourable consequences for gilt wastage and first parity reproductive performance.

PROJECT 1C–108: THE SENSITIVITY OF SOWS TO STRESSORS THROUGHOUT GESTATION

Project Leader:
Jean-Loup Rault
(University of Melbourne)

Project Participants:
Pieter Langendijk (SARDI),
Kate Plush (Sun Pork Farms SA)

Aims and Objectives

The best way to mix gestating sows is still controversial. Sows habituate to different housing conditions based on their physiological stress-response. Pregnancy hormones secreted during gestation may underlie this hyporesponsivity to stressors through physiological adaptation. Alternatively, sows may habituate through behavioural adaptation by changing their social strategies. This project aimed to elucidate the mechanisms regulating the stress response of sows that are mixed into groups during early gestation and its implications for stress-coping ability and reproductive performance.

Key Findings

Experiment 1 could not confirm that sows become hypo-responsive to stressors in the first trimester of gestation. However, the resident-intruder test showed that pregnant gilts experienced aggressive encounters quicker than ovariectomised gilts. We found weak evidence that the hormone allopregnanolone may be involved in some components of social interaction, with allopregnanolone concentrations positively correlated with lower aggressiveness. Nonetheless, the alfaxan treatment as an allopregnanolone agonist could not explain most of the differences between pregnant and ovariectomised gilts.

Experiment 2 showed that sows started and used more high aggressive behaviours such as bites, head knocks, and pushes, at a floor space allowance of 1.45 m^2 per sow on day 2 whereas encounters at 2 m^2 and especially 2.9 m^2 were more frequent but less aggressive, with more nose contacts or threats. Differences between space allowances vanished on day 9. Hence, social interaction patterns differed, with more aggressive and less frequent interactions between sows at smaller space allowances and shortly after mixing.

The results of these two studies suggest that sows respond through behavioural adaptation rather than any physiological adaptation when they are mixed into groups.

Application to Industry

Overall, these experiments support the hypothesis that sows habituate to different housing conditions through behavioural adaptation by changing their social strategies.

Offering more space at mixing can increase the frequency of mild or neutral social interactions (e.g. threats and nose contacts) within a group of unacquainted sows while reducing the intensity of aggression (e.g. bites).

These differences were no longer apparent by day 9 after mixing, supporting previous observations that the effect of space on social interactions is more pronounced within the first days after mixing unacquainted sows.

Producers may offer more space allowance to sows upon mixing and for the short period after the establishment of the group, to allow sows to better adapt to the mixing process. Mixing sows successfully into groups should be possible at any stage of pregnancy as there does not appear to be a preferred stage of pregnancy where sows are more physiologically suited to the mixing process.

Research Summaries for Subprogram 1C continued

PROJECT 1C–109: ANIMAL WELFARE MONITORING IN PIG RESEARCH

Project Leader:
Maxine Rice
(University of Melbourne)

Project Participants:
Paul Hemsworth,
Jean-Loup Rault,
Jeremy Skuse,
Ellen Jongman,
Lauren Hemsworth
(all University of Melbourne)

Aims and Objectives

Increasing community concern about farm animal welfare has highlighted a need for a valid method of on-site welfare assessment. For a welfare monitoring system to be effective and acceptable by all key stakeholders (including industry, government, science, farmers, veterinarians, educators, and animal welfare groups), it must be able to measure broadly-accepted welfare indices in a way that is practical, reliable and repeatable. The current project developed an assessment tool to monitor and benchmark the welfare of animals in the husbandry and housing systems under study in Pork CRC-funded projects.

Key Findings

1] The animal based indices that were originally selected within the project included fear of humans, BCS, bursitis, lameness, skin injury scores, stereotypies, panting, manure on body and play behaviours.

2] After a follow-up workshop the list was reduced to four key animal based indices that should be used to assess the welfare of sows allocated to various experimental treatments in Pork CRC projects. These key indices are injury score, body condition score, lameness score and salivary cortisol.

3] Fourteen resource based criteria were identified and accepted. These should be easily assessed as they are likely to be compliant in most R&D settings.

4] This project developed the animal welfare monitoring protocols for sows and piglets in research settings to assess and benchmark the welfare of animals in husbandry and housing systems under study in Pork CRC-funded projects.

5] These animal welfare assessment protocols will be applied to all Pork CRC projects involving sow R&D that are funded after January 2014. They will be also applied to previously funded Pork CRC sow projects that have already been collecting data on the four key animal based indices.

Application to Industry

Four key animal based indices were identified and discussions are continuing on establishing index scores that reflect appropriate animal welfare outcomes. These scores will be assessed by a colour coded 'traffic-light' scoring system: red shows where there is a high risk of poor welfare, orange indicates that the risk to welfare is moderate, while green indicates good or appropriate welfare.

The animal welfare monitoring protocol for sows and piglets in research is designed to monitor and benchmark the welfare of animals in husbandry and housing systems under study in Pork CRC-funded projects. The system will be reviewed after 12 months.

PROJECT 1C–110: STALL-FREE GESTATION HOUSING

Project Leader:
Ray King (R.H King Consulting)

Project Participants:
Pat Mitchell &
Emalyn Loudon (APL),
Roger Campbell (Pork CRC)

Aims and Objectives

- To provide industry with information on group housing sows during gestation, so that they implement group housing systems effectively and efficiently on-farm.
- To provide the Australian pork industry with the latest information on sow feeding during gestation and ways to alleviate the adverse effects of seasonal infertility on sow production.

Key Findings

Two refresher courses for pork producers who had already shifted, or were contemplating shifting, to group housing systems from weaning and/or soon after mating were completed at Toowoomba on 16/17 October and in Melbourne on 18/19

October, 2012. Over 150 pork producers and other people associated with the Australian pork industry attended these events. These presentations together with case studies published by Australian Pork Limited should provide enough information and confidence to pork producers who need to change to the APL defined type of stall-free accommodation before 2017. The amount of information and experience of pork producers for the shift to lower confinement systems where sows may be completely stall free, or at the very most, restricted for up to 24 hours for insemination is probably more equivocal.

Two publications that consolidated much of the recent work from the Pork CRC and APL were prepared and published.

- The first publication summarised the sow feeding work from Pork CRC and APL projects. The results indicated contrary findings to long held beliefs about sow feeding. Increasing feed intake of dry sows in early pregnancy will ensure that the less dominant sows get adequate nutrition and improve overall performance of sows in groups. Conversely, increasing feed intake in late pregnancy has little or no benefit.
- The second publication summarised APL and Pork CRC work conducted in the seasonal infertility area and provides key information and recommendations that pork producers should consider going into the next summer season.

Application to Industry

These sow group housing presentations together with case studies published by APLshould provide enough information and confidence to pork producers who need to change to the APL defined type of stall-free accommodation before 2017. Subsequent workshops for producers implementing group housing from weaning until entry to farrowing accommodation are planned for early 2014.

The two publications provide up to date information on the correct feeding strategies for feeding dry sows in groups as well as implementing different strategies to prepare for each summer period. These publications have been distributed to each pork producer in Australia.

PROJECT 1C–111: EFFECT OF GROUP HOUSING AFTER WEANING ON SOW WELFARE AND SEXUAL BEHAVIOUR

Project Leader:
Jean-Loup Rault
(University of Melbourne)

Project Participants:
Paul Hemsworth
(University of Melbourne),
R. Morrison (Rivalea Australia),
A. Tilbrook (SARDI),
C. Hansen (University of Copenhagen, Denmark)

Aims and Objectives

This project compared the effects of grouping sows after weaning or after insemination on sexual behaviour, aggression, injuries, stress and reproductive performance. On the day of weaning, 360 sows were either housed in groups of 10 sows at 4.4 m^2 per sow (18 groups) or kept in individual stalls (18 groups in each of 10 sows in individual stalls). Within two days after insemination, a cohort of sows were moved to groups of 7 sows at 2.1 m^2 per sow, grouping those sows from stalls and keeping familiar groups of sows that had been grouped at weaning.

Key Findings

Group-weaned sows showed no difference in the wean to first insemination interval within 5 days of weaning, the onset of oestrus or the length of oestrus compared to stall-housed sows. However, 7% less group-weaned sows were inseminated within 5 days of weaning, and the sexual receptivity test revealed that group-weaned sows were less receptive than stall-housed sows, showing less spontaneous standing during boar exposure and partly compensating by showing a greater response to the back-pressure test in presence of the boar.

Group-weaned sows also showed greater variability in insemination rate, with 3 out of 18 pens retaining only 5 sows out of 10 after day 7. Mixing after weaning resulted in higher levels of stress than mixing after insemination, based on cortisol concentration and aggression, and group-weaned sows lost an average 2.8 kg while the body weight of stall-housed sows remained stable during this first week post-weaning. No treatment effects were found on reproductive variables (conception rate, return rate, farrowing rate, total piglets, born and born alive, and culling rate), but a larger sample size is required to provide sufficient power to test these effects.

Application to Industry

Sows housed in groups at weaning experienced higher stress than sows housed in individual stalls at weaning and housed in groups after insemination.

Although group-weaned and stall-housed sows performed equally well overall, the greater variability in performance such as insemination rate between pens of group-weaned sows may reduce the predictability of this system.

A possible lower sexual receptivity in group-housed weaned sows also emphasises the importance of appropriate and sensitive oestrus detection protocols in group-weaning systems.

Research on a larger sample size is needed to assess whether group-weaning affects farrowing performance, particularly between-batch variability and therefore could result in under-use of housing facilities and economic losses for pork producers. This study was performed using what may be considered close to best practice of weaning sows into groups. Therefore results could be sub-optimal in other settings (e.g. mixed parity, dynamic grouping, no sow protection at feeding, restricted feed post-weaning, etc.).

Research Summaries for Subprogram 1C continued

PROJECT 1C–112: EFFECTS OF GROUP HOUSING ON SOW PRODUCTIVITY AND WELFARE: REVIEW

Project Leader:
Paul Hemsworth

Project Participants:
Paul Hemsworth (University of Melbourne) and Christian Hansen (University of Copenhagen) with the support of Ms. Megan Verdon, Dr Jean-Loup Rault and Ellen Jongman (University of Melbourne), Ms. Lisbeth Hansen (Danish Pig Research Centre) and Ms. Kate Plush (University of Adelaide)

Aims and Objectives

To review the scientific literature on the effects of group housing from both post-weaning and post-insemination on sow productivity and welfare.

To identify key research areas that could form a 'road map' for a 3 to 5-year R&D investment and potential collaboration between Pork CRC, the Danish Pig Research Centre and the University of Copenhagen.

Key Findings

The literature review examined factors affecting the welfare of sows in groups with the aim of identifying key research priorities to address risks to sow welfare. This review also provides the Australian pork industry with information on how to successfully mix sows and manage them under group housing systems.

Floor space allowance markedly affects sow welfare, although sows in groups appear to quickly adapt to reduced space soon after mixing and during gestation. In addition to quantity of floor space, the quality of space is also important: spatial separation between sows can also be provided with visual or physical barriers and stalls. Thus optimising factors such as floor space and other design features, such as barriers as well as providing access to resources such as feed, water and a lying area, appear to be important in reducing aggression and stress at mixing and beyond.

Feeding levels, dietary ingredients and feeding systems can also affect aggression and stress. Increased feeding levels, particularly around mixing, together with additional/alternative fibre sources may improve sow welfare by reducing stereotypies and aggression at these critical times. The move towards group housing of sows, above all, requires increased stockperson skills and knowledge in observing and managing individual animals, as well as the group as a whole, in group housing systems.

Application to Industry

The extensive literature review on the principles of grouping sows post-weaning and post-insemination to minimise welfare risks and maximise reproductive performance culminated with the joint Pork CRC/APL publication, *Mixing Sows-How to maximise welfare*. This industry document was published in April 2014 and launched at the Sow Housing Workshops at Toowoomba on 2 April and Melbourne on 4 April, 2014 and is now available to all Australian pork producers.

The literature review also identified a number of areas for future R&D investment and collaboration between Pork CRC, the Danish Pig Research Centre and the University of Copenhagen. The R&D areas included mixing pens, socialisation of juvenile gilts and increased satiety and enrichment for dry sows.

PROJECT 1C–113: WELFARE AND PRODUCTIVITY OF SOWS AND LITTERS IN FARROWING CRATE COMPARED TO LACTATION PEN

Project Leader:
Paul Hemsworth (AWSC-UoM)

Project Participants:
Clara Singh, Megan Verdon, Tracie Storey, Maxine Rice (all AWSC-UoM), Charles Farms

Aims and Objectives

The project comprised two experiments which examined the effects, on the welfare of sows and their piglets, of loose housing duration lactation ('lactation pens') following temporary confinement in a farrowing crate from day 110 of gestation to day 3 of lactation.

Key Findings

The lactation pens increased both the interaction between sows and piglets and the maternal behaviour of sows

based on the behavioural responsiveness of sows to recordings of piglet vocalisations. In one of the two experiments, piglets in the lactation pens displayed more play behaviour but less injurious or harmful behaviours, such as sucking and chewing other piglets.

There was evidence of increased skin injuries in both sows and piglets in the lactation pens. However, the skin injuries for both sows and piglets in both housing treatments were generally minor scratches.

There were no differences in piglet pre-weaning growth and mortality between litters that were loose-housed following temporary confinement for 3 days postpartum and those that remained in crates throughout lactation.

Application to Industry

The increased maternal behaviour observed in sows in the lactation pens may have short and long-term effects on piglet welfare. For example, increased maternal behaviour may reduce piglet mortality by enhancing the sows' response to piglet vocalisations in the event of a crushing. Furthermore, maternal interactions may facilitate social learning and development in piglets, which may in turn reduce piglet fear responses and aggression at weaning. These early rearing influences may consequently improve piglet welfare and productivity by reducing stress and injury at weaning, thus improving rates of growth and feed efficiency post-weaning. Thus the pork industry may benefit from further investigations into the long-term effects of increased maternal behaviour of sows on piglet behavioural development.

The positive effects of the lactation pen on increased piglet play behaviour and reduced piglet injurious or harmful behaviours in one of the two experiments suggests that the implications of pen space on the behavioural development of piglets also warrants further study.

These present findings and recent overseas research indicate that housing individual sows and their litters in lactation pens following temporary confinement in a farrowing crate early in lactation when the risk of piglet mortality is high, offers an opportunity to minimise piglet mortality while reducing welfare risks to both sows and their piglets. For those producers that are interested but hesitant in transitioning to a totally confinement-free system, temporary confinement early post-partum appears to provide an intermediary step that offers an overall improvement in both sow and piglet welfare before transitioning to a totally confinement-free system.

PROJECT 1C–114: REDUCING SOW STRESS AROUND FARROWING

Project Leader:
Kate Plush (Sun Pork Farms SA)

Project Participants:
Lisa McKenny, Tanya Nowland, William van Wettere (all University of Adelaide), Robyn Terry (SARDI)

Aims and Objectives

The project aimed to gain a greater understanding about: how confinement affects the behaviour and potential stress of sows at farrowing; how confinement prior to farrowing and the provision of nesting materials impacts sow performance as well as piglet survival; how the provision of a synthetic olfactory agonist diffuser block in the farrowing crate can reduce sow anxiety and improve piglet performance and; how the use of dietary magnesium in a lactation diet could reduce behavioural indicators of sow stress during farrowing and reduce cortisol levels. The objectives were to positively affect sow welfare whilst in the farrowing crate and improve piglet survival, especially in first few days of age.

Key Findings

Providing sows with the freedom of movement in a 360° farrowing crate in the lead up to and during parturition did not negatively affect piglet mortality and altered some of the sows pre-farrow behaviours. Providing sows with nesting materials (straw and hessian sacks) during the pre-farrow stage stimulated sows to perform nest building behaviours. Additionally, the use of straw in the conventional farrowing crate improved post-natal survival. The use of straw in the farrowing crate is however problematic in that it may block effluent pits which, the use of an inexpensive hessian sack avoids and enabled the sow to exhibit nesting behaviour.

Research Summaries for Subprogram 1C continued

Application to Industry

As a result of the outcomes in this study the following recommendations are made:

- Sows housed in farrowing crates with the ability to turn around in the periods leading up to farrowing and during farrowing did not negatively impact piglet survival and positively affected some sow behaviours. Therefore sows can farrow unconfined during this critical period however, close supervision throughout farrowing is recommended to ensure piglet survival is not negatively impacted.
- Providing straw or hessian sacks pre farrowing allowed sows to exhibit natural nest building behaviours. The use of straw in the conventional farrowing crate decreased piglet mortality pre- and post-fostering. However, the use of straw can block effluent pits easily whereas the use of the hessian sack could not. Therefore the use of a hessian sack during these critical times is a cost-effective and easy strategy to implement for positive sow welfare advantages.
- The use of the synthetic olfactory agonist in the farrowing crate did not influence sow cortisol levels in response to a snout rope test nor did it effect piglet mortality rates and production. The use of a synthetic olfactory agonist in the farrowing crate is not recommended.
- The use of two diets with increased magnesium levels prior to and post-farrowing did not impact sow cortisol levels, farrowing or piglet performance. Whilst small differences were seen in mortality prior to fostering, the addition of two magnesium sources fed to sows during the transition phase from gestation to lactation did little to impact sow welfare. As a result of these outcomes it is not recommended that increased magnesium levels be included in pre- and post-farrowing diets.

PROJECT 1C–115: NUTRITIONAL MANAGEMENT STRATEGIES TO REDUCE AGGRESSION AT MIXING OF UNFAMILIAR SOWS

Project Leader:
Tracy Muller (CHM Alliance)

Project Participants:
Rob Hewitt and Rob van Barneveld (CHM Alliance)

Aims and Objectives

This project compared strategies for reducing aggression at mixing of sows by:

1] Implementing a higher feeding level of 4.0 kg/day and the use of enrichment in the form of a supplemental nutrient block.

2] Feeding a diet containing Sugarbeet pulp (SBP) and Magnesium oxide (MGO), alone or in combination, prior to and during mixing.

Key Findings

In Experiment One, chase behaviour decreased and lying time increased when the higher feeding level was imposed or when the supplemental nutrient block was introduced at mixing.

In Experiment Two, the inclusion of 20% sugarbeet pulp and/or 0.2% magnesium oxide in the diets of sows a couple of days prior to mixing, failed to have any significant effect on the behaviour or welfare parameters that were measured in the experiment. The feeding of these types of "satiety" products may only be effective if they are included in the diet at higher inclusions

In both experiments, fighting and fresh scratch injuries often significantly decreased within a couple of the days after mixing, providing further evidence that the sow quickly adapts to group housing.

It is recommended that the supplemental block be examined for longer term use during gestation to possibly improve satiation and welfare of sows in group housing systems.

Application to Industry

Providing sows with either an increased feeding level of 4.0 kg/day or the use of a supplemental nutrient block would appear to be useful to decrease foraging behaviour at feeding time which in turn decreases aggressive chase behaviour. Although most aggressive behaviours associated with feeding time and mixing unfamiliar sows were not affected, the supply of the supplement block may provide enrichment for sows in group housing.

The feeding of products such as sugar beet pulp may only be effective in decreasing aggressive behaviour in group housed sows if included in the

diet at higher levels, which may not be commercially accepted. Fighting time associated with mixing unfamiliar sows is highest on the first day of mixing and greatly decreases by the following day. Thus it is suggested that strategies to reduce fighting may need only be considered for the very early stages of mixing.

PROJECT 1C–116: ENRICHING THE ENVIRONMENT OF GROUP HOUSED SOWS USING STRAW / HAY IN RACKS

Project Leader:
Dr William van Wettere

Project Participants:
University of Adelaide and SunPork Farms South; Co funded by Pork SA through the Pig Industry Fund

Aims and Objectives

1] To determine whether providing group housed, gestating sows (fed via ESFs) with access to straw or hay in racks would reduce aggression and improve reproduction.

2] To determine which substrate (Straw versus hay) was most valued and used by group housed gestating sows.

Key Findings

- Incidences of aggression (number and duration) decreased significantly between day 2 and 9 post-mixing.
- Access to straw or hay in racks did not affect aggressive interactions or reproduction.
- Sows appeared to place greater value on hay, based on the higher incidence of guarding behaviour exhibited.
- The provision of substrate reduced the proportion of sows removed from group pens due to failure to eat.
- Weight gain and P2 backfat was reduced by the provision of straw (but not hay).
- Providing sows access to either Hay or Straw increased the incidences of mummified foetuses 0.1 (control) to 0.2 (Hay and Straw) per litter.
- Straw and Hay filled racks, and associated substrate, continued to retain sow interest on day 30 post-grouping, suggesting their potential as a long-term enrichment.
- Regardless of treatment, pre-weaning mortality was higher in sows, which farrowed before day 115 of gestation compared with days 115 and 116 of gestation (despite no difference in total litter size). Indicating strategies to reduce the incidence of short gestations may be beneficial to reduced pre-weaning mortalities within the Australian breeding herd.

Application to Industry

Providing sows with opportunities to express natural behaviours, such as foraging, and access to malleable substrates, is commonly referred to as enrichment, and is a high priority for producers, retailers and consumers. Access to foraging, digestible substrates such as straw or hay, represents one strategy to provide sows with nutritional enrichment and a focus for foraging behaviour. This study demonstrated no effect of providing straw or hay in racks on the incidence of aggression amongst group housed sows, which were fed via electronic sow feeders. However, based on guarding behaviour and exploration on the rack and associated substrate it is apparent that both substrates continue to be of interest to group housed sows for at least the first 30 days after grouping. Sows appear to value hay more highly as a resource (as evidenced by higher incidences of guarding behaviour). However, sows spent more time exploring the straw filled racks and associated fallen substrate on days 9 and 30 post-grouping compared to Hay and Control, suggesting that straw may retain their interest for longer. Interestingly, providing access to Hay and Straw reduced the proportion of sows failing to eat from the ESF's, suggesting that providing these substrates may reduce pressure at the ESF, thus encouraging less dominant sows to eat. Weight gain and P2 backfat were reduced in sows with access to straw indicating an impact on sow appetite for their grain based ration. This may require re-formulation of concentrate rations to ensure no negative impact on productivity. Based on usage, the provision of hay or straw in racks may be a commercially relevant method of 'enriching' the environment of group housed, gestating sows.

Research Summaries for Subprogram 1C continued

PROJECT 1C 118: SHAM CHEWING AND SOW WELFARE AND PRODUCTIVITY

Project Leader:
Lauren Hemsworth

Project Participants:
Paul Hemsworth
and Jean-Loup Rault
(University of Melbourne)

Aims and Objectives

Stereotypies are repetitive behaviours induced by frustration, repeated attempts to cope, and/or Central Nervous System dysfunction. While it is believed that stereotypies develop due to suboptimal environments and indicate a welfare concern, the actual welfare implications remain poorly understood. Despite the move from stall to group-housing during gestation, stereotypies such as sham chewing are still anecdotally observed in group-housed sows. To date, the welfare implications of stereotypic behaviour in pigs, particularly sham chewing, have received little examination.

The present project examined the relationships between sham chewing and the welfare and productivity of group-housed nulliparous gestating sows.

Key Findings

1] Sham chewing was recorded in 97% of the 170-nulliparous group-housed sows observed on day 8 of gestation, and 91% of the 150-nulliparous group-housed sows observed on day 52 of gestation. Based on the limited literature this was substantially higher than expected.

2] Sows on average were observed in the present study performing sham chewing at 10% and 9% of the visible observation points on days 8 and 52 of gestation.

3] There were few significant relationships found between sham chewing and welfare and productivity variables in the present study. Sows that performed sham chewing behaviour in less than or equal to 5% of visible observations on days 8 and 52 had less still-born piglets and lower cortisol concentrations on day 8, respectively. Several studies report a relationship between the performance of stereotypic behaviour and lower levels of HPA activation. However, there has been, and still is, ongoing discussion and research on the welfare significance of stereotypies. There is a report in the literature that sows performing sham chewing give birth to fewer piglets born alive.

Application to Industry

1] Sham chewing was recorded in over 90% of the 170-nulliparous group-housed sows observed in the present study. Based on the limited literature on sham chewing this is substantially higher than expected.

2] While the present findings provide limited evidence of relationships between sham chewing and sow welfare and productivity, a better understanding of the aetiology of the behaviour would assist in appreciating the implications of sham chewing. For example, understanding the factor(s) leading to sham chewing would provide an opportunity to manipulate this causal factor(s) in controlled experiments to examine the effects on sow welfare and productivity.

Since the present study shows a high level of sham chewing in group-housed sows and some limited evidence of relationships between sham chewing and sow welfare and productivity, and with the ongoing discussion and research on the welfare and productivity implications of stereotypies, further research of the welfare and productivity implications is recommended. Further research may be both pertinent from a sow welfare and productivity perspective and prudent in terms of addressing community and NGO criticisms of indoor sow group housing.

PROJECT 1C–119: BRAIN-DERIVED NEUROTROPHIC FACTOR AS AN INDICATOR OF ENVIRONMENTAL ENRICHMENT EFFECTIVENESS

Project Leader:
Jean-Loup Rault
(University of Melbourne)

Project Participants:
Cameron Ralph (SARDI),
Andrew Lawrence
(University of Melbourne)

Aims and Objectives

- To investigate the changes in brain-derived neurotrophic factor (BDNF) depending on whether enrichment has been provided or not.
- To investigate whether BDNF can be measured in saliva through ELISA, and its correlation with plasma and serum BDNF to determine the best sampling matrix.
- To investigate the correlation between BDNF concentration changes and other behavioural measure (maze test).
- To establish the variation in BDNF concentrations between various conditions (within individuals overtime, age effect).

Key Findings

Overall, serum BDNF concentration was higher in pigs provided with environmental enrichment, in the form of a foraging block, compared to pigs housed in a barren environment. The provision of enrichment early in life, before weaning, resulted in a more pronounced BDNF concentration increase than enrichment provided later in life, after weaning. BDNF concentration reduced as the pigs aged from 3 to 11 weeks of age. There was no correlation between BDNF and the performance of the pig in a maze test. BDNF could be reliably measured in serum, but we could not reliably measure BDNF in plasma and it was not detectable in saliva.

Application to Industry

Measuring BDNF in pig serum is a promising tool to assess the effect of providing pigs with environmental enrichment. However, further research is needed to determine whether various forms of enrichment are more or less effective, and to link changes/differences in BDNF to other indicators of improved pig welfare.

PROJECT 1C–120: HUMAN ENRICHMENT PROGRAM FOR BREEDING SOWS: PROOF OF CONCEPT

Project Leader:
Professor Paul Hemsworth,
University of Melbourne

Project Participants:
Rebecca Morrison
(Rivalea Australia),
Lauren Hemsworth,
Maxine Rice, Jean-Loup Rault,
Kym Butler and Megan Hayes
(all University of Melbourne)

Aims and Objectives

The objective was to investigate the effect of daily short term (2 minutes) human enrichment (HE) of group housed gestating sows on their stress resilience,emotionality and reproductive performance. The study involved 360 sows over two replicates and also investigated the effect of parity (P1 and 2 and P3 and older).

Key Findings

Daily human enrichment/ interaction with sows had no effect on any measure of stress resilience or reproductive performance.

Human enrichment did however reduce the animals "fear" of humans during routine procedures such as pregnancy testing and vaccination. In one of the two replicates HE also increased serum brain-derived neurotrophic factor (BDNF) concentrations at 5 weeks of gestation. Several studies have shown that environmental enrichment increases BDNF, resulting in higher stress resilience.

Application to Industry

This was a proof of concept study which showed that human enrichment commencing after mixing reduced the fear of humans based on responses to technicians conducting pregnancy testing and vaccinations and in one replicate increased BDNF concentration which is an indicator of improved affective state and higher stress resilience. Provides excellent background information of HE on most indictors of stress resilience and behaviour and suggests further longer term studies are required.

PROGRAM

2 Herd Health Management

This program aimed to enhance animal health, while reducing antibiotic use in commercial pork production. The research involved novel diagnostic tools to monitor pathogen loads in production units and better characterise virulence genes which cause disease. These technologies will enable more strategic use of antibiotics.

SUBPROGRAM 2A	**NOVEL DISEASE DIAGNOSTICS**
SUBPROGRAM 2B	**HEALTHY ROBUST PIG GENOTYPES**
SUBPROGRAM 2C	**REPLACEMENT OF ANTIBIOTICS WITH EFFECTIVE INTEGRATED HEALTH STRATEGIES**

Subprogram 2A: Novel Disease Diagnostics

The Subprogram involved the development of diagnostic tools for rapidly detecting pathogens in the pig and its environment. Diagnostics developed for the major respiratory and enteric pathogens affecting the Australian herd have been combined with antibiotic sensitivity and virulence gene testing. Tests were also developed to assess the general immune and health status of herds, with the aim of applying these on farm. The projects will permit producers and veterinarians to identify and effectively address disease situations before they impact animal health and performance.

PROJECT ID	TITLE
2A–101	Validation of a data collection protocol on Australian Pig Farms *(confidential)*
2A–102	Real-time detection of airborne pathogens in the piggery
2A–103	Comparing The Mucosal And Systemic Immune Response After APP-Alive Vaccination With Natural Challenge
2A–104	Evaluation of diagnostic tests to detect Clostridium difficile in piglets
2A–105	Reduce the risk of post-weaning E.coli diarrhoea using a potentially innovative feeding ingredient
2A–106	A comprehensive risk factor analysis of E.coli disease in the piggery environment
2A–107	Antibiotic sensitivity of Haemophilus parasuis plus Actinobacillus pleuropneumoniae and other respiratory pathogens
2A–108	Evaluation of oral fluid samples for herd health monitoring of pathogens and the immune response in pigs
2A–109	Development and validation of assays to measure gut health in order to identify risk factors for E.coli disease in weaner pigs
2A–111	An investigation into the extent of occurrence of novel pathogenic Brachyspira species, including newly recognised agents of swine dysentery, in Australian pig herds
2A–112	On-farm immunoassay test kit for inflammatory diseases to test the immune status of a herd
2A–113	Enhancing the efficacy of vaccination through zinc supplementation
2A–114	Identifying, tracking and controlling swine dysentery in Australian pig herds
2A–115	Novel Porcine Actinobacillus species – diagnostic tools and pathogenicity evaluation
2A–117	Erysipelothrix rhusiopathiae Epi-Interface, a New Approach to the Management of Porcine Erysipelas.
2A–118	Drinking water quality and its impacts on the health and performance of pigs

Research Summaries for Subprogram 2A

PROJECT 2A–102: REAL-TIME DETECTION OF AIRBORNE PATHOGENS IN THE PIGGERY

Project Leader:
Dr Marc Marenda,
(Faculty of Veterinary and Agricultural Sciences)

Project Participants:
Dr Phillip Markham,
Ms Anne Watt,
Professor Glenn Browning
(all University of Melbourne)

Aims and Objectives

To develop a robust method to quantify microbes in the air of piggeries. Monitoring the concentration of airborne microorganisms helps to improve general hygiene standards in the farm, and to detect problems in herd management or in building ventilation.

To assemble a panel of rapid assays for the detection and quantification of bacterial pathogens commonly found in pigs. These assays are integrated into a standardised air analysis protocol, in order to diagnose pathogenic agents and to control infectious risks with minimal disturbance to the animals, introduction of sampling bias, or lengthy laboratory analyses.

Key Findings

A cyclonic air sampler was successfully tested and validated in laboratory and in farm conditions. Up to 3 cubic meters of air can be collected in 10 minutes. Airborne particles are trapped into a small volume of liquid for laboratory analysis. The sampler gave consistent results with varied operating settings.

The counts of bacterial colonies accurately reflected the concentration of airborne bacteria and correlated well with animal densities. In normal farm conditions, the ambient microbial load ranged between 10 and 100 organisms per litre of air.

Four quantitative Real time PCR (qPCR) assays were validated for the detection of Entero-toxinogenic *E. coli* (ETEC), and a unique, two-step qPCR assay was designed for the detection of *Actinobacillus pleuropneumoniae* (APP). Three conventional PCR assays for the detection of *Streptococcus suis*, *Haemophilus parasuis* and *Mycoplasma hyopneumoniae* are also under validation.

The lowest limits of detection for the qPCR assays was estimated at 10 organisms for APP, and 200–1000 organisms for ETEC.

Farm air samples were found to contain ETEC and APP close to the limit of detection by qPCR, in the absence of overt clinical signs.

Application to Industry

The data recorded from regular monitoring of ambient microbial loads in the farm can be integrated into genetic selection schemes to increase the resilience of pigs in adverse microbial conditions, and to manage infectious risks by improving the general hygiene of piggeries. The analysis requires conventional microbiology to count total colonies on agar plates, which can be automated. Targets values can be set for each farm area and deviations from the normal titres can be detected rapidly (24–48 hours).

Specific pathogens can be detected at low levels in the farm environment. The sample can be frozen and analysed without culture by PCR or qPCR, or processed fresh for isolation and identification of live pathogens and antimicrobial susceptibility testing. The quantitative detection of pathogens by qPCR can be completed in 24–72 hours and can help to differentiate true outbreaks from background endemic infections.

Research Summaries for Subprogram 2A continued

PROJECT 2A–103: COMPARING THE MUCOSAL AND SYSTEMIC IMMUNE RESPONSE AFTER APP VACCINATION WITH NATURAL CHALLENGE

Project Leaders:
Narelle Sales, Alison Collins and Damian Collins, Department of Primary Industries, Elizabeth Macarthur Agricultural Institute

Aims and Objectives

APP-Alive is a live intranasal vaccine to prevent *Actinobacillus pleuropneumoniae* (APP) in pigs. When vaccine failures became apparent, we developed IgA based ELISA tests to investigate the immune response at the mucosa of the respiratory tract. The antibody responses found in blood and lungs of a serovar 5 vaccinated herd were compared to those of an apparently APP-free herd and two herds with endemic serovar 7 infection.

During test development, the vaccine at the collaborating farm was changed from APP-Alive to intramuscular immunisation (IM), with a killed whole cell (bacterin) vaccine which was unlikely to stimulate the same level of mucosal IgA response. However, we continued with the project to develop the tests as potential diagnostic tools and to examine the mucosal and serum antibody profiles in the different herds.

To develop APP serovar specific IgA based tests, seven different APP antigens were isolated. We found that lipopolysaccharides (LPS) were the most specific antigens for the serovars of interest when tested against anti-sera to Serovars 1, 7 and 15.

Key Findings

On-farm results from these two new ELISA tests poorly supported the APP classification status originally given to each farm. Therefore, test results from the EMAI ELISA's were compared to results from two other IgG ELISA tests, Swinecheck® APP (5A–5b) and ID Screen® APP 4–7 Indirect using the same samples. The EMAI ELISA's for both serum IgG and IgA were rated as good for serovar 5 and excellent for serovar 7 at detecting allegedly truly positive animals using Swinecheck® and ID Screen® APP results as the "gold standards". As these gold standards were not developed for use with lung washings a similar assessment of the EMAI ELISA tests using lung mucosal samples was not possible. We could only conclude, on the basis of the serum sample correlations and a single vaccinated pig with a high level of IgG present in Bronchoalveolar Lavage(BAL), that if elevated levels of antibodies to either serovar *were* present in BAL they would be detected by the EMAI IgA ELISAs.

The EMAI ELISAs, Swinecheck® and ID Screen® test results all supported the assertion that there were Serovar 7 negative pigs in the Serovar 7 herd; Serovar 7 positive pigs in the serovar 5 vaccinated herd; one Serovar 7 positive sample in the APP free herd and serovar 5 negative pigs in the serovar 5 vaccinated herd. The results of all tests were compared with lung damage scores obtained at abattoir sampling. There was no correlation between EMAI ELISA antibody levels in individual pigs and their pneumonia score at slaughter.

Neither vaccination nor infection appeared to produce a consistent detectable rise in mucosal IgA in the herds. However, the triple IM vaccination protocol, followed by an 8 week interval prior to sampling, was too long for the detection of the IgA mucosal response which recent work has shown occurs in the initial stages of vaccination/infection. However, the sera IgA response, which occurs in the later stages, was evident and more reliable than the induced IgG response for detecting antibody response.

Application to Industry

The EMAI ELISA tests will be suitable for future live vaccination efficacy studies but more frequent collection of blood and /or mucosal fluid samples, pre and post immunisation will be necessary to better define and quantify the specifics of the immune response to vaccination.

PROJECT 2A–104: EVALUATION OF DIAGNOSTIC TESTS TO DETECT CLOSTRIDIUM DIFFICILE IN PIGLETS

Project Leaders:
Professor Thomas Riley (University of Western Australia)

Project Participants:
Mr Daniel R Knight and Ms Michele M Squire (University of Western Australia)

Aims and Objectives

The project aim was to provide guidance to the pork industry, veterinarians and veterinary diagnostic laboratories about the suitability of currently available commercial assays to detect *C. difficile* in Australian piglets. To achieve this we evaluated the performance of four commercial assays to detect *C. difficile* in 157 specimens of piglet faeces obtained from neonatal piglets (49 scouring) aged <14 days during the period June 2012 to March 2013. Assays included two commercially available PCR methods for the detection of toxin A and B genes; (illumigene® *C. difficile* amplification assay (IG, Meridian Bioscience) and BD GeneOhm™ Cdiff Assay (GO, BD Diagnostics), an enzyme immunoassay for toxins A and B (QC, TechLab C. diff Quik Chek™ (Alere) and direct culture; *C. difficile* ChromID™ agar (CA, BioMérieux). Assays were compared against enrichment culture (EC) as a "gold standard".

Key Findings

- Overall, *C. difficile* was isolated by EC from 39.5% (n=62) of samples. PCR revealed 58.1% (n=36) of isolates were positive for at least one toxin gene (*tcdA/tcdB*). Five isolates (8.1%) had the uncommon genotype of tcdA-/tcdB-/CDT+ and the remainder (n=21, 33.9%) were negative for any toxin genes.
- PCR ribotyping of the isolates revealed heterogeneity of strain types, many of which are known to cause disease in humans.
- Compared with EC, the sensitivity, specificity, Positive Predictive Value, and Negative Predictive Value were, as follows: for CA; 100.0, 96.0, 88.9 and 100.0%; QC; 38.9, 92.6, 66.7 and 80.0%; GO; 42.9, 97.9, 88.2 and 82.3% and IG; 25.0, 95.8, 69.2 and 77.1%.

- CA performed the best of all the comparator assays with high sensitivity and specificity in recovery of *C. difficile* from piglet faeces irrespective of strain type.
- The performance of the molecular based assays (QC, GO and IG) in the detection of *C. difficile* in porcine faeces was unacceptably poor. Concordance with EC was low, due to a large number of false negative results, which could be attributable to a number of host and/or microbial factors including strain type, faecal composition and sample deterioration.

Application to Industry

This study highlights the high prevalence and unique strain types of C. difficile present in Australian neonatal piglet populations, and the need for further examination of existing assays and development of new rapid assays for detection of C. difficile in piglets. The results underscore the importance of developing porcine-specific assays with high sensitivities, PPVs and NPVs for the rapid reliable detection of C. difficile and its toxins in porcine faeces. However in the interim C. difficile ChromID™ agar provides all diagnostic laboratories with the ability to detect C. difficile in pigs in 24h.

There is an urgent need for better surveillance at national and local levels of the strain types circulating in Australian pig populations as there will most likely be temporal changes both in the strains of C. difficile found in the piglets and the risk factors contributing to their establishment and spread in piggeries. This data is also necessary for analysing public health risks, if any.

Given the findings of this project and the increasing body of literature in this field, both global and domestic, every effort should be made by the pork industry to increase awareness among veterinarians, animal health groups and producers, of C. difficile as a pathogen of piglets and the challenges of detection and diagnosis.

PROJECT 2A–105: REDUCING THE RISK OF POST-WEANING E. COLI DIARRHOEA USING A POTENTIALLY INNOVATIVE FEEDING INGREDIENT, LUPIN HULLS

Project Leader:
Professor John Pluske (Murdoch University)

Project Participants:
Dr Jae Kim (DAFWA), Mr Robert Hewitt and Professor Robert van Barneveld (Sun Pork Farms)

Aims and Objectives

This project comprised three studies aimed at determining the impacts that feeding non-starch polysaccharides (NSP) have on aspects of gastrointestinal tract structure and function, production, post-weaning diarrhoea and circulating measures of physiology and immune function.

1] *Virulence testing and serotyping of an enterotoxigenic E. coli (ETEC) isolate*, was directed at confirming the nature of the *E. coli* isolate used at Murdoch University in controlled infection studies.

2] *Determining the insoluble fibre requirement of weaner pigs when fed a diet containing either a low or high level of soluble fibre*, examined the effects of soluble and insoluble fibre on post-weaning diarrhoea (PWD), production, and physiological responses.

3] *Reducing the risk of E. coli by establishing a fibre recommendation after weaning*, was a commercial validation study conducted at CHM Westbrook based on the findings from Experiment 2.

Key Findings

Experiment 1 clearly demonstrated that the toxin and serotype profile of the ETEC isolate used at Murdoch University for controlled infection studies is representative of those found in field cases of PWD.

Experiment 2 examined different ratios of insoluble NSP (iNSP) (as Opticell®) and soluble NSP (sNSP; as purified or semi-purified sources) in the diets under conditions of ETEC infection. Results suggested that using an iNSP source for weaner pigs in antimicrobial-free diets with lower sNSP levels had some beneficial effects on measures related to GIT structure and function, expression of PWD, and production in the 2 weeks after weaning, however in the third week after weaning, beneficial effects of higher sNSP levels were noted. Furthermore, and as measured by expression of tight-junction protein gene expression in the small intestinal epithelium, increasing the dietary iNSP content when there was minimum inclusion of sNSP enhanced intestinal barrier function. Diminished barrier function is a key aspect associated with weaning, so even in the absence of clinical disease/inclusion of antimicrobial compounds in feed/water, higher levels of dietary insoluble NSP could be considered to assist in the restoration of barrier function in the post-weaning period.

In contrast to Experiment 2, Experiment 3, which examined the inclusion of Opticell® (albeit at lower levels than used in Experiment 2) or sugar beet pulp (SBP), failed to improve the performance of pigs in the post-weaning period. Pigs in this study received medications that most likely contributed to the lack of effects, suggesting that the concomitant use of medications is likely to reduce any beneficial effects of feeding iNSP.

Application to Industry

The type and level of NSP play important roles for pig growth, GIT structure and function, expression of diarrhoea, and aspects of physiology of weaner pigs.

Under conditions of higher pathogenic bacterial load and antimicrobial-free production, increasing the iNSP content in the diet and trying to minimise sNSP levels for weaner pigs immediately after weaning should be considered.

Data from the commercial validation study suggest, however, that the effects of including antimicrobial compounds need to be considered when evaluating the potential efficacy of manipulation of fibre types and content of the diet to reduce PWD and improve production indices.

Research Summaries for Subprogram 2A continued

PROJECT 2A–106: A COMPREHENSIVE RISK FACTOR ANALYSIS OF POST-WEANING DIARRHOEA

Project Leader:
Professor Michael Ward (University of Sydney)

Project Participants:
Ms Lechelle Van Breda and Dr Om Dhungyel (University of Sydney)

Aims and Objectives

Determine the risks inherent in a piggery environment responsible/contributing to *Escherichia coli* disease via an epidemiological risk factor characterisation study.

Key Findings

Escherichia coli disease in pre- and post-weaned piglets has a major impact on the Australian pork industry. Using a snapshot survey approach 22-pig producers located across southeastern Australia were recruited. More than 1,100 faecal samples and detailed management and other information was collected:

- Scours prevalence in pre- and post-weaned pens was 17% and 24%, respectively.
- The most prevalent enterotoxigenic genes were F18 (32%) and STb (32%); the most common combination in herds was F4: STb.
- Of 60 factors screened with logistic regression, recent disease events (within the last 12 months) and presence of bedding were risk factors for scours.
- Using Bayesian network analysis, the importance of herd-level management was confirmed; larger herds and those where other livestock were managed on the same farm were more at risk of scours.
- *E. coli* resistance to a range of antibiotics was detected, such as tetracyclines (75%), trimethoprim-sulfamethoxazole (45%) and neomycin (35%).
- Resistance to third-generation cephalosporins (3GC; an antibiotic class *critically important* to human health) occurred in 6.1% of *E. coli* isolates.
- 3GC resistance was more likely to be detected in normal (non-scours) pens.
- Four extended spectrum ß-lactamase (ESBL) genes – previously unreported in Australian pigs – were detected.
- *E. coli* isolates were susceptible to five of six disinfectants tested.

In a separate longitudinal study, the number of male piglets per pen and sow condition score at weaning were identified as key risk factors. Disease was seasonal, and during outbreak periods, a high diversity of *E. coli* clones was observed. This project represents the most comprehensive study of *E. coli* disease in Australian pig herds conducted in the past 20 years.

Application to Industry

Controlling *E. coli* disease via management – such as more attention to hygiene and husbandry in large herds, reviewing the use of bedding, and improved biosecurity – allows producers to improve productivity and profit, and to reduce their reliance on antibiotic therapy. Antibiotic resistance appears widespread in the industry. Judicious use of available effective antibiotics for *E. coli* is critical. With continued and increasing concern over antibiotic resistance as a public health issue, modifying risk factors for *E. coli* disease also will enhance market access. Surveillance for antibiotic resistance and resistance genes in clinically normal post-weaned pigs will provide further market assurance.

PROJECT 2A–107: ANTIBIOTIC SENSITIVITY OF HAEMOPHILUS PARASUIS PLUS ACTINOBACILLUS PLEUROPNEUMONIAE AND OTHER RESPIRATORY PATHOGENS

Project Leader:
Dr Conny Turni (University of Queensland)

Project Participants:
Denise Dayao (PhD student)

Aims and Objectives

In the last decade, the emergence of antimicrobial resistant forms of bacterial pathogens has become a problem in the treatment of bacterial diseases of livestock. Despite this problem, no data was available on the resistance status of respiratory bacterial pathogens in Australia. For one of the main pathogens, *Haemophilus*

parasuis, there was not even an accepted, validated, standardised methodology for testing for antimicrobial resistance. Therefore, the first aim of this study was to develop a method to test for *H. parasuis* antimicrobial sensitivity. Once validated methods for the testing of *H. parasuis* were developed, the project set out to look at antimicrobial resistance in key respiratory pathogens.

The next objective of the project was to find the underlying genetic cause for the phenotypic resistance observed. A wide variety of genes that have been reported in the literature to cause the kind of resistance observed for the Australian isolates were screened.

The last part of this project looked at the resistance of respiratory bacteria within a pig, across a batch of pigs and between pig batches (all from the same farm) to determine whether resistance is evenly distributed in a bacterial population on a farm. For this study, isolates of *A. pleuropneumoniae* were collected from pigs (from a single farm) at slaughter at three different occasions (ten isolates from the primary isolation plate of each lung). The three antimicrobial agents examined were tilmicosin, tetracycline and amoxicillin.

Key Findings

A new validated method for sensitivity testing for *H. parasuis* has been established and the method has been published. We have also sent the method to different laboratories so it can be implemented for the pig industry This method is not yet accepted at the international level, but we are currently collaborating with a laboratory in Germany and one in the USA to do the testing required for the uptake of the method at the international level.

We have looked at antimicrobial resistance in *Actinobacillus pleuropneumoniae*, *Bordetella bronchiseptica, H. parasuis* and *Pasteurella multocida*. The resistance to some of the older antibiotics, such as erythromycin and tetracycline, was marked in all species, for example 89% and 75% of *A. pleuropneumoniae* isolates showing resistance to these two agents, respectively. A worrying outcome was the resistance to the newer antimicrobial agents, such as tilmicosin where resistance was found in 25% of the *A. pleuropneumoniae* isolates. As well, an elevated minimal inhibitory concentration for tilmicosin was found in 22% of the *H. parasuis* isolates tested. There were also isolates observed with multiple drug resistance. This work has been published in two peer- reviewed articles in an international journal. Overall, while antimicrobial resistance is less of a problem in Australia than in many other countries, resistance is present in key pathogens and the industry and associated health professionals need to address the issue.

The next objective of the project was to find the underlying genetic cause for the phenotypic resistance observed. A wide variety of genes that have been reported in the literature to cause the kind of resistance observed for the Australian isolates were screened. Isolate resistance to beta-lactams and tetracyclines could be explained to a large extent by resistance genes detected, bla_{ROB-1} and *tet*B, respectively. However, the screening for eight genes reported to be associated with marolide (ie tilmicosin, erythromycin) resistance gave only negative results. So at this point, the resistance to macrolides cannot be explained by any of resistance genes examined in this study. Further studies are needed to explain the resistance mechanism of the Australian isolates resistant to macrolides.

The last part of this project looked at the resistance of respiratory bacteria within a pig, across a pig batch and between pig batches (all from the same farm) to determine whether resistance is evenly distributed in a bacterial population on a farm. For this study isolates of *A. pleuropneumoniae* were collected from pigs (from a single farm) at slaughter at three different occasions (ten isolates from the primary isolation plate of each lung). The three antimicrobial agents examined were tilmicosin, tetracycline and amoxicillin. Genetic fingerprinting analysis established that the isolates collected were clonal. Among the 367 clonal isolates from three different batches of pigs, isolates that were either resistant or susceptible to tilmicosin were found. In some isolates, there was also statistically significant evidence of two populations in the second sampling for tilmicosin and amoxicillin, with one population showing a lower zone diameter (that is tending towards resistance) and the other showing a higher zone diameter (tending towards more susceptible). The results suggest that a single clone of a porcine respiratory pathogen on a farm can consist of both susceptible and resistant types, with variation in zone diameters of multiple isolates varying across time.

Application to Industry

This project had the following outcomes:

- Validated disk diffusion and MIC antibiotic sensitivity method for testing *H. parasuis* isolates.
- Knowledge of the current resistance patterns in the key pathogens – *A. pleuropneumoniae, B. bronchiseptica, H. parasuis* and *P. multocida*.
- Knowledge of the genes responsible for the phenotypic resistance patterns observed for Australian isolates to beta-lactams and tetracyclines.
- Establishment of occurrence of variation in antimicrobial sensitivity of one clonal bacterial population on a farm and thus the need for diagnostic laboratories to consider testing multiple animals and multiple isolates within an animal to determine antimicrobial sensitivity patterns and provide sound advice to clinicians seeking effective antimicrobial treatment strategies on a farm.

This knowledge is essential to establish effective, sustainable antimicrobial treatment and prevention programs.

Research Summaries for Subprogram 2A continued

PROJECT 2A–108: EVALUATION OF ORAL FLUID SAMPLES FOR HERD HEALTH MONITORING OF PATHOGENS AND THE IMMUNE RESPONSE IN PIGS

Project Leader:
Deborah Finlaison (NSW DPI)

Project Participants:
Alison Collins (NSW DPI), Chris Richards and Associates

Aims and Objectives

1] Develop capability and knowledge for the collection of oral fluid samples and determine storage and transport conditions needed for optimal quantitative PCR and ELISA performance under Australian conditions.

2] Determine if the currently recommended methods for oral fluid processing sufficiently reduce inhibitors that affect the ability of qPCR to detect pathogens.

3] Demonstrate that PCV2 (DNA and antibodies), Bungowannah virus (RNA) and *Lawsonia intracellularis* (antibodies and pathogen) can be detected in oral fluid samples.

4] Determine if the presence or quantity of pathogen or antibody detected in oral fluids correlates with that detected in serum and that this technique therefore has the potential for herd health monitoring of a range of both endemic and exotic diseases in the Australian pig population.

5] Make diagnostic testing for PCV2 and *Lawsonia intracellularis* using qPCR and serology, by means of oral fluid sampling/collection, available for Australian pig veterinarians and producers.

Key Findings

- PCV2 and *Lawsonia intracellularis* DNA can be detected in oral fluid samples collected from the field.
- A commercially available PCV2 antibody ELISA kit was successfully adapted for the detection of PCV2 antibodies in oral fluid samples.
- A correlation was identified between oral fluid samples and the mean serum results for the PCV2 quantitative PCR and PCV2 antibody ELISA, and oral fluids could be utilised in the field for PCV2 and *L.intracellularis* surveillance.
- Oral fluid samples must be stored and transported at ≤4°C for optimal detection of nucleic acid and antibodies.
- Laboratory studies demonstrated that detection of Bungowannah virus RNA in oral fluids is possible.
- The inhibitory effect of oral fluid samples on the detection of nucleic acid appears to occur prior to the PCR step and results in a reduction in sensitivity.
- Oral fluids could also be used for monitoring *L.intracellularis* infection, as the qPCR on oral fluids correlated well with serum ELISA results. However, it was not possible to adapt Lawsonia serological assays for the oral fluid matrix. An improvement in test sensitivity without compromising test specificity is required.

Application to Industry

This proof of concept project indicates that oral fluid testing should be a cost-effective means of herd health monitoring that has the potential to be used to detect a wide range of both viral and bacterial pathogens and associated antibody responses. The techniques and understanding developed as part of this project could lead to significant innovations in Australia in herd health monitoring, animal welfare and nutrition. The adoption of oral fluid sampling could be easily introduced at the farm level as collection kits are commercially available.

Before oral fluids can be used for disease surveillance (including emergency animal disease surveillance) by pathogen or antibody detection, the diagnostic tests will need to be validated.

PROJECT 2A–109: ASSAYS TO MEASURE GUT HEALTH IN ORDER TO IDENTIFY RISK FACTORS AND CONTROL STRATEGIES FOR E.COLI SCOURS IN WEANER PIGS

Project Leader:
Dr Alison Collins

Project Participants:
NSW DPI and Nutreco

Aims and Objectives

1] Enumerate bacteria from seeded faeces using Nutreco culture techniques (ISO standards).

2] Develop quantitative PCR assays for specific bacterial groups (total E.coli, F4 ETEC, Enterobacteriaceae, Lactobacilli and Clostridium perfringens).

3] Compare numbers and ratios of commensal to pathogenic bacterial using bacterial culture techniques and qPCR.

4] Determine bacterial ratios in herds/pigs with and without *E.coli* disease.

5] Next generation sequencing and analysis of microbial community diversity in scouring and healthy pigs.

Key Findings

The new qPCR assays for enumeration of Enterobacteriaceae, Lactobacilli, *Clostridium perfringens* and *E.coli* in weaner pig faeces proved to be an accurate alternative to the more time consuming enumeration by bacterial culture. The qPCR results correlated well with traditional bacterial culture techniques (ISO standards). The new assays also enabled testing of 100 samples in a day relative to the culture techniques that could only test 10 samples over 2 days, providing time and cost savings. Samples for qPCR could be frozen before transit to the lab without loss of accuracy, which is not possible with bacterial culture techniques.

No simple relationship between scouring and decreased ratios of commensal (Lactobacilli) to pathogenic bacteria (*E.coli*) was found over the 7 farms. On two farms scouring correlated well with increased pathogen load and decreased commensal load, but other factors appeared to be responsible for scouring on the other 5 farms. The increased abundance of Lactobacilli in scouring pigs has been reported previously and may be part of the host's response to disease.

Excitingly, we were able to identify other commensal bacteria that are less abundant in scouring pigs and these butyrate producing bacteria may provide a more accurate measure of gut health than the Lactobacilli. It would be fairly easy to develop qPCR assays for the 3 most important butyrate producing bacteria to monitor gut health and microbial stability.

The impact of antibiotics on bacterial populations was somewhat surprising with increased pathogen loads and decreased commensal bacteria in medicated pigs. Reduced abundance of protective commensal bacteria (including both lactate and butyrate producing bacteria) in medicated pigs could exacerbate disease in scouring weaners. However, further studies are needed to investigate the impact of specific antibiotics on both commensal and pathogenic bacteria.

Application to Industry

This project has developed some tools to monitor intestinal health in weaner pigs and has identified other bacteria important for intestinal health. These tools can be used to monitor the impact of dietary additives such as fatty acids, probiotics, prebiotics, organic acids, yeasts, zinc and copper, essential oils and antibiotics on scouring in post-weaner pigs.

The ultimate application of this research is to develop tools to evaluate alternatives to antibiotics for the control of post- weaning scours and we have achieved this. The qPCR assays can also be used to evaluate the impact of management practices on post-weaning diarrhoea, such as genetics, disinfection, cross-fostering gilt and sow litters, mixing of pigs, housing and temperature control.

PROJECT 2A–111: AN INVESTIGATION INTO THE EXTENT OF OCCURRENCE OF NOVEL PATHOGENIC BRACHYSPIRA SPECIES, INCLUDING NEWLY RECOGNISED AGENTS OF SWINE DYSENTERY, IN AUSTRALIAN PIG HERDS

Project Leader:
Professor David Hampson (Murdoch University)

Project Participants:
Dr Tom La and Dr Nyree Phillips (Murdoch University)

Aims and Objectives

The main aim of this project was to determine to what extent novel agents of swine dysentery, distinct from the classical agent *Brachyspira hyodysenteriae*, including "*Brachyspira suanatina*" and "*Brachyspira hampsonii*" are present in Australian pig herds. A subsidiary aim was to investigate the distribution, diversity, antimicrobial susceptibility and predicted virulence of strains of *Brachyspira hyodysenteriae* in Australian herds, including those with mild or no obvious disease.

Key Findings

During the 12 month study, *B. hyodysenteriae* was detected in 27 of the 89 herds examined. Of the 27 herds, six were reported as not showing signs of disease and five showed some mild signs of uncertain significance and aetiology. "*B. hampsonii*" and "*B. suanatina*" were not found in any of the samples tested.

Genotyping a subset of the *B. hyodysenteriae* isolates revealed that they were diverse and distinct from earlier Australian isolates or those from overseas. Related isolates were found in some herds with epidemiological links through movement of pigs.

Resistance to the important antimicrobials tiamulin, tylosin, lincomycin and olaquindox occurred and was more common than in Australian isolates tested in previous years. Three distinct multi-drug resistant isolates were identified from different herds.

Application of a test for virulence showed a high agreement between the test result and origin of the isolates from herds with no disease or only mild disease. This test appears to be a good predictor of strains that are less able to colonise and cause disease, and can be recommended for more wide-scale diagnostic use.

Application to Industry

This study has demonstrated that "*B. hampsonii*" and "*B. suanatina*", the newly described agents of swine dysentery in North America and Europe, are not likely to be present in Australia. On the other hand the classical agent *B. hyodysenteriae* is relatively common and widespread. The strains that are currently circulating generally are different from those found in the past, and are different from strains from other countries. Evidence was found for the likely transmission of strains between piggeries that are linked through movement of pigs. More strains showed antimicrobial resistance than in the past, and of particular concern was the identification of three different multi-drug resistant strains.

A major finding was identification of *B. hyodysenteriae* in farms that had no disease, or only mild disease of previously unknown aetiology. Strains from these farms were shown to lack some genes, which potentially may reduce their ability to colonise. These results support the usefulness of testing isolates for these genes, but also emphasise the need for routine testing of herds to check whether they carry *B. hyodysenteriae*.

Research Summaries for Subprogram 2A continued

PROJECT 2A–112: ON FARM IMMUNOASSAY TEST KIT FOR INFLAMMATORY DISEASES TO TEST THE IMMUNE STATUS OF A HERD

Project Leaders:
Dr Jae Cheol Kim (DAFWA), Dr Diana Turpin (Murdoch University)

Project Participant:
Professor John Pluske (Murdoch University)

Aims and Objectives

The aim of this project was to develop an oral fluid diagnostic kit using lateral flow technology that would quickly show (i.e. within 1-2 hours from collection of samples to diagnosis) the immune status of a large herd. Based on this, decisions could then be made regarding the need for nutritional and/or veterinary intervention with the option for more testing (e.g. pathogen screening).

The first step in this project was to validate the proposed concept before initiating the development of a prototype.

Two major hypotheses were tested to validate selected reactive proteins as biomarkers for herd immunity. The selected reactive proteins examined in this project included the three main acute phase proteins for pigs: haptoglobin, C-reactive protein and PigMAP as well as soluble cluster of differentiation 14 and neopterin.

The two major hypotheses were:

1] Oral fluid levels of reactive proteins are strongly correlated to plasma levels of the reactive proteins.

2] The proposed single-point measurement in an oral fluid sample collected by hanging a cotton rope in a pen represents the mean levels of reactive proteins determined by individual sampling of the reactive proteins.

If the above two hypotheses could be supported, the project would progress to developing a prototype for the oral fluid diagnostic kit (stop/go milestone).

Key Findings

The preliminary outcomes of the first stage of this project supported the first hypothesis that the concentration of C-reactive protein and haptoglobin in the oral fluid of individuals correlates to the concentration in the plasma. However, with regard to the second hypothesis, results demonstrated that only haptoglobin concentration in the oral fluid sample collected by a one-point group sampling technique (hanging cotton in the pen) was positively correlated with the mean haptoglobin concentration determined by oral fluid sampling from individual pigs in the group. In saying this, while most of the commercial farms used for sampling were experiencing underlying health issues, all farms were already receiving veterinary intervention (in-feed medication or a vaccination program) at the time of sampling. High haptoglobin values were detected for two out of the seven farms tested and this was most likely due to management issues. Therefore, a relationship between saliva haptoglobin and health status still needs to be established and further to this, more data is required for the group saliva and mean individual saliva correlations in pens that are immunocompromised.

Application to Industry

The finding that haptoglobin could potentially be a suitable marker for the development of an immunoassay kit used to detect inflammatory disease from oral fluid is a valuable outcome, however further validation of these findings is required involving more sampling on commercial farms experiencing herd health problems before veterinary intervention.

PROJECT 2A–113: ENHANCING THE EFFICACY OF VACCINATION THROUGH ZINC SUPPLEMENTATION

Project Leader:
Robert Hewitt (Sun Pork Farms Queensland)

Project Participants:
Andres Corso (ZnPro), Tracy Muller (Sun Pork Farms)

Aims and Objectives

This project aimed to deliver a simple technique for increasing the efficacy of vaccination through a simple dietary inclusion of products already available for use in Australia. It aimed to provide evidence that the inclusion of amino acid complexed zinc will enhance humoral immune response to vaccination.

Supplementation of diets with amino acid complexes of zinc has led to increases in lactation performance and improved udder health in dairy cows, maintenance of egg production through nutritional stress events in layer hens and improvements in small intestinal integrity during severe heat stress in pigs.

Zinc is an essential trace element for the immune system, with both innate and specific parts of the immune system being influenced by its presence. Oral zinc supplementation of the elderly resulted in significant improvements in circulating lymphocytes and increased the IgG response to tetanus vaccine and humoral immune response was improved in lactating dairy cows. The inclusion of zinc methionine in the diet of feedlot cattle resulted in an improved rate of disease recovery when challenged, similarly, its role in enhancing immune response in poultry is understood.

Zinc methionine's role in pigs has been less well investigated. This study saw the inclusion of super nutritional levels of zinc in both sulfate and amino acid complex form, in a bid to increase the response to vaccination, similar to that seen in beef cattle and poultry.

Key Findings

Results from this study showed there was little difference in growth performance between treatments resulting from feeding zinc above nutritional requirements, nor did it lead to comparable enhancements in immune response from vaccination with tetanus toxoid.

The antibody titres observed followed the expected pattern of protection, with the peak being reached two to six weeks after vaccination. However, the addition of 50 ppm of zinc from the zinc amino acid complex

saw a reduction in the antibody titre (SP ratio). This response wasn't expected, however, it should be remembered that a higher antibody titre does not necessarily protect the animal better – in the case of tetanus (in humans), there is a ten-fold window of titres that is effective against infection.

Despite its use as a recall antigen in many studies it appears that tetanus toxoid is influenced by zinc. Tetanus toxin has a zinc-binding sequence in a region frequently used as a B- and T-cell binding site; saturation of this site with zinc will lead to decreased recognition by the immune system. Therefore, the results observed may in fact be a result of the enhanced availability of zinc from the zinc amino acid complex.

The lack of difference when chromium methionine was used in conjunction with the zinc amino acid complex is likely explained by its immunomodulatory activity. In lactating dairy cows, supplementing with an amino acid and lactate-bound chromium resulted in significant elevation in tetanus toxoid antibody titres. Therefore, it appears that the inclusion of chromium in this treatment was potentially offsetting any saturation effects from the enhanced availability of zinc.

Application to Industry

Despite evidence in cattle and poultry of enhanced vaccination response from the supplementation of diets with zinc amino acid complex, this study, was not able to improve the immune response. There is some evidence within this study that chromium may be of specific interest in elevating antibody titres, where it appeared to have a restorative effect on the zinc amino acid complex treatment.

PROJECT 2A–114: IDENTIFYING, TRACKING AND CONTROLLING SWINE DYSENTERY IN AUSTRALIAN PIG HERDS

Project Leader:
David Hampson, Tom La and Dr Nyree Phillips

Project Participant:
Murdoch University

Aims and Objectives

The project had six objectives

1] Continue the previous investigation into the occurrence of infection with *B. hyodysenteriae* in Australian pig herds, using colonic samples obtained at slaughter checks and/or faeces.

2] Characterise the *B. hyodysenteriae* isolates identified in the current project and Project 2A–111 using multilocus sequence typing.

3] Determine antimicrobial susceptibility patterns for the isolates.

4] Further validate the swine dysentery ELISA kit by testing sera from these herds.

5] Investigate potential carriage of *B. hyodysenteriae* and other pathogenic *Brachyspira* species by aquatic birds.

6] Test typical and atypical *B. hyodysenteriae* isolates for their virulence potential by using them to experimentally infect pigs.

Key Findings

This study showed that *Brachyspira hyodysenteriae* occurs in many Australian herds, including in herds that appear to be healthy and were presumed not to be infected. Examination of isolates from herds with disease and from herds that appeared healthy failed to identify any consistent features that could be used to differentiate between them. Two experiments were conducted in which pigs were experimentally challenged with strains of *B. hyodysenteriae* recovered either from herds with swine dysentery or from healthy herds. One of the strains from a healthy herd that was tested in both experiments colonised the pigs but did not cause disease. Two other strains tested from healthy herds, and which lacked some genes thought to be involved in causing disease, did colonise and cause mild disease in some pigs, in a way that was similar to what occurred with the control strains isolated from herds with disease.

Testing of blood samples from pigs in herds with or without disease using an ELISA test showed that it was useful for detecting infected herds, but also suggested that some apparently healthy herds also were infected.

Many of the strains tested were resistant to the common antimicrobials used to control swine dysentery in Australia, and four strains were identified that were resistant to all three drugs tested.

Application to Industry

The results confirm that swine dysentery is wide spread and can be present in apparently healthy herds. Refinement of the ELISA test may assist in diagnosing such herds. Resistance to three commonly used antimicrobials has increased over time and isolates from healthy herds appear to be pathogenic. There is need for constant surveillance and the development of more rapid diagnostics and alternatives to antimicrobials.

Research Summaries for Subprogram 2A continued

PROJECT 2A–115: NOVEL PORCINE *ACTINOBACILLUS* SPECIES – DIAGNOSTIC TOOLS AND PATHOGENICITY EVALUATION

Project Leader:
Dr Conny Turni
(University of Queensland)

Project Participants:
Pat Blackall and
Youssef Abs El-Osta
(University of Queensland)

Aims and Objectives

Whether there are indeed one or more potential new species in the collection of *Actinobacillus* like organisms held by our laboratory.

The pathogenic role of the new species was then evaluated by examining field data linked to the isolates. For this part, the help of front line diagnostic laboratories and veterinarians was sought.

Key Findings

This work confirmed the inadequacy of the 16S rDNA identification within the family *Pasteurellaceae.* None of the strains identified as *A. porcitonsillarum/minor* by 16S rDNA sequencing were confirmed as such with the multi-locus sequence analysis approach used in this project. The work also highlighted that no single conserved gene by itself can be used for identification in this family.

A new species was found, which for the purpose of the report was named *Actinobacillus* Taxon C1. Some of the *Actinobacillus* Taxon C1 isolates are apparently quite pathogenic and appear to be causing significant pleurisy, lung lesions and abscesses, but is also associated with lesions and death at the farm level. Some of the farms had 40% lung lesions, 30% lung abscesses and 13.8% pleurisy at the abattoir. It was noted by one of the vets involved that the lesions, abscesses and pleurisy went down when this new species was targeted with antibiotics. This would further suggest that the new species is associated with pathological signs observed at slaughter. The fact that the *apxIBD* operon was found and that this operon is normally needed for either ApxI or ApxII toxins further points to the possibility of *Actinobacillus* Taxon C1 causing significant pathology.

Application to Industry

The finding of a new species, named *Actinobacillus* Taxon C1 for the interim, which is associated with lesions and abscesses at the abattoir, but also with lesion and death at the farm level is an important finding for the industry. The similarity of some of the lesions/abscesses at slaughter associated with *Actinobacillus* Taxon C1 with the lesions and abscesses associated with *A. pleuropneumoniae* could indicate that these lesions could have been misidentified as *A. pleuropneumoniae*-linked lesions at slaughter check. The finding of up to 30% lungs with abscesses and 40% lungs with lesions reported on farms free of *A. pleuropneumoniae* but positive for *Actinobacillus* Taxon C1 suggests a significant impact on the industry by this organism.

The awareness of this new species is making it possible to have a closer look at farms with high pleurisy and farms, thought to be associated with *A. pleuropneumoniae,* to determine if *Actinobacillus* Taxon C1 is a problem on these farms.

Future directions would be to develop a PCR for the rapid and confident identification of *Actinobacillus* Taxon C1, so that front line laboratories can identify the species easily and therefore screen large sample numbers for this species to evaluate the impact on farms.

PROJECT 2A–117: ERYSIPELOTHRIX RHUSIOPATHIAE EPI-INTERFACE, A NEW APPROACH TO THE MANAGEMENT OF PORCINE ERYSIPELAS

Project Leader:
Narelle Sales (NSW DPI,
Elizabeth Macarthur
Agricultural Institute)

Project Participants:
Ian Marsh, Leah Stroud,
Bethany Bowring and Daniel
Bogema (NSW DPI, Elizabeth
Macarthur Agricultural Institute)

Aims and Objectives

Characterise *E. rhusiopathiae* isolates using Multi Locus Sequence Typing, virulence gene and antibiotic resistance profiles from DNA sequences derived from whole genome sequencing. Integrate this profile with bacteriological data, farm disease and management information in an Epi-Interface database to establish a better understanding of the epidemiology of erysipelas. We aimed to establish this as an affordable, ongoing and dynamic ecological and epidemiological tool to (1) improve management of porcine erysipelas in the Australian pig industry and (2) develop a model for disease data collection that can be applied to both pig and other livestock industries. Information from this Epi-Interface will aid future decisions in vaccine development and the judicious use of antibiotics.

Key Findings

In this study, one hundred and eighty *E. rhusiopathiae* isolates underwent whole genome sequencing (WGS) of which 178 were successful. From the whole genome sequences, we were able to generate 46 MLSTs from a range of archived and contemporary isolates Of these, nine were equivalent to previous studies and 37 were new to this study. WGS were screened for 47 putative virulence genes producing 24 distinct profiles (virotypes). Antibiotic sensitivity testing showed that all strains were susceptible to amoxicillin and a single isolates displayed lincospectin or penicillin resistance.

This WGS data and the associated clinical information was integrated into the Epi-Interface (database) and screened systematically. Results demonstrated that Australian and International isolates of *E. rhusiopathiae* are quite distinct. Isolates from 45 farms were associated with suspected vaccine breakdowns of which 29 (64%) were attributable to three MLSTs.

Furthermore, this study identified a bacteriophage, detected in 14% of the studied isolates. Bacteriophages have been identified as potential anti-bacterial agents that may be instrumental in overcoming antimicrobial resistance.

Application to Industry

This innovation study has generated a dynamic resource to improve the understanding of this highly variable pathogen in the Australian pig industry. It has also provided insight into the quantity and quality of meta data that is required nationally for improved management of porcine erysipelas. The Epi-Interface developed in this project will have cumulative commercial value as data is added. The genome sequences generated during this pilot study have stand-alone commercial value for data mining in relation to future diagnostic, vaccine and antibiotic development.

There is growing evidence that environmental data is critical to the understanding of erysipelas. Fortunately, the modular nature of the Epi-Interface allows for the inclusion of new data sets, such as environmental data. Pre-existing data can then be reanalysed in relation to the newly added information.

PROJECT 2A–118: DRINKING WATER QUALITY AND ITS IMPACT ON THE HEALTH AND PERFORMANCE OF PIGS

Project Leader:
Dr Louise Edwards
(Ridley AgriProducts Pty Ltd)

Project Participants:
57 Industry Participants,
Ridley AgriProducts Pty Ltd,
University of Melbourne

Aims and Objectives

This Innovation Project aimed to develop a greater understanding of:

1] The quality and management of drinking water being delivered to pigs on Australian pig farms.

2] The impacts that it may be having on pig performance, health and welfare by specifically targeting the delivery of water-soluble antibiotics in drinking water.

Key Findings

- A survey of 57 industry participants representing 5 different states was successfully conducted. This study generated an understanding of the types of water sources being utilised and current water management practices. Samples of both source and drinking water were collected from all participating piggeries for water quality determination.
- Bore water was found to be the most common water source. On farm water management including cleaning and sanitation practices were found to be variable across farms. Accessibility at the drinker was inconsistent in terms of the type of drinkers, or combinations in use, the number of drinkers per head, their height and their location within the shed, including water flow rates.
- The quality of both the source and drinking water was found to be sub-optimal in one water quality parameter or more. The most common water parameters to exceed the acceptable standard were: pH, hardness, Cl, Na, Fe, Mn and microbiological levels. Typically, microbiological contamination was greater in the shed compared to the source. In most cases, producers did not appear to be routinely testing water quality.
- Despite many farms presenting with sub-optimal water quality only a relatively small number of participants had implemented water treatment systems. In contrast, over 75% of participants administered antibiotics in drinking water via a dosing medication system.
- Preliminary laboratory study findings indicated that the solubility, stability and antibacterial activity of several commercially available veterinary antibiotics appeared to be compromised when prepared in water from different farm water sources of sub-optimal quality. These initial observations warrant further investigation particularly when considering antimicrobial stewardship.

Application to Industry

The study findings suggest that water quality represents a significant challenge to the Australian Pig Industry. Simple steps were identified to assist producers assess their individual water quality challenges. Further research is required to understand the impact of sub-optimal water quality and in turn the most effective water treatment and management practices to ensure that pig performance, health and welfare is optimised. Over 75% of producers were administering antibiotics via drinking water however, preliminary findings from a laboratory study demonstrated that water of sub-optimal quality negatively impacted the solubility and anti-bacterial activity of commercially available antibiotics. The results indicate that good quality water and its management is essential for appropriate antibiotic use and in turn antimicrobial stewardship.

Subprogram 2B: Healthy Robust Pig Genotypes

Subprogram 2B aimed to develop selection strategies to include quantitative and genomic traits and information to increase the disease resilience and robustness of pig genotypes. The definition and physiological consequences of disease tolerance was defined to evaluate the benefits of selection for disease tolerance and selection for disease resistance and disease resilience in pigs. The subprogram involved considerable collaboration with groups across the world.

PROJECT ID	TITLE
2B–101	Quantifying variation in environments within and across herds
2B–102	Development of economic methodology to incorporate robustness in pig breeding programs
2B–103	Selection for disease resilience – Pilot Study
2B–104	Development of practical strategies to consider environmental sensitivity, survival and productivity in pig breeding programs
2B–105	Genetic parameters for health, survival, immune competence, post-weaning growth and disease resilience of pigs
2B–106	Simple tests for immune responsiveness of sires and the association with piglet mortality

Research Summaries for Subprogram 2B

PROJECT 2B–101: QUANTIFYING VARIATION IN ENVIRONMENTS WITHIN AND ACROSS HERDS

Project Leader:
Dr Susanne Hermesch (AGBU, UNE)

Aims and Objectives

Animals vary in their response to differences in the environment. This environmental sensitivity may lead to genotype by environment interactions if genotypes differ in their response to diverse environments. These interactions have implications for breeding programs if animals are selected in one specific environment and progeny are expected to perform well in a wide range of environments.

Specific information about environmental conditions is usually not available on farm. Pigs raised together are exposed to similar overall environmental conditions. Therefore, the quality of an environment may be quantified by the mean performance of a group of pigs raised together.

Performance records from over 265,000 pigs recorded in nine herds over a ten-year period were used for the analyses. Methodology and random regression models were developed to quantify variation in environments within and across herds and to evaluate whether there were any breed by environment interactions or sire by environment interactions.

Key Findings

Variation in environments: Mean performance of contemporary groups varied by about 150 g/day for growth rate and by about 5 mm for backfat across herds and years independent of the model used. A similar spread of mean performance was also found within herds and within years showing that even in these well-managed farms, considerable environmental variation existed between individual groups of pigs.

Breed by environment interactions: Breeds differed in their responsiveness to variation in environmental conditions with Large White being the most environmentally sensitive or least robust breed for growth rate and backfat. This breed was the leanest breed in comparison to Landrace and Duroc supporting the hypothesis that leaner genotypes tend to be less robust and less able to perform consistently across a range of environments.

Sire by environment interactions: Extensive analyses were performed using random regression models to evaluate sire by environment interactions which were found for growth rate but were less apparent for backfat.

Application to Industry

Producers: The unadjusted mean performance of a group of pigs is a simple environmental descriptor that can easily be derived from standard performance records collected on farms to quantify variation in environmental conditions within herds.

Breeders: The methodology developed in this study to quantify sire by environment interactions can be used to obtain estimated breeding values (EBVs) for the intercept and slope of sires. These EBVs should be used to select sires with consistently superior performance across environments. This is a long-term breeding goal. Further, the variation in EBVs for the intercept and slope can be used to select sires whose progeny are best suited for a specific environment. This information should be used by breeders and producers to better match sires to the environments their progeny are likely to encounter.

Researchers: Multiple environmental descriptors were significant for growth rate, highlighting the need to develop methodology that combines multiple environmental factors. Further, it was shown that residual variance was lower in superior environments for growth rate. Therefore, the environmental descriptor may be extended by taking variation between animals within the same environmental into account.

PROJECT 2B–102: DEVELOPMENT OF ECONOMIC METHODOLOGY TO INCORPORATE ROBUSTNESS IN PIG BREEDING PROGRAMS

Project Leaders:
Susanne Hermesch, Cameron Ludemann and Peter Amer

Project Participants:
AGBU and AbacusBio Pty Ltd

Aims and Objectives

Improving robustness is based on improving health and survival of pigs as well as reducing environmental sensitivity and variability in performance. Selection for improved robustness requires economic values for additional traits describing aspects of robustness. Further, new methodology is required to quantify the economic importance of environmental sensitivity and variability in performance of pigs within batches.

Concepts and methodology to quantify economic importance of environmental sensitivity and batch variability were presented in this Project. Further, a user-friendly tool was developed to derive economic values for a wider range of traits including various traits describing survival of piglets, growing pigs and sows.

Key Findings

The economic importance of environmental sensitivity depends on the position of the selection environment relative to the environment of commercial pigs. Less environmental sensitivity is economically advantageous if selection occurs in a superior environment. In contrast, more environmental sensitivity is economically beneficial when selection takes place in an inferior environment. The magnitudes of economic values for environmental sensitivity depend on the difference between selection versus commercial environments as well as non-linearity of profit along the environmental trajectory.

The primary determinant of the economic impact of batch variability was the opportunity cost of delaying termination date of a batch of pigs in order to minimise the number of underweight pigs at termination. The nature of the price penalties applied for underweight carcases was also found to be important, although not as influential as might have been expected. Further refinements to economic values of traits that can influence batch variability will be possible, once this batch variability model has been calibrated using industry data and consultation.

A spreadsheet, called PigEV, has been developed to compute economic values for a wider range of traits including a number of maternal and survival traits that so far have not had economic values derived for them in Australia. The sow component of the model uses equations to define the economic values of number of piglets born alive, piglet survival, age at puberty, sow mature weight and sow longevity. Further, economic values were presented for the genes of the sow affecting growth of the progeny. The finishing model estimates economic values for average daily gain, feed conversion ratio (or daily feed intake) and carcase fat depth at P2. The models above are combined to construct a terminal line and a maternal line index. The terminal line index uses only traits relevant for the growing pig. The maternal line index accounts for the fact that sows contribute to profitability through expression of their own maternal traits and their direct genetic effects on growing pigs as they contribute half of the genes to slaughter pigs.

Application to Industry

The tool PigEV allows users to define breeding objectives in pigs using their own input parameters in regard to cost structures, performance and marketing information. Further this tool can be used to evaluate the economic consequences of alternative management practices. Therefore, it may be used by producers to evaluate the economic feasibility of introducing a new technology.

Methodology was developed to evaluate economic importance of environmental sensitivity and batch variability. This part is more theoretical as new concepts had to be developed. Further information is required from industry to evaluate this new framework for specific industry situations and to identify factors affecting the economic importance of reduced environmental sensitivity and lower batch variability.

Research Summaries for Subprogram 2B continued

PROJECT 2B–103: SELECTION FOR DISEASE RESILIENCE – PILOT STUDY

Project Leader:
Susanne Hermesch[1]

Project Participants:
N. Sales[2], T. McKenna[3], C. R. Parke[3], M. M. Bauer[3]

[1]Animal Genetics and Breeding Unit, University of New England
[2]Elizabeth Macarthur Agricultural Institute
[3]University of Queensland

Aims and Objectives

The aims of this project were:

- To develop procedures to record multiple weight measurements, immune parameters and disease incidence on farm.
- To develop an assay for haptoglobin.
- Identify environmental factors.
- Estimate heritabilities for immune and growth traits.

Key Findings

A data set with 15 growth and 20 immune traits was developed for genetic analyses of disease resilience in pigs. These data were combined with all performance traits available to show that selection for direct and maternal genetic effects will influence growth in a similar pattern. Estimates of weekly batch quantify environmental influences. This random effect accounted for 11 to 59% of phenotypic variation for various growth traits, while heritabilities and common litter effects varied from 0.04 to 0.37 and from 0.02 to 0.33 for these traits. Most immune traits were moderately to highly heritable. There were 14 immune traits with moderate to high heritability estimates ranging from 0.20 to 0.68. Weekly batch accounted for most of the phenotypic variation for immunoglobulins and haptoglobin demonstrating that these measures are good indicators of herd health.

A scoring system for disease incidence was developed which provides an avenue to monitor incidence of specific diseases. The majority of mortalities (68%) occurred shortly after weaning while most treatments (57% of all treatments) were required for grower pigs. These medical interventions were often related to tail biting in this high-health herd.

Disease resilience was defined as a two-dimensional trait which requires information about prevalent infection challenge and performance of pigs when challenged by infection.

Measurements of air quality (temperature, humidity, carbon dioxide and ammonia) were collected in individual pens housing weaner, porker or finisher pigs. Considerable variation was found in the micro-environments of individual pens for these air quality measures.

Application to Industry

Immune traits were recorded shortly after weaning. The moderate to high heritability estimates for these immune traits available early in life prior to selection of pigs offer opportunities for genetic improvement of health status of pigs.

Micro-environments within a shed can be easily monitored with simple and cost-effective air quality measures. A better monitoring system of air quality of individual pens will have positive effects for the health and welfare of pigs.

The scoring system for disease incidence can be used to monitor incidence of various diseases more precisely on farms. Adoption of this scoring system requires appropriate software and training to ensure consistency of scores among operators.

A measurement technique was developed for haptoglobin which is a good indicator of herd health.

Information required to define disease resilience was outlined at an industry workshop. So far, the project has resulted in 5 publications and 2 presentations available to industry.

PROJECT 2B–104: DEVELOPMENT OF PRACTICAL STRATEGIES TO CONSIDER ENVIRONMENTAL SENSITIVITY, SURVIVAL AND PRODUCTIVITY IN PIG BREEDING PROGRAMS

Project Leader:
Susanne Hermesch
(AGBU, UNE)

Project Participants:
Sarita Guy
(University of Sydney),
Hélène Gilbert
(INRA, France)

Aims and Objectives

- Better definition of environments for genetic analyses.
- Development of genetic models for evaluation of genotype by environment interactions.
- Evaluation of selection strategies.
- Fostering adoption of results.

Key Findings

Providing the best environment possible to pigs is the first priority. The methodology developed in this project can be used to describe fluctuations in environmental conditions over time using information readily available on farms. The models can take systematic changes in husbandry practices into account and provide alternative avenues to consider information about multiple traits in an overall environmental index. Information about growth and feed intake was most informative for describing environmental conditions and for estimating genotype by environment interactions.

Variation in estimates of environmental variables based on backfat, muscle depth and feed intake generated economic differences of $17 per pig. Farmers should improve environmental conditions on farms to improve health, welfare and productivity of pigs.

Multiple genetic models were developed for evaluation of genotype by environment interaction. Sire by environment interaction models and multi-trait models provide simple methodology that can be used to evaluate the extent of genotype by environment interaction. This can be

extended to evaluation of response of selection lines, or sire lines using random regression models, and allows appropriate selection of sires so that their progeny are allocated to the environments best suited to them.

The more efficient selection line (line with low residual feed intake) was less sensitive to environmental changes than the less efficient line. This favourable association reveals good opportunities for genetic improvement of both robustness and efficiency.

Sensitivity analyses demonstrated the importance of accurate genetic correlations, in particular for traits with less information and for trait combinations with unfavourable associations. Genetic parameters should be updated regularly in breeding programs.

Post-weaning survival was the most important trait in the breeding objective based on the genetic standard deviations of breeding objective traits. Results indicated that it would take about 12 generations to improve post-weaning survival by one percent because information for this trait is limited at selection. The use of genomic information to boost genetic improvement of post-weaning survival should be explored.

Application to Industry

Genetic improvement of robustness and health remains challenging. The genetic models developed in this study can be applied to alternative traits, and can be adjusted easily for systematic effects on an individual-farm basis. These innovations can be applied in breeding programs that have large data sets, preferably from multiple farms, with appropriate data structure available.

More weight measurements should be collected on farms, including sow mature weight which is an important trait in the breeding objective, because growth is regarded as a health indicator, it was most informative in describing environmental conditions and genotype by environment interactions were found for growth in multiple herds.

PROJECT 2B–105: GENETIC PARAMETERS FOR HEALTH, SURVIVAL, IMMUNE COMPETENCE, POST-WEANING GROWTH AND DISEASE RESILIENCE OF PIGS

Project Leader:
Susanne Hermesch (AGBU, UNE)

Project Participants:
Sarita Z.Y. Guy (University of Sydney), Narelle Sales & Tanya McKenna (NSW DPI), Mark M. Bauer (University of Queensland)

Aims and Objectives

Estimate genetic parameters for traits describing disease resilience for genetic improvement of health of growing pigs.

Key Findings

Immune and haematological traits had moderate to high heritabilities. Further, multiple immune and haematological traits had significant genetic correlations with growth traits. Average growth of a group of pigs was lower for groups of pigs that required more medication. This finding confirms the concept of growth as a health indicator.

A simple score about whether a pig was medicated or not was lowly heritable in this high-health herd which offers new opportunities for genetic improvement of health of pigs. The heritability was not significantly affected by the approach to account for non-medicated pigs which provides extra flexibility for the definition of this trait for genetic evaluations. Medication of pigs has economic and welfare costs. The economic value of medication score is based on the cost of medication and loss in productivity due to the disease incidence.

Disease resilience is a two-dimensional trait which requires definition of environmental challenges. In this regard, it is important to separate other environmental, non-infection stressors from infection challenges. Methodology was developed to obtain finer descriptions of possible infection challenges by removing climatic effects from environmental descriptors using performance data recorded on farms.

An on-farm measure of haemoglobin was genetically the same trait as haemoglobin measured in the laboratory. However, the on-farm measure of haemoglobin had a lower heritability than the laboratory measure due to larger residual variation which indicates measurement errors for the on-farm measure.

Application to Industry

It is recommended to measure white blood cell counts and haemoglobin as well as post-weaning growth in weaner pigs. Haptoglobin and immunoglobulin (Ig) G and IgM may be recorded if cost-effective measurement techniques are available. Recording these traits in weaner pigs at five weeks of age has practical advantages for the application and adoption of these traits. At this age, weaners may also be recorded for juvenile IGF1 which is an early selection criterion for genetic improvement of efficient leant meat growth. Outcomes from this study warrant recording of white blood cell counts, haemoglobin, post-weaning growth and possibly haptoglobin and IgG and IgM in weaner pigs at 35 days in other pig populations that have information about feed intake, juvenile IGF1 or post-weaning survival available.

On farm-measures of immune and haematological traits should be explored if it is not possible to obtain measurements from the laboratory.

Medication records are available on farms and the promising results from this study should be confirmed with further data. Medication score has economic and welfare cost and this trait should be incorporated in breeding objectives of pig breeding programs for genetic improvement of health in growing pigs.

Research Summaries for Subprogram 2B continued

PROJECT 2B–106: SIMPLE TESTS FOR IMMUNE RESPONSIVENESS OF SIRES AND THE ASSOCIATION WITH PIGLET MORTALITY

Project Leader:
Dr Kim Bunter

Project Participants:
Jo-Anne Harper (Rivalea, Australia), Dr Cherie Collins (Rivalea, Australia), Dr Susanne Hermesch (AGBU, UNE) and Dr Brad Hine (CSIRO Agriculture – Productive and Adaptive Livestock Systems)

Aims and Objectives

The aim of this project was to develop a testing procedure to obtain immune competence phenotypes for mature boars, and to subsequently investigate if sire variation in immune competence was reflected by differences in the survival of their offspring (pre- and post-weaning), and/or potentially other performance attributes.

Key Findings

The project developed a commercially practical procedure to obtain immune competence phenotypes for mature boars. Boars were allocated into immune competence groups based on their relative rankings for humoral immunity (antibody production) and cell-mediated immunity (delayed-type hypersensitivity skin test). Immune grouping of boars was significantly ($p=0.004$) associated with estimated breeding values for preweaning survival of piglets. This suggests that variation in immune competence of sires was transmitted to offspring, with impact on survival outcomes for piglets. There was no evidence for antagonistic associations between immune competence grouping of boars and genetic merit for other economically important traits.

Application to Industry

Direct selection for improved health and disease resistance attributes is difficult to achieve for pig breeding companies due to a lack of cost-effective measures, combined with high health status and extensive vaccination schedules of nucleus herds. These aspects limit opportunities to develop selection criteria based on standardised natural disease challenges. One alternative approach for animal breeding applications is to assess immune competence in selection candidates using measureable, heritable phenotypes generated by a model test procedure, for use as indirect selection criteria. These phenotypes must be obtainable in a commercial setting, where restrictions exist on the use of un-registered products to induce measurable immune responses, required to assess immune competence.

In this study, we successfully developed a model test procedure for measuring immune competence phenotypes of commercial boars, and demonstrated that immune competence grouping of these boars was associated with mortality outcomes of their progeny. Immune competence testing using the testing procedure developed here is therefore feasible in the Australian pig industry. Results from similar test procedures applied in other industries have demonstrated reduced incidence and severity of disease(s), as well as cost savings and production benefits for genotypes with high immune responsiveness. We recommend further work in the Australian pig industry to establish the potential gains from immune competence testing in nucleus pigs for health, welfare and production outcomes of their progeny.

Subprogram 2C:
Replacement of Antibiotics with Effective Integrated Health Strategies

This Subprogram aimed to develop alternative strategies to control and/ or reduce the impact of disease on animal health and performance, while reducing reliance on antibiotics. Strategies investigated included vaccines, nutraceuticals and pre and pro-biotics designed to alter the microbial populations in the gastrointestinal tract and/ or reduce the inflammatory responses associated with infection.

PROJECT ID	TITLE
2C–101	Bacteriophage to control *Enterotoxigenic E coli*
2C–102	Strategies to quantitatively measure and reduce the load of Lawsonia in commercial herds
2C–105	Use of plant derived compounds to condition piglet intake at weaning and reduce post-weaning use of therapeutics
2C–106	Bacteriophage-displayed peptides for the control of pathogens in swine
2C–107	Investigation of oral rennin (chymosin) supplementation as a farm level protocol to improve the passive transfer of immunity in neonatal piglets
2C–108	Passive Immunisation for Oedema Disease
2C–109	Reducing sucker mortality through use of an innovative in-feed supplement
2C–110	Dietary manipulation of the pro-inflammatory cascade to minimise impacts on production and health indices in weaner pigs experimentally infected with an enterotoxigenic strain of E. coli
2C–113	Bacteriophage-displayed peptides for the control of pathogens in swine
2C–114	Establishing the links between higher-fibre diets fed to pigs after weaning, microbial diversity and metabolic function in the gastrointestinal tract, and enhanced gut health
2C–115	Establishing the underlying causes of pleurisy to enable the development of effective prevention and treatment measures
2C–116	Live attenuated Actinobacillus pleuropneumoniae vaccine strains
2C–117	Investigating the further use of aerosol disinfection for control of APP15 in a large chronic respiratory disease endemic site
2C–118	Using microencapsulated ingredients to enhance efficacy and improve production efficiency within an integrated health strategy
2C–119	Alternative to vitamin E for the cost-effective maintenance of cellular antioxidant capacity in weaner pigs experimentally infected with enterotoxigenic strain of E. coli
2C–120	Lactoferrin as a new feed additive improves sow milk production and pig production
2C–121	A novel and safe fogging sanitiser for MRSA decolonisation and reduction of Actinobacillus pleuropneumoniae aerosol transmission between pigs
2C–122	Alternatives to antibiotics for diarrhoea control, improved production and maintenance of intestinal health in weaner pigs *(confidential)*
2C–123	Self-assembled peptides as antimicrobial nanomaterials
2C–124	Evaluation of an atypical Brachyspira hyodysenteriae strain as a live vaccine to control swine dysentery *(confidential)*
2C–125	Lauric acid, a potentially new feed additive for the Australian pork industry
2C–126	Utilisation of next generation sequencing for identifying Streptococcus suis clones responsible for recurrent outbreaks and identifying effective S. suis autogenous vaccine candidates
2C–128	Protection from Escherichia coli-associated diseases after weaning in pigs using xenogeneic polyclonal antibodies specific for Escherichia coli fimbriae *(confidential)*

Research Summaries for Subprogram 2C

PROJECT 2C–101: BACTERIOPHAGES TO CONTROL *ENTEROTOXIGENIC E. COLI*

Project Leader:
Emeritus Professor Mary Barton (University of South Australia)

Aims and Objectives

This study was designed to evaluate the efficacy of a bacteriophage (phage) cocktail for the treatment of diarrhoea caused by antibiotic resistant enterotoxigenic *Escherichia coli* (ETEC). ETEC is an important infective agent of neonatal and weaned piglets causing diarrhoea leading to serious morbidity, mortality and economic loss. Phages are viruses specific for bacteria only and can rapidly kill the host by lysis *i.e.* bursting the bacterial cell. ETEC strains from NSW were used in enrichments to isolate and purify lytic phages specific for these pathogenic strains only.

Methodology

The trial was carried out at a commercial herd in NSW. Six litters of piglets were selected at onset of scouring and all received the standard electrolyte treatment via waterer. A cocktail of phages specific for a number of enterotoxigenic *E. coli* (ETEC) strains isolated at the test site was administered orally to the three treatment litters on day 0 @ 8am and 3pm. The remaining litters were controls. No antibiotics were given to either group. Scour scores, rectal swabs and weight were collected days 0, 2 and 6. Swabs were analysed for the presence of ETECs and phages. The *E. coli* isolates were checked for susceptibility to the phages in the cocktail. Environmental swabs were taken days 0, 2 and 6 and tested for the presence of phages.

Key Findings

1] The test site had multiple ETEC strains present.

2] More than one ETEC strain was evident at the test site.

3] Only piglets in one litter carried *E. coli* that were lysed by phages in the cocktail.

4] Clinical results (scour score, behaviour & general appearance) indicate that the phages may have been effective in treating the piglets in this litter.

5] No control group had the same pathogen profile to allow comparison.

6] The efficacy of phage treatment could not be definitively demonstrated without comparison to controls.

7] No significant differences between treatment and controls were noted in ADG & scour score – most litters were heavier & healthier than the litter that responded.

8] The data suggests that phages have potential for treatment of ETEC induced diarrhoea.

9] A trial at a facility with infections due to one or few known & characterised ETEC strains should be carried out.

10] Isolation and characterisation of phages specific for ETEC strains should be ongoing to develop a library of therapeutic phage candidates.

Application to Industry

The findings to date have no commercial relevance and are for research purposes only.

PROJECT 2C–102: STRATEGIES TO QUANTITATIVELY MEASURE AND REDUCE THE LOAD OF LAWSONIA IN COMMERCIAL HERDS

Project Leader:
Dr Alison Collins

Project Participants:
NSW DPI and Rivalea

Aims and Objectives

1] Develop faecal sampling protocols for the reproducible quantification of *Lawsonia* load in commercial herds.

2] Determine the variability in *Lawsonia* load in the absence of significant management changes.

3] Correlate production measures with excretion of *Lawsonia* numbers to identify the critical threshold of *Lawsonia* that leads to production losses over a wide range of management systems.

4] Evaluate ileitis control strategies such as vaccination, improved hygiene and medication in a field trial.

Key Findings

- Monitoring *Lawsonia* numbers by qPCR in pooled faecal samples is a reliable method to identify when herds are suffering from both clinical and sub-clinical ileitis.

- The *Lawsonia* qPCR can be used to monitor the effect of management changes on ileitis control because in the absence of significant management changes, *Lawsonia* numbers do not vary over time and over consecutive batches of pigs.
- *Lawsonia* numbers in faeces correlate negatively with ADG and feed intake, ie. higher *Lawsonia* numbers are detected in pigs with more severe production losses.
- The critical threshold of *Lawsonia* that causes production losses in pigs on commercial farms was determined. ADG was reduced from 847 to 707g/day when excretion of *Lawsonia* increased from 10^7 to 10^8 *L.intracellularis*. However, production losses do occur in sub-clinically affected pigs when they shed more than 10^6 *Lawsonia*.
- Vaccination against ileitis and disinfection of pens proved to be more effective at controlling ileitis and led to improved ADG and feed intake compared with olaquindox medication.

Application to Industry

- New antemortem test to quantify the severity of ileitis in real time and determine if scouring or poor growth are caused by significant numbers of *Lawsonia* bacteria.
- Pooled faecal samples collected from herds can be used to monitor *Lawsonia* load and ileitis control in the absence of significant management changes.
- Pooled faecal samples and serology can be used to monitor the impact of management changes on ileitis control, immunity and especially the removal of antibiotics.
- A new tool to evaluate alternative ileitis control strategies on farm, including dietary modifications (essential oils, organic acids, prebiotics and probiotics), hygiene and other treatments concurrent with vaccination.

PROJECT 2C–105: USE OF PLANT DERIVED COMPOUNDS TO CONDITION PIGLET INTAKE AT WEANING AND REDUCE POST-WEANING USE OF THERAPEUTICS

Project Leader:
Dr Eugeni Roura
and Ms Rousset Palou

Project Participants:
University of Queensland,
Sun Pork Farms

Aims and Objectives

The objectives were:

1] To screen essential oils (EO) for their antimicrobial activity and ability to be transferred from the sow's diet to placental fluids, colostrum and milk.

2] To develop a product, which would improve piglet performance and health and potentially link post weaning feed intake with sow milk influenced via selected EOs.

Key Findings

Across all compounds, the transference to milk was higher than to placental fluids. The results have implications when considering the potential pre-natal conditioning effect of the different EOs. In addition, the research uncovered a powerful synergistic effect between EO and sow milk against ETEC but milder against lactobacillus. It was concluded that the transmission of dietary volatile compounds to sow milk might reduce the pathogenic bacterial burden in suckling piglets.

A semi commercial study using selected EOs fed the sow immediately before parturition and during lactation showed a marked and significant effect of treating the sow diet on piglet post weaning growth performance. The responses were independent of whether the weaner diet contained the same EOs or not.

Application to Industry

The project identified an innovative intervention in sow feeds based on a unique combination of EOs based on high transfer to maternal fluids and high antimicrobial activity. As a result the dietary intervention with the selected EOs improved the performance of post-weaned piglets and showed a high potential to improve their health (thus with a potential to reduce antibiotics) and welfare.

PROJECT 2C–106: BACTERIOPHAGE-DISPLAYED PEPTIDES FOR THE CONTROL OF PATHOGENS IN SWINE

Project Leader:
Dr Sharon Bishop-Hurley

Project Participants:
CSIRO Animal,
Food and Health Sciences

Aims and Objectives

To use phage display to isolate phage display peptides that bind to the receptors/epitopes on the cell surface of *E. coli* 0157 using direct selection and subtraction procedures.

At the end of the selections the phage displayed peptides were tested for potential antimicrobial activity using functional-based assays. The binding of the phage peptides to *E. coli* 0157 using dot-blot assays were also tested.

Key Findings

The key findings were:

1] As proof-of-concept, phage peptides that completely inhibited the growth of *E. coli* 0157 were isolated.

2] The sub-libraries generated in this project are a resource to be used for further isolation of antimicrobial phage peptides.

3] It was demonstrated that, using dot-blots, the phage peptides bound to cell surface receptors on *E. coli*. This could be used as a strategy for the isolation and development of vaccine candidates.

Application to Industry

This project produced/proved the proof of concept. The therapeutic developed from this project would be used on-farm by pork producers for control of pathogenic *E. coli* strains.

Research Summaries for Subprogram 2C continued

PROJECT 2C–107: INVESTIGATION OF THE IMPACT OF ORAL RENNET SUPPLEMENTATION ON THE SERUM GLOBULIN CONCENTRATION IN NEONATAL PIGLETS

Project Leader:
Dr Peter Cockcroft

Project Participants:
Caitlin J Jenvey,
Dr Will van Wettere
and Michael P Reichel
(University of Adelaide)

Aims and Objectives

To evaluate the benefits of oral rennet supplementation administered during the early post-partum period in a population of piglets derived from induced and non-induced primiparous (PP) and multiparous (MP) sows.

Key Findings

- Oral rennet supplementation of piglets derived from either induced or non-induced MP or PP sows did not influence serum globulin concentrations in piglets at 48–72 hours post-farrowing, piglet bodyweight (at weaning), growth rate or mortality rate.
- Dam parity (MP sows compared to PP sows), combined with a reduction in litter size, had a significant and positive influence on piglet bodyweight at birth and at weaning, serum globulin concentrations, growth rate and survivability.

Application to Industry

This study indicates that piglets supplemented with rennet are unlikely to result in increased serum immunoglobulin with the dose rates used in this study. This study provides additional evidence regarding the association of small piglets with lower serum immunoglobulin levels, higher mortality and lower growth rates. Piglet survivability rates may be improved by increased monitoring of PP sows.

PROJECT 2C–108: PASSIVE IMMUNISATION FOR OEDEMA DISEASE

Project Leader:
Andrew Morris

Project Participants:
Chris Richards & Associates,
University of Queensland

Aims and Objectives

To isolate Veratoxin from *E.coli*, to demonstrate the toxicity of the Verotoxin and demonstrate the Verotoxin can be denatured.

This was step one of an overriding strategy to develop a toxoid vaccine that can be used to produce anti-Vera toxic antibody that can be injected into pigs to prevent Oedema Disease.

Key Findings

Further techniques are required to produce higher quantities of toxin and/or more specific purification methods.

Genetically modified organisms were used in previous trials for better results.

Application to Industry

This attempt was not successful as the time and finance ran out prior to the technical problems being solved. However the production of an anti-Vero toxic antibody product for prevention of oedema disease is still a worthy goal.

PROJECT 2C–109: REDUCING SUCKER MORTALITY THROUGH A NOVEL IN FEED ACID DURING LATE GESTATION AND LACTATION

Project Leader:
Dr Cherie Collins

Project Participants:
S Beer[1], C Clark[2],
J Doubleday[2], P McKenzie[3],
M. van der Heijden[4]

[1]Rivalea (Australia) Pty Ltd, Corowa NSW 2646; [2]AusPac Ingredients Pty Ltd, Tamworth NSW 2340 [3]McSwine, VIC; [4]Selko Feed Additives, Tilburg, The Netherlands

Aims and Objectives

The aim of this project was to facilitate the development and assessment of a new in feed additive containing high levels of ß1-4 mannobiose in combination with a mix of synergistic organic acids. The new product (Fysal Fit4 Plus) was assessed for its ability to modify faecal microbial populations in the sow as well as its ability to reduce pre-weaning mortality.

A total of 688 primiparous sows (Large White x Landrace) were allocated to one of four dietary treatments at 14 weeks of gestation: A: Control (no acidifiers); B: 6 kg/t Fysal (blend of short chain fatty acids); C: 4 kg/t Fysal Fit4 (blend of short and medium chain fatty acids plus low dose ß1-4 mannobiose); D: 4 kg/t Fysal

Fit4 Plus (blend of short and medium chain fatty acids plus a high dose ß1-4 mannobiose). The treatment acids were included in the gestation diet from 14 weeks of gestation and then the lactation diet post farrowing. Measures of litter growth performance and mortality were obtained along with measurements of sow feed intake during lactation. Faecal samples were obtained from a subset of sows at 9 weeks of gestation, 15 weeks of gestation and again during the second week of lactation for microbiological enumeration for *Clostridium perfringens,* Coliforms*, E. coli, Lactobacillus* species and *Enterobacteriaceae*.

Key Findings

Pre-weaning mortality in litters from the control sows was 16.9 % compared to 16.2 %, 18.7 % and 15.7% for the Fysal, Fysal Fit 4 and Fysal Fit4 Plus treatment groups (x^2= 5.50, P=0.14). Piglet growth rates and litter weaning weights were similar amongst treatments, whilst sow feed intake was modestly improved when sows were offered the Fysal Fit4 Plus diets. Microbial analysis of the faecal samples collected at mid-lactation showed distinct reductions in *E. coli* counts when sows had been offered the acidified gestation and lactation diets, with the counts numerically lowest in the Fysal Fit4 Plus treatment group. The outcomes from this study confirm that the inclusion of Fysal Fit4 plus in late gestation and lactation diets can reduce key faecal microbial populations in the sow. Numerical improvements in pre-weaning mortality were observed, however further investigation with a larger number of mixed parity sows would be warranted to confirm and quantify any benefits to producers.

Application to Industry

The outcomes from this investigation suggest that the dietary inclusion of Fysal Fit4 Plus during late gestation and throughout lactation can reduce the population of gram negative bacteria. The results from this initial screening study show promise and warrant further investigation on a larger population of mixed parity, commercially housed sows.

PROJECT 2C–110: DIETARY MANIPULATION OF THE PRO-INFLAMMATORY CASCADE TO MINIMISE IMPACTS ON PRODUCTION AND HEALTH INDICES IN WEANER PIGS EXPERIMENTALLY INFECTED WITH AN ENTEROTOXIGENIC STRAIN OF E. COLI

Project Leader:
Dr Jae Kim (DAFWA)

Project Participants:
Dr Bruce Mullan (DAFWA), Professor John Pluske (Murdoch University), Mr Robert Hewitt and Professor Robert van Barneveld (Sun Pork Farms)

Aims and Objectives

To investigate whether dietary supplementation of vitamin E and a low dose acetylsalicylic acid (aspirin), a cyclooxygenase inhibitor, will synergistically reduce production of PGE_2 and hence reduce the infection responses in weaner pigs.

Key Findings

Experiment 1 (*E. coli* infection study) demonstrated that a low dose of aspirin supplementation (125 ppm) significantly improved amino acid utilisation efficiency (as assessed by circulating plasma urea level) and tended to decrease PGE_2 production in the liver without affecting small intestinal histology and tight junction protein mRNA expression in the jejunal epithelium, while vitamin E supplementation greater than 100 IU significantly decreased both the acute reduction of plasma vitamin E content after weaning and plasma haptoglobin content after *E. coli* infection. Supplementation of aspirin improved average daily gain and feed conversion efficiency after weaning.

Experiment 2 (Commercial validation study) showed that either a low dose of aspirin or supplementation of 250 IU vitamin E in diets significantly improved feed conversion ratio until week 3 post-weaning.

However, overall, there was no synergistic effect of the combined supplementation of aspirin and vitamin E on performance, intestinal barrier function and immune function of weaned pigs.

It is concluded that aspirin and vitamin E supplementation independently improved feed utilisation efficiency but no synergistic effect was observed on performance, intestinal barrier function and immune function of weaned pigs. Based on tissue measurements, it is conceivable that aspirin supplementation improved performance of weaned pigs by reducing inflammation-associated amino acid waste through modulation of PGE_2 biosynthesis, while vitamin E supplementation improved performance of pigs by reducing the severity of infection through an eicosanoid-independent pathway such as oxidative tissue damage due to its antioxidant property.

Application to Industry

As a result of the outcomes in this study the following recommendations have been made:

1] A low dose of aspirin (125 ppm), pending any successful application to the APVMA in the future, is an effective way to modulate biosynthesis of immunosuppressive molecule PGE_2 and hence to reduce the immunity-associated amino acid waste.

2] Supplementation of greater than 100 IU vitamin E is recommended to decrease the severity of *E. coli*-associated infection through an eicosanoid-independent pathway such as oxidative tissue damage due to its antioxidant property around weaning.

Research Summaries for Subprogram 2C continued

PROJECT 2C–113: BACTERIOPHAGE-DISPLAYED PEPTIDES FOR THE CONTROL OF PATHOGENS IN SWINE

Project Leader:
Dr Sharon Bishop-Hurley

Project Participant:
CSIRO

Aims and Objectives

Enterotoxigenic *Escherichia coli* (ETEC) is a pathogen of swine, causing diarrhoea in young piglets. Currently, ETEC is controlled by the therapeutic use of antibiotics; however, new approaches are needed due to the increasing resistance of *E. coli* to commonly used antibiotics. Controlling ETEC through the use of novel, pathogen-specific antimicrobials would deliver benefits in terms of reducing the current levels of antibiotics used by the Australian pork industry. Receptors/ epitopes on the cell surface of ETEC play a significant role in its colonisation and persistence within the swine herd and thus represent a significant target for disruption by inhibitory antagonistic molecules.

The overall aim of this project was to discover phage displayed peptides that could potentially be used as a replacement for antibiotics for the control of ETEC in young piglets.

Key Findings

A novel subtractive phage display approach was used to select for peptides binding to the cell surface of *E. coli*. In total, 47 phage displayed peptides were isolated, representing 43 unique sequences.

The key findings were:

1] A group of five phage displayed peptides were able to bind to the majority of swine *E. coli* isolates (46 of 49 isolates tested).

2] Two custom synthesised peptides (EBT3/2 and 2OBT3/1) were antimicrobial towards swine *E. coli* isolates with one (2OBT3/1) being bactericidal.

3] Two custom synthesised peptides (p2ECT2/4 and pJCT3/2) were found to self-assemble to form a gel-like material.

Application to Industry

This project has resulted in peptides with potential industry applications.

1] Two unique peptides were isolated (EBT3/2 and 2OBT3/1) that could potentially represent a new class of antimicrobials for controlling swine *E. coli* in young piglets. This would deliver benefits in terms of reducing the current level of antibiotics used by the Australian pork industry as well as peptides that may have the potential to be antimicrobial towards antibiotic-resistant *E. coli* isolates.

2] Two peptides (p2ECT2/4 and pJCT3/2) have the potential to be further developed into an antimicrobial gel with potential applications for treating wounds or coating medical devices when combined with an antimicrobial peptide.

3] Five phage displayed peptides have the potential to be further developed into a rapid diagnostic device, specific for swine *E. coli*.

PROJECT 2C–114: ESTABLISHING THE LINKS BETWEEN HIGH FIBRE DIETS FED TO PIGS AFTER WEANING, MICROBIAL DIVERSITY AND GUT HEALTH

Project Leader:
Professor John Pluske (Murdoch University)

Project Participants:
Dr Sasha Jenkins (University of WA), Dr Jae Kim (DAFWA), Dr Alison Collins and B Bowring (NSW DPI)

Aims and Objectives

The overall aim of this project was to use state-of-the art sequencing approaches coupled with advanced statistical methodologies to determine the impact of different fibre diets and ETEC infection on microbial diversity and function in the GIT of post weaned piglets. This will provide a better knowledge base and understanding of GIT microbial ecology including whether certain bacterial genera are more closely related to improved GIT health than others. This information is needed so that targeted post-weaning management can be developed and adopted to improve diet formulation, antibiotic use efficiency, and GIT health and function. Additionally, identification of key taxa associated with the suppression of pathogens could be used in the innovative design of probiotic, prebiotic, diet formulations and feeding strategies that favourably select for the beneficial GIT microbiota. Such innovations will increase the productivity and profitability that ultimately enhances the competitiveness of the Australian pork industry.

Key Findings

1] Identification of feeding practices that favourably select for the GIT microbiota which promote growth and likely GIT health.

2] Increased understanding of the role(s) of butyrate and (or) lactate producing bacteria in maintaining GIT structure and function.

3] Identification of taxa associated with improved growth performance, GIT health and reduced *E. coli* shedding after infection with ETEC. As indicators of GIT health, these taxa could be used in either the development of microbial diagnostic tools for routine monitoring on farms or probiotics for treating scouring and other GIT diseases and conditions.

4] Profiling microbial community diversity using next generation sequencing provides a cost-effective, rapid and sensitive readout of microbial responses to feed additives and disease.

Application to Industry

Retrieved sequences from identified beneficial taxa (Methanobacteriaceae, Bacteroidetes, Lachnospiraceae, Ruminococcaceae, Dethiosulfovibrionaceae, Desulfovibrionaceae, Oxalobacteraceae, Christensenellaceae, Lactobacillales and Bifidobacteriaceae) can now be exploited in the design of:

a] High quality specific oligonucleotide primers and probes for more sophisticated diagnostics

and screening exercises in commercial laboratories.

b] The development of low-cost microbial diagnostic tools for the routine on-farm monitoring of pathogenic and beneficial GIT bacteria.

Further culturing and selective isolation of these microbes could be useful in the development of probiotics for treating scouring and other gastrointestinal diseases. Ultimately, this would improve the health and welfare of piglets and lead to early detection of disease and rapid intervention during outbreaks. Adoption of better post-weaning management options, feeding strategies (improved diet formulations, probiotics/prebiotics, medicines) and low-cost monitoring tools that lead to an improved GIT microbiota stability will result in increased productivity, reduced reliance on medications and improved animal welfare.

PROJECT 2C–115: ESTABLISHING THE UNDERLYING CAUSES OF PLEURISY TO ENABLE THE DEVELOPMENT OF EFFECTIVE PREVENTION AND TREATMENT MEASURES

Project Leader:
Dr Conny Turni
(University of Queensland)

Project Participants:
Dr Peter McKenzie
(Rivalea Australia),
Dr Pat Blackall,
Dr Tamsin Barnes,
A/Professor Joanne Meers,
Dr Kit Parke and
Dr John Al-Alawneh
(all University of Queensland)

Aims and Objectives

Pleurisy has a huge impact not only at the production stage but also at the abattoir with time delays at slaughter, increased waste and compromised carcass weights. In recent years an increase of pleurisy at the abattoir has been noted in Australia and overseas. As there is no knowledge of the species of bacteria and the viruses involved in pleurisy at the abattoir in Australia this study was undertaken to close this knowledge gap.

Key Findings

A total of 46 Queensland farms were involved in the project. The most prevalent bacteria were *Mycoplasma hyopneumoniae* and *Streptococcus suis*, found on 34 and 38 farms, respectively. Twenty nine farms had positive results for PCV2. Other bacteria were *Actinobacillus pleuropneumoniae* (7 farms), *Haemophilus parasuis* (1 farm), *Pasteurella multocida* (24 farms), *Actinobacillus* species (29 farms), *Mycoplasma hyorhinis* (4 farms), *Streptococcus porcinus* (1 farm), *Streptococcus minor* (1 farm), *Mycoplasma flocculare* (9 farms) and Bisgaaard Taxon 10 (1 farm). Most of the farms had more than on species of bacteria.

Most of the bacteria were in low numbers, however, some species such as *S. suis*, *P. multocida* and *A. pleuropneumoniae*, were in high numbers being indicative that they are potentially the causative agents of the pleurisy. There was a higher risk of a positive result for *M. hyopneumoniae* if the batch had a pleurisy score greater than 10 percent.

The high percentage of farms positive for *S. suis* type 1 at the abattoir was surprising. Even though pigs are carriers of *S. suis*, outbreaks of disease associated with *S. suis* are normally between three to 12 weeks of age. Hence, the common presence of *S. suis* type 1 in the lungs of pigs with pleurisy at about 22 weeks of age is surprising.

Chronic pleurisy is supposed to be attributed to a variety of pathogens; hence it is not surprising that no single infectious cause for all instances of pleurisy could be found. Of the organisms found only four are regarded as important primary respiratory pathogens – *M. hyponeumoniae*, *A. pleuropneumoniae*, *H. parasuis* and PCV2. Of these primary pathogens, only *M. hyopneumoniae* and PCV2 were found in a large percent of the farms. The finding of these two pathogens in a high percent of farms is a concern as these pathogens act synergistically with other pathogens causing severe respiratory disease. As most of the other bacteria found in this study are regarded as secondary pathogens, indicates that the finding of *M. hyopneumoniae* and PCV2 in a large percentage of farms is an important finding. This suggests that the protocols in place for the control of *M. hyopneumoniae* and PCV2 should be revisited.

Application to Industry

Pleurisy has a tremendous impact on the cost of the production and the cost of the slaughter process. Studies in England have shown that the herds with pleurisy prevalence running at >10% at slaughter experienced post-weaning mortalities rates around 3.3% higher than unaffected units. These studies have predicted that each 1% increase in pleurisy prevalence relates to a reduction of 1.55–2.5 g/day average lifetime weight gain at batch level or in other terms, each 1% increase in pleurisy prevalence at batch level resulted in 0.07 kg decrease in average slaughter dead weight per pig. In other words pleurisy is costing the producer a lot of money. It is vital to understand the bacterial and viral species that are associated with chronic pleurisy. For the farmer the knowledge gained on the bacterial species involved in pleurisy, as well as the antimicrobial sensitivity, is useful and will ensure targeted investigations and the development of appropriate effective treatment and prevention programs.

The main points from this research are the importance of the two primary pathogen species in pigs with pleurisy, PCV2 and *M. hyopneumoniae*. As well, the importance of the secondary pathogens, which have so far been ignored in the fight against respiratory disease, was shown.

The outcomes achieved are the knowledge of the bacterial and viral species that are found in pigs with pleurisy at the abattoir and this knowledge will give farmers the opportunity to investigate if these species are controlled on their farm and implement control measures.

Research Summaries for Subprogram 2C continued

PROJECT 2C–116: LIVE ATTENUATED ACTINOBACILLUS PLEUROPNEUMONIAE VACCINE STRAINS

Project Leader:
Dr Conny Turni
(University of Queensland)

Project Participants:
Aileen Vanderfeen
(ACE Laboratories),
Pat Blackall
(University of Queensland),
Peter McKenzie
(Rivalea Australia)

Aims and Objectives

The aims of this project were:

- Develop an attenuation method for *Actinobacillus pleuropneumoniae* that is accepted by the APVMA.
- Attenuate relevant strains of *A. pleuropneumoniae.*
- Do a safety trial (pen trial).
- Do a homologous trial with one of the attenuated strains.

Key Findings

The trials in this project showed that the live streptomycin-dependent vaccine is safe in naïve pigs and does not cause lesions or symptoms of disease despite being a live vaccine. The efficacy trial outcome definitely pointed to a weight loss of pigs not being vaccinated in the days past challenge. Even though not statistically significant, the vaccine did seem to improve the clinical signs with both vaccinated groups being much more alert and did not appear "tucked in", a condition which suggests poor food consumption. The only animals to show no clinical signs were vaccinated animals. While some vaccinated animals did show clinical signs, the signs were displayed much later in the seven-day period after challenge than the control group. The control group had a higher lung score for three out of four pigs and from these pigs; *A. pleuropneumoniae* could be retrieved, while the vaccinated groups had, two out of seven pigs each with lesions.

Overall, it seemed that the vaccine displayed efficacy and the farm management thought it worthwhile to test the vaccine on non-naïve pigs. This vaccine could have significant benefits. Fewer doses than the current vaccines is required and can be worked in with the production schedule. *A. pleuropneumoniae* is one of the most expensive diseases as it affects pigs in the grow-out-phase of production – with many current vaccines failing to prevent deaths at this stage. If death at this stage of the production can be avoided with vaccination with a live streptomycin-dependent vaccine, there would be large cost savings.

Application to Industry

The vaccine is currently in the process of being registered. This would mean that the vaccine will be for use in Australia and ACE laboratories are able to produce the vaccine. Further research is being conducted to look at transport options and storage options of the vaccine.

The toxin profiling determined that there are no extra toxins in the strains from different farms and states in the serovars used for vaccine strains. This is a reassuring result, as it means all the vaccine strains produced in this project will cover the range of field isolates in all four serovars. Hence, the vaccine could be used as a single strain vaccine when a single serovar is known to be the cause or as a multi-valent vaccine when more than one serovar is present as a challenge.

PROJECT 2C–117: INVESTIGATING THE FURTHER USE OF AEROSOL DISINFECTION FOR CONTROL OF APP15 IN A LARGE CHRONIC RESPIRATORY DISEASE ENDEMIC SITE

Project Leader:
Dr Peter McKenzie

Project Participants:
Rivalea Australia

Aims and Objectives

The objectives were to investigate the effects of fogging weaner and grower-finisher sheds on sites where APP is endemic on animal health, survival and performance. Fogged weaner rooms were subject to aerosol disinfection from entry to 9 weeks of age. This fogging was carried out using pedestal misting fans with timers set to fog for 30 mins every two hours. Three fans per room were utilised during the initial 2.5 weeks post weaning and four fans per room thereafter. The disinfectant used was Viragard at a rate of 1:1000

The grower-finisher facility was aerosol disinfected with a fixed Scolexia high-pressure system. The disinfectant used was once again Viragard at a rate of 1:1000, with the system running at a pressure of 750 psi and 10-micron nozzels. The misting system ran for 10 mins every 2 hours outside of staff working hours, and then on a restricted schedule during the day.

Key Findings

The outcomes from this project showed promise for mitigating the negative effects of APP in conventional progeny accommodation. Fogging during the weaner period resulted in a delay in the first APP outbreak after movement to the grower/finisher accommodation. The pigs fogged as weaners had one less water medication and a trend for fewer mortalities during the initial 5 weeks in the grower-finisher period.

Application to Industry

The technology has promise as a means of reducing the impact of respiratory disease and specifically APP on pig health and performance.

PROJECT 2C–118: USING MICROENCAPSULATED INGREDIENTS TO ENHANCE EFFICACY AND IMPROVE PRODUCTION EFFICIENCY WITHIN AN INTEGRATED HEALTH STRATEGY

Project Leader:
Mr Rob Hewitt

Project Participants:
Sun Pork Farms
and Jefo Australia

Aims and Objectives

The objective was to investigate two microencapsulated materials namely ZnO (ZincoPlus) and essential oils (Porcinat) on the performance and health of pigs weaned at 21 days of age (5.8 kg).

The study was of 28 days duration and included the following treatments:

- A negative control diet – containing no ZnO.
- A positive control diet containing 3,000 ppm ZnO.
- The same basal diet containing 1.0 kg/tonne ZincoPlus.
- Basal diet containing 1.0kg/tonne Porcinat.
- Basal diet containing 1 kg/tonne of each microencapsulated material.

Key Findings

Pigs offered the diets containing 3,000 ppm ZnO or 1.0kg/tonne ZincoPlus exhibited the best performance in the first week after weaning.

In the second and third weeks after weaning the 3,0000 ppm ZnO diet supported the highest feed intake and growth rate and these pigs were heavier at 2,3 and 4 weeks than those on all other treatments except for those on the diet containing both microencapsulated materials.

During weeks 3 and 4 pigs offered the diet containing Porcinat exhibited the best feed efficiency.

In week 4 the feed efficiency of pigs on the Porcinat treatment was 7.0% ($P<0.05$) and 9.3% better ($P<0.05$) than that of pigs on the negative control diet and diet containing 3,000 ppm ZnO respectively.

Application to Industry

The results support the use of two diets during the first four weeks after weaning and show that in the first two weeks that the protected ZnO product could replace 3,000 ppm ZnO with minimal adverse effect on growth performance and substantially reduce Zn excretion.

The protected essential oil material (Porcinat) would appear to have considerable potential as a performance enhancer in second stage weaner diets.

Both materials are produced by Jefo and distributed in Australia by Jefo Australia Contact – Wayne Bradshaw (wbradshaw@jefo.com).

PROJECT 2C–119: ALTERNATIVES TO VITAMIN E FOR THE COST-EFFECTIVE MANAGEMENT OF CELLULAR ANTIOXIDANT CAPACITY IN WEANER PIGS EXPERIMENTALLY INFECTED WITH ENTERTOXIGENIC STRAIN OF *E. COLI*

Project Leaders:
Dr Jae Cheol Kim and
Dr Diana Turpin (DAFWA)

Project Participant:
Professor John Pluske
(Murdoch University)

Aims and Objectives

The aim of this project was to explore the effectiveness of alternative feed additives that can partially replace vitamin E in diets for weaner pigs while maintaining cellular antioxidant and anti-inflammatory capacities. A standard commercial inclusion level of vitamin E (70IU/kg) in the diet was compared with high inclusion levels (200IU/kg) and partial inclusion levels (50IU/kg). The partial inclusion level diets included either quercetin (a plant flavonoid) (30mg/kg) or a combination of copper (175ppm) and vitamin C (500mg/kg). An in-feed antibiotic (amoxicillin) was also included as another treatment given the pork industry has traditionally used in-feed antibiotics to ameliorate pathogen infection and mitigate the post-weaning malaise. Five out of the six treatment groups were challenged with a strain of enterotoxigenic *E. coli* (ETEC) one week after weaning.

It was hypothesised that:

1] Supplementation of 200 IU vitamin E in *E. coli*-infected pigs would improve antioxidant and anti-inflammatory capacity compared with pigs in the infection control group, in addition to improvements in post-weaning performance.

2] Partial replacement of vitamin E with quercetin (replacing 150 IU vitamin E with 30 mg quercetin) would have comparable antioxidant and anti-inflammatory capacities to the infected pigs supplemented with 200 IU vitamin E.

3] Partial replacement of vitamin E (150 IU) with 175-ppm copper and 500 mg vitamin C would have

Research Summaries for Subprogram 2C continued

comparable antioxidant and anti-inflammatory capacities to the infected pigs supplemented with 200 IU vitamin E.

Key Findings

The ETEC challenge induced an inflammatory and oxidative stress response, however, supplementation of 200IU vitamin E did not result in an improvement in performance, antioxidant or anti-inflammatory capacities compared with control pigs. Further to this, partial replacement of vitamin E with quercetin or a combination of copper and Vitamin C (replacing 150 IU of vitamin E) also had no effect on the immune response under the project's experimental conditions. The pigs fed an in-feed antibiotic along with the negative controls (pigs not infected with ETEC and fed a control diet) had the lowest growth of *E. coli* and pigs given the in-feed antibiotic had the lowest levels of plasma haptoglobin and C-reactive protein highlighting the anti-inflammatory effect of antibiotics.

Application to Industry

The lack of improvement in weaner performance and inflammatory response in weaner pigs supplemented with higher levels of vitamin E was unexpected based on previous reports. The inclusion of alternative antioxidant ingredients as partial replacements of vitamin E (quercetin and a combination of copper and vitamin C) also showed no extra benefit with regard to post-weaning performance and anti-inflammatory and anti-oxidant responses. The disparity between the current results and what has previously been reported could be explained by differences in experimental conditions, the selected inclusion levels for the diet supplements or the level of pathological state reached by the pigs subjected to the ETEC challenge. Nevertheless, these results do highlight the effectiveness of in-feed antibiotics at treating ETEC and the importance of the anti-inflammatory effect of antibiotics. Exploring the anti-inflammatory effect of antibiotics may assist swine industries worldwide as they explore alternatives to antibiotics.

PROJECT 2C–120: LACTOFERRIN AS A NEW FEED ADDITIVE IMPROVES SOW MILK PRODUCTION AND PIG PRODUCTION

Project Leader:
Professor Bing Wang (CSU)

Project Participants:
Susie Kracht, Marefa Jahan, Yen Ho, Peter Wynn (people joined part of feeding work: Elliot Hathway, Ziaul Haque, Birendra Bhattachatyya, Allan Gunn) (all CSU)

Aims and Objectives

To demonstrate lactoferrin as a new feed additive improves sow milk production and pig production.

Key Findings

Maternal nutritional intervention of lactoferrin in gilts during gestation and lactation:

1] Tended to improve piglet body weight gain and therefore helps to optimise piglet growth.

2] Significantly increased gilt milk production.

3] Tended to increase litter size (through lower incidences of stillborn and mummified piglets) and piglet weaning weight.

4] Significantly increased the concentration of Iga in gilt serum and Iga in piglet serum ($p<0.05$).

Application to Industry

1] To file a patent application on maternal lactoferrin supplementation improves milk production.

2] To support a large sample size trial to confirm and refine the pilot study findings.

3] To develop lactoferrin rich feeds for pregnant and lactating sows and gilts.

PROJECT 2C–121: A NOVEL AND SAFE FOGGING SANITISER FOR MRSA DECOLONISATION AND REDUCTION OF *ACTINOBACILLUS PLEUROPNEUMONIAE* AEROSOL TRANSMISSION BETWEEN PIGS

Project Leader:
Professor Darren Trott (University of Adelaide)

Project Participants:
McSWINE, Ecas4 Australia, University of South Australia, Charles Sturt University, Barry Lloyd Pty Ltd, Murdoch University

Aims and Objectives

1] To test an electrochemically activated solution – an anolyte generated by electrolysing a dilute sodium chloride solution in a four-chamber electrolytic cell by Ecas4 Australia, as a cost effective air decontamination process when administered as a dry fog. That is safe, non-toxic and does not contribute to antimicrobial resistance, with high efficiency broad-spectrum disinfection capability and specific killing action against *Actinobacillus pleuropneumoniae* (*A. pp*) to prevent transmission between pigs.

2] To determine whether the disinfection protocol proof-of-concept pilot can be up scaled to a workable model that could be regularly implemented in a farm setting for control and prevention of transmission of aerosolised bacterial pathogens including *A. pp.*

Objective: To develop a compound protocol that is safe, with no residual effect, has broad-spectrum bacterial activity and does not co-select for antimicrobial resistance.

Key Findings

SYBR green-dye-based real-time quantitative PCR was optimised to detect and quantify low levels of total bacteria and *A. pp* targeting the 16S rRNA and apxIVA genes, respectively, using previously published primer sets. Using the Coriolis air sampler device, the sample collection protocol to capture *A. pp.* from the farm environment was optimised and very low levels of *A. pp* (5.1×10^5 genomic units) were detected in both weaner rooms and grower/finisher sheds at a continuous flow farm with endemic pleuropneumonia. Furthermore, a novel step was introduced into the qPCR by treating samples with 50-µm propidium monoazide to quantify differentially live and dead bacterial cells in the sample, an ideal rapid quantitative assay for determining the effectiveness of aerosol disinfection methods.

A proof-of-concept trial was conducted in a recently vacated weaner room at the same continuous flow piggery using a protocol adapted from a previous Pork CRC project (2C–117). A 1-log10 reduction in total bacterial count was observed after the first hour of fogging, a 2-log10 reduction was observed after fogging for two and three hours, while 99.9% (3.7-log10) of total bacteria were effectively inactivated by Ecas4 dry fogging after five hours of discontinuous treatment.

Application to Industry

The outcomes of this innovative project will support application of Ecas4 technology specifically in disinfection of respiratory pathogens in the farm environment and fulfil the aims of Sub-Program 2C: Replacement of Antibiotics with Effective Integrated Health Strategies. An added bonus of this project is that we have optimised a diagnostic assay to detect low levels of *A. pp* (as little as 0.1 pg of DNA) from the air of the farm environment and a novel qPCR method to discern live bacteria from dead bacteria, addressing another Pork CRC Sub Program 2A: Novel Disease Diagnostics.

Research Summaries for Subprogram 2C continued

PROJECT 2C–123: SELF-ASSEMBLED PEPTIDES AS ANTIMICROBIAL NANOMATERIALS

Project Leader:
Sharon Bishop-Hurley (CSIRO)

Aims and Objectives

Self-assembling peptides have become an important class of hydrogels attracting considerable research and commercial interest due to their broad range of biomedical and biotechnological applications. In a previously funded Pork CRC project, we discovered two peptides (JCT3/2 and 2ECT2/4) that spontaneously self-assembled to form a hydrogel in bacterial growth media. Because these two peptides were newly discovered, our aims were to:

1] Characterise the hydrogels.

2] Assess the potential of developing these hydrogels into a coating for controlling *Escherichia coli* biofilms on surfaces.

Key Findings

JCT3/2 and 2ECT2/4 were novel peptides that formed highly stable hydrogels in physiological solutions and salts (JCT3/2). In particular they:

1] Formed SS-Gels in a range of biological media including media used for tissue culture, physiological saline (JCT3/2) and in blood.

2] JCT3/2 and 2ECT2/4 exhibited shear-thinning (viscous flow under stress) and self-healing (recovery after shear-thinning) properties and could be needle injected.

3] We incorporated two molecules into the JCT3/2 hydrogel and monitored their rates of release into solution under physiological conditions. We found that the released cationic antimicrobial peptides retained their anti-bacterial activity towards *E. coli* O157, preventing its growth on surfaces over a 48 hr period.

4] An attachment of a cationic antimicrobial peptide to the JCT3/2 peptide imparted 'inherent' antimicrobial activity to the self-supporting hydrogel, preventing the colonisation of *E. coli* on its surface.

Application to Industry

JCT3/2 in particular was found to have a wide range of applications to the food, medical and animal industries. Some examples of applications include:

1] JCT3/2 has the potential to be further developed into an antimicrobial gel with potential applications to wound control or as an antimicrobial coating preventing the colonisation of bacteria onto surfaces.

2] JCT3/2 could potentially be used to encapsulate select antimicrobial peptides for their oral delivery to the gastrointestinal tract of pigs and other animals.

3] Because of its injectable qualities, JCT3/2 and 2ECT2/4 could potentially be used as an adjuvant for the delivery of live attenuated vaccine strains, improving their performance.

PROJECT 2C–125: LAURIC ACID, A POTENTIALLY NEW FEED ADDITIVE FOR THE AUSTRALIAN PORK INDUSTRY

Project Leader:
Professor John Pluske

Project Participants:
Dr Diana Turpin and Dr Sam Abraham (Murdoch University), Dr Alison Collins (NSW DPI), Professor Frank Dunshea (University of Melbourne)

Aims and Objectives

Three experiments were conducted in this project. The overall aim of these studies was to examine the effects of feeding increasing levels of lauric acid (LA; Experiment 1) or monolaurin (MLA, the monoglyceride formed from LA; Experiment II), relative to LA, on aspects of production (especially feed intake), meat quality and faecal bacteriological indices in late finishing pigs. Experiment III examined whether LA (20 g/kg) could have positive health outcomes in finishing pigs infected with *Lawsonia intracellularis*.

Key Findings

The following key findings can be drawn:

- **Experiment I:** increasing levels of LA (0–25 g/kg) fed in the first 7 days after offer showed maximum average daily gain occurring at 11.8 g/kg (~1.2%), and for average daily feed intake from d 7-28, the maximum occurred at 13.4 g/kg (~1.3%). Pigs fed diets LA 15 and LA 20 had

a lower FCR during days 7–14 of the experiment. Feeding increasing levels of LA linearly decreased, albeit non-significantly, the proportion of *Streptococcaceae* in the faeces of pigs.

- **Experiment II:** at day 26, after 14 days of feeding, there was a significant Linear effect of feeding MLA on final BW. However, there was no difference (contrast; $p>0.05$) in BW between feeding LA or the average of the MLA treatments. Modelling the MLA inclusion rate demonstrated that for (a) ADG d 12–26, maximum ADG (1.12 kg/day) occurred at an inclusion rate of MLA of 20 g/kg (2%), and (b) FCR d 12–26, minimum FCR occurred also at an inclusion rate of 20 g/kg (2.4).
- **Experiment III:** pigs fed 20 g/kg (2%) LA under conditions of a *Lawsonia intracellularis* challenge showed a strong statistical trend to shed lower *Lawsonia intracellularis* numbers than control pigs at days 7 and 14 post-infection, and there was a significant interaction between treatment and time with higher *Lawsonia intracellularis* numbers excreted by Control pigs at day 7 post-infection. Furthermore, feeding LA significantly reduced the variation in voluntary feed intake between pigs early in infection and also the feed: gain ratio in mid infection.

Application to Industry

Lauric acid or monolaurin used in late-finishing pigs shows potential application for use in late-finishing Improvac-treated males or female pigs for production gains and (or) amelioration of a *Lawsonia intracellularis* challenge. Further studies should be conducted in commercial facilities to confirm or refute these findings.

PROJECT 2C–126: UTILISATION OF NEXT GENERATION SEQUENCING FOR IDENTIFYING *STREPTOCOCCUS SUIS* CLONES RESPONSIBLE FOR RECURRENT OUTBREAKS AND IDENTIFYING EFFECTIVE *S. SUIS* AUTOGENOUS VACCINE CANDIDATES

Project Leader:
Dr Sam Abraham
(Murdoch University)

Project Participants:
Dr. Mark O'Dea, Ms Tanya Laird, Mr Alec Truswell, Mrs Rebecca Abraham
(all Murdoch University)

Aims and Objectives

1] To identify the dominant clones of *S. suis* that colonise healthy pigs and cause clinical disease.

2] To determine whether tonsillar sampling of live pigs is a feasible diagnostic method for rapid identification of circulating *S. suis* clones.

Key Findings

- Tonsil swabs did not yield any isolates with genomic signatures indicative of pathogenic *S. suis* circulating in Australia, however a large number of *S. suis*-like organisms were isolated.
- Genomic comparison indicated that *S. suis* isolated from tonsils were genetically distinct from pathogenic *S. suis* causing invasive clinical infections in Australian pigs, and likely to be a separate subspecies.
- Whole genome sequencing of 148 clinical isolates from diseased pigs demonstrated serotypes 2, 3 and 1/2 are the predominant serotypes in Australia.
- Phylogenetic analysis found ST1, ST25 and ST27 to be the main MLSTs identified in pathogenic clones.
- Australian isolates belonging to ST1 (serotypes 1/2, 2 and 14) had a significantly higher number of potential virulence genes than other pathogenic clones.
- It is recommended that a trivalent, autogenous vaccine targeting the above serotypes and MLSTs be developed to control highly pathogenic *S. suis* infections.

Application to Industry

This project highlighted the major pathogenic *S. suis* strains found in Australian pigs, providing knowledge that will be fundamental to development of vaccines to combat disease. This study has demonstrated the advantage in the use of robotics methods over conventional methods for *S. suis* recovery; and that isolation of *S. suis* from tonsils of pigs is ineffective for isolating pathogenic strains.

Additionally, this project refined and streamlined methods for processing and analysing *S. suis* with a whole genome sequencing pipeline developed in association with other studies, that will be highly useful for future genomic studies on Australian *S. suis* as well as for rapid typing in outbreaks.

PROGRAM

3 Healthy Pork Consumption

The research developed quality assessment and assurance tools for pork for domestic and overseas markets and an understanding of key Asian markets and how the High Integrity Australian Pork concept fits within these markets. The inherent properties of pork that contribute to improved consumer health when pork is consumed as part of a total diet was also investigated.

SUBPROGRAM 3A	**OPTIMAL PORK QUALITY FOR MULTIPLE MARKETS**
SUBPROGRAM 3B	**INHERENT PROPERTIES OF AUSTRALIAN PORK TO ENHANCE CONSUMER HEALTH**
SUBPROGRAM 3C	**MARKET DEMAND FOR HIGH INTEGRITY AUSTRALIAN PORK**

Subprogram 3A: Optimal Pork Quality for Multiple Markets

The objective of the subprogram was to improve the eating quality of Australian pork by developing predictive models across supply chains, developing an on-line test for boar taint and technologies to assess carcasses and primal cuts for different markets and the traceability of pork to underpin the integrity of Australian pork.

PROJECT ID	TITLE
3A–101	Body composition and physiological changes associated with immunocastration at two different live weights
3A–102	Information Management and Data analysis Tool for Physi-Trace *(confidential)*
3A–103	Effects of various eating quality pathway factors on pork quality
3A–104	On-line lean meat yield measurements of pig carcasses *(confidential)*
3A–105	Verification of eating quality pathways for delivering consistently high quality pork
3A–106	Determining the effect of ageing period, cut type, cooking method and internal temperature on sensory and technological quality of pork
3B–101	Determining the variability in the eating quality of Australian fresh pork
3A–108	Information Management and Data analysis Tool for Physi-Trace – Stage 2 *(confidential)*
3A–109	Validation of pork eating quality pathways in three commercial supply chains
3A–110	The influence of rate and length of dietary vitamin E supplementation on the shelf life and retail display quality of Australian Pork
3A–111 & 3A–113	Establishing the critical control points for improving fresh pork meat quality: ■ A post mortem metabolism investigation; ■ Impact of enzymatic oxidative/glycolytic potential
3A–112	Benchmarking meat quality parameters of high integrity pork between conventional and deep-litter housing systems
3A–114	Development of a Near-infrared spectroscopy (NIRS) online test for boar taint *(confidential)*
3A–116	Development of a generic pork eating quality model and interactive tool
3A–117	Development of Cytochrome b5 (CYB5A) as a selection marker for boar taint *(confidential)*
3A–118	Investigation of Tenderness and Water Holding Capacity of Aged Pork Loins in Two Packaging Systems
3A–119	On line lean meat yield measurement of pig carcases – commercial validation *(confidential)*
3A–120	Validation of a rapid test for boar taint *(confidential)*

Research Summaries for Subprogram 3A

PROJECT 3A–101: BODY COMPOSITION AND PHYSIOLOGICAL CHANGES ASSOCIATED WITH IMMUNISATION OF PIGS AGAINST GONADOTROPHIN RELEASING FACTOR (GNRF) AT TWO DIFFERENT LIVE WEIGHTS

Project Leader:
Karen Moore

Project Participants:
DAFWA,
University of Melbourne

Aims and Objectives

The aim of this project was to identify and compare the physiological, nutritional and pork quality changes that occur over 28 days following the second injection of the immunocastration vaccine, Improvac®, in light and heavy weight pigs.

Key Findings

- When pigs are immunised at a light weight (50 kg) and/or on a restricted diet they have a reduced propensity to deposit fat, however the restriction in feed intake adversely affects growth rate and carcass weight.
- The majority of fat deposition for males immunised at heavy live weights (80 kg) occurs from Day 14 to 28 after the second vaccination and is associated with reduced lean deposition and increased feed intake.
- The increased fat deposition associated with immunisation against GnRF at heavy LWs results in an increase in back fat but has no impact on IM fat.
- Gender did not influence objective or eating quality in this study. However, fail rate for quality grade (20.7% IM vs 29.8% EM) and re-purchase intention (26.7% IM vs 38.7% EM) were significantly lower for pork from immunised males compared to entire males across all treatment combinations.
- Androstenone and skatole levels measured in belly fat were significantly higher for entire males than immunised males. Androstenone was also higher in entire males slaughtered at heavy weights than at lighter weights.
- For skatole 18.7% of light entire males and 31% of heavy entire males exceeded the sensory threshold. One heavy immunised male also exceeded the sensory threshold for skatole.
- For androstenone 13.4% of heavy entire males exceeded the sensory threshold (>1.0 ug/g). No immunised males exceeded the threshold.
- The results show that boar taint remains a threat to eating quality even in entire males slaughtered at very light weights.

Application to Industry

- Immunisation against GnRF can successfully reduce the boar taint compounds androstenone and skatole and the fail rates of pork for eating quality and re-purchase intention compared to entire males. However, the problem of increased back fat and therefore carcass payment penalties remain.
- Strategies need to be developed to limit the increase in back fat and decrease in lean deposition of immunised males at heavier live weights. Potential strategies include feeding the appropriate lysine level, using pST for 2 weeks only and suppressing voluntary feed intake.

PROJECT 3A–103: EFFECTS OF VARIOUS EATING QUALITY PATHWAY FACTORS ON PORK QUALITY

Project Leader:
Professor Frank Dunshea (University of Melbourne)

Project Participants:
Rivalea Australia,
Australian Pork Limited

Aims and Objectives

Outcomes of this study are being used to develop a non-prescriptive eating quality system for pork. This system, once implemented, will allow industry to improve consumer perceptions of pork as a quality meat and lead to a process of continuous improvement in pork eating quality.

Previous research has determined and documented the importance of a number of pre- and post-slaughter management factors on pork eating quality, but this information has not been integrated into an eating quality system for pork. Also, few studies have reported effects of pathway interactions on pork eating quality, with the majority of data only available for the loin muscle. The objective of this study was to determine the influence and size of these factors, and their interactions, to improve pork consistency and reducing the fail rate of pork to less than 10%.

This study involved 60 (Large White x Landrace, PrimeGro™ Genetics) pigs of three sex groups (entire male, female and surgical castrates) with 20 pigs per sex. Three primal cuts (loin, silverside and shoulder) from both sides of the carcase and three cooking methods (roast and stir fry (all primals) and grilling as steaks (loin only)) were evaluated by untrained consumers who consumed pork at least monthly. Each cut was either aged for 2 or 7d post-slaughter and cooked to either a 70 or 75°C endpoint temperature. This design of this study was a 3x2x2x7 factorial. Objective quality assessments conducted included pH, colour, drip loss, cook loss, shear force, intramuscular fat content. By way of magnitude, over 3360 samples were assessed at over 60 consumer sessions.

Key Findings

Overall liking of pork was influenced, in order of importance, by flavour, tenderness, juiciness and aroma.

Juiciness, flavour, overall liking, quality grade and intramuscular fat content were influenced by sex of the pig, with lower scores obtained for pork from entire males than surgical castrates, with females intermediate. Fail rate (% of evaluations rated as unacceptable (1) or below average (2) for quality grade was higher for pork from entire males than from females and surgical castrates. The main effects of ageing period and cooking temperature did not result in significant improvements in sensory quality. However, across the seven cut x cooking method combinations, loin steaks and

Research Summaries for Subprogram 3A continued

silverside roasts obtained the lowest scores for tenderness, juiciness, flavour, overall liking, quality grade and re-purchase intention and had higher fail rates for quality grade. Pork from the shoulder (blade and chuck tender) was more preferred than those from the loin and silverside. Fail rates of stir fried pork were lower than for roasts, for all three primals evaluated.

Positive effects of cooking to an endpoint temperature of 70°C were found for stir fry for tenderness, juiciness and overall liking, whilst steaks cooked to 70°C were also juicier and obtained higher scores for flavour, overall liking, quality grade and re-purchase intention than those cooked to 75°C.

This study is the most comprehensive sensory analysis ever conducted by the Australian pork industry.

Application to Industry

The results are some of the first to explore the effects of animal, cooking and cut factors on the eating quality of Australian pork judged by consumers. They have implications across the supply chain.

PROJECT 3A–105: VERIFICATION OF EATING QUALITY PATHWAYS TO PRODUCE CONSISTENTLY HIGH QUALITY PORK

Project Leader:
Professor Frank Dunshea

Project Participants:
University of Melbourne, Australian Pork Limited, SARDI, DAFWA, CHM Alliance, Swickers Kingaroy Bacon Factory

Aims and Objectives

Improving the positioning of Australian pork through differentiation is required for the development of new export and domestic market opportunities, particularly with the increasing threat of fresh pork imports into Australia. The approach taken in this project was to undertake a simulation study involving Australian pigs, using feed ingredients typically used in US and Danish diets and slaughtering animals at heavier average liveweights than Australian pigs and comparing pork and eating quality attributes with that of typical Australian pork. The hypothesis of this study was that the effect of increased age at slaughter would result in increased intramuscular fat of pork and together with ageing of pork for 28 d, rather than 7d, will reduce the fail rate of pork to less than 10%.

Loin and silversides were prepared into steaks and roasts, respectively, with ageing treatment of 7 or 28 d post-slaughter allocated within muscle. Steaks were cooked to achieve an endpoint temperature of 70°C and roasts were cooked to a 75°C internal temperature and evaluated by a consumer panel.

Key Findings

- Dietary treatment/age at slaughter did not influence sensory attributes of pork. This suggests that relatively small differences in pork sensory quality due to slaughter weight/dietary treatment do not necessarily discount the inclusion of heavier carcases in an eating quality system for Australian pork.
- Extended ageing for 28 d did not result in additional improvements in pork sensory quality compared with ageing for 7 d for both the loin and silverside.
- The overall fail rate (quality grade score) of pork loin steaks was 11.5% – almost meeting the target cut off of <10%. In contrast, the fail rate of the silverside was 22.6% for quality grade score.
- Further research to reduce the fail rate of the silverside primal to less than 10% is required.
- Intramuscular fat levels were very low in the loin muscle, averaging 0.47±0.31% and 2.03±1.23% for the silverside.
- Overall liking of pork was influenced, in order, by flavour, juiciness and tenderness.

Application to Industry

Outcomes of this study are being used to develop a non-prescriptive eating quality system for pork. This system, once implemented, will allow industry to improve consumer perceptions of pork as a quality meat and lead to a process of continuous improvement in pork eating quality.

PROJECT 3A–106: DETERMINING THE EFFECT OF AGEING PERIOD, CUT TYPE, COOKING METHOD AND INTERNAL TEMPERATURE ON SENSORY AND TECHNOLOGICAL QUALITY OF PORK

Project Leader:
Professor Frank Dunshea

Project Participants:
University of Melbourne, Australian Pork Limited, Rivalea (Australia) Pty Ltd., SARDI

Aims and Objectives

To determine the effect of ageing period, cut type, cooking method and final internal temperature on eating quality attributes of pork from entire male and immunocastrated males.

Key Findings

This study was of a similar experimental design to 3A–103 (in which ageing period, cut type, cooking method and endpoint temperature was investigated), except that immunocastrated and entire males were used. This study was conducted to fill knowledge gaps for immunocastrated males and aimed to determine the influence and size of these factors, and their interactions, on pork eating quality.

The key findings from this study include:

- Although intramuscular fat levels were higher in all muscles from immunocastrated males compared with entire males, no effect of gender on eating quality was found in this study.
- Fail rate for quality grade and re-purchase intention was lower for pork from immunocastrated males than entire males (17.8 vs. 15.7%, respectively) across all treatment combinations.

- Cooking effects had a major impact on eating quality – cooking pork steaks to 75°C reduced juiciness and overall liking scores compared to cooking to an endpoint temperature of 70°C.
- Shoulder cuts were more preferred than those from the loin and silverside. Fail rates of shoulder roast and stir fry (5.6 and 5.3%, respectively) met the target of < 10% compared with the cuts from the loin and silverside. Fail rates were higher for silverside roasts (26.9%), loin steak (25%) and silverside stir fry (21.9%) followed by loin roast (19.1%) and loin stir fry (13.4%).

Cooking education is recommended, focused on retailers and consumers to provide information on cooking practices to optimise performance of different pork cuts. The application of outcomes arising from this study will need to be validated across different supply chains and further modifications made to pathway interventions implemented by these supply chains in order to deliver pork of consistently high quality to their customers. This will be the focus of further Pork CRC research in 2013/14.

Application to Industry

Outcomes of this study are being used in the development of a non-prescriptive eating quality system for pork focussed on reducing the variability in pork quality. It is anticipated that, once implemented, this system will allow industry to improve consumer perceptions of pork as a quality meat and lead to a process of continuous improvement in pork eating quality.

PROJECT 3B–101: DETERMINING THE VARIABILITY IN EATING QUALITY OF AUSTRALIAN FRESH PORK

Project Leader:
Dr Cameron Jose (DAFWA)

Project Participants:
Megan Trezona (DAFWA),
Darryl D'Souza (APL),
Karen McNaughton (SARDI)

Aims and Objectives

To quantify and redefine the inconsistencies in eating quality occurring in fresh Australian pork. The association of pH of pork in relation to consumer acceptance was investigated in the loins of female and male pigs across two supply chains.

Key Findings

- Of all the samples tested, 21% of loin steaks were considered to fail in eating quality, while consumers would not purchase 29% of samples based on the eating quality experience. On the other hand, 38% of samples were graded as either 'above average' or 'excellent' for quality grade.
- Consumers preferred loin steaks with a higher pHu, favoring samples that were towards the higher end of the pH range. This increased linearly across the range of pHu sampled. The largest effect of pHu was observed for tenderness in female carcases, a 22% improvement in tenderness scores across the range.
- Consumers discriminated against samples with poor objective meat quality measurements. In particular shear force influenced quality grade and re-purchase intention the most, with consumers favoring samples with lower shear force. Shear force correlated highly with tenderness, thus highlighting the importance of tenderness in consumer acceptance.
- Objective measures, shear force, drip loss, cook loss and L value (darkness) were all influenced positively by pHu and pH24. The fact that pH24 correlated with these measures reinforces the importance of the rate of pH decline on meat quality.
- Glycogen concentration at slaughter correlated strongly with pHu, however lactate concentration did not. This suggests that glycogen concentration at slaughter is a driver of pHu and pH decline and could be manipulated nutritionally pre-slaughter.
- Drip loss percentage was different between supply chains. This may be a result of differences in processing factors influencing early post mortem decline or different rates of chilling.
- The pHu and rate of pH decline are likely to be the biggest drivers of meat quality variations. Optimising muscle fibre types to favour less stored glycogen is likely to be an effective way to decrease variations in pH and meat quality when coupled with technologies during processing.

Application to Industry

The application of strategies to manage the variability in pH and pH declines need to be applied across all sectors of the supply chain. This issue may be genetics related and investigation of fibre types across genotypes would seem warranted. Managing pH declines through the addition of technologies along the slaughter floor and in chillers will likely aid in minimising variation and improving meat quality. Such strategies need further investigation.

PROJECT 3A–109: VALIDATION OF PORK EATING QUALITY PATHWAYS IN THREE COMMERCIAL SUPPLY CHAINS

Project Leader:
Professor Frank Dunshea

Project Participants:
University of Melbourne,
CHM Alliance, Rivalea Australia,
Craig Mostyn Group,
Australian Pork Limited

Aims and Objectives

To investigate the effects of gender (females and immunocastrated males) and four processing interventions (ageing period, electrical stimulation, hanging method and moisture infusion) on different pork cuts (loin steak, loin stir fry, loin roast, silverside roast and silverside stir fry) across three supply chains to improve eating quality consistency and reduce the fail rate of pork to less than 10%.

Key Findings

Eating quality of pork from immunocastrated males was comparable to females across all three supply chains involved. Fail rates (determined by the percentage of consumers who rated pork as either unacceptable (1) or below

Research Summaries for Subprogram 3A continued

average (2) on a 1–5 scale) were reduced by electrical stimulation, aitchbone hanging as well as moisture infusion, but not ageing period. Ageing of pork for either 7 or 14 days post-slaughter neither markedly improved eating quality attributes nor lowered fail rates compared with pork aged for 2 days. Further understanding of factors influencing the ageing potential of pork are required to provide the Australian pork industry with the ability to implement ageing as a key intervention to improve eating quality consistency.

Moisture infusion was effective in reducing the fail rate of pork, particularly loin stir fry, however, its effect across all cuts and across supply chains was not consistent. Aitchbone hanging reduced the fail rate of loin stir fry to 9% compared with a fail rate of 21% for this cut from Achilles hung carcases. Across all three supply chains, fail rates of <10% were also achieved for moisture infused loin stir fry and loin roast.

Application to Industry

Eating quality of pork from females and immunocastrated males was comparable, highlighting that immunocastrated males can be successfully included in any pathway system to improve pork eating quality consistency.

The eating quality of Australian pork can also be improved by implementing processing interventions, including electrical stimulation, moisture infusion and hanging method, but the effects of these were shown to vary between different cuts and supply chains. Further work is needed to understand why extended ageing, for up to 14 days post-slaughter, did not improve eating quality or reduce fail rates of different pork cuts.

Overall, the response to different processing interventions imposed to improve pork eating quality consistency varied between supply chains and between cuts. Any system introduced to improve pork eating quality will therefore need to be non-prescriptive and flexible to allow individual supply chains to adopt different interventions to deliver high quality pork to their customers.

PROJECT 3A–110: THE INFLUENCE OF RATE OF DIETARY VITAMIN E SUPPLEMENTATION ON THE SHELF LIFE AND RETAIL DISPLAY QUALITY OF AUSTRALIAN PORK

Project Leader:
Dr Cameron Jose (Murdoch University)

Project Participants:
Megan Trezona, Gerrard Smith, Bruce Mullan and Jae Kim (DAFWA), Amy Suckling (Craig Mostyn group)

Aims and Objectives

To investigate the impact of increasing levels of muscle vitamin E and extended storage time on several measures of shelf life in pork *M.longissimus dorsi*.

The experimental hypothesis – that Vitamin E will stabilise the shelf life of pork under extended storage periods (14 and 28 days), thus allowing lengthened storage periods.

Key Findings

Increased muscle vitamin E concentrations improved the shelf life of pork loin as measured by TBARS, but in the non-stored product only. Storage past 14 days resulted in a non-significant trend of improved TBARS concentrations with increased vitamin E concentrations. Although this trend was non-significant, adding vitamin E through supplementation seemed to keep the product from reaching the TBARS spoilage threshold even in the long aged product after 6 days of retail display.

Increasing levels of intramuscular fat in the muscle resulted in a large increase in the development of TBARS in the long stored product only and thus resulted in a shorter shelf life and reaching the spoilage threshold for TBARS after 4 days of display (28 day stored) at the high end of the intramuscular fat range.

There was an aging benefit to improving tenderness (37% decrease in shear force) from 0 to 14 days. This is an improvement from recent pork CRC reports. Further investigation is warranted.

Application to Industry

It is suggested that vitamin E improves shelf life under a threshold mechanism, as to where a level must be reached and no further benefit is observed. In the current experiment muscle vitamin E concentrations were relatively high even in the lowest supplementation level, thus it is suggested that the lack of impact of vitamin E in the long stored product was due to the presence of sufficient vitamin E concentrations. Vitamin E did not seem to improve colour measurements and as a result, it is suggested that colour measurements are not a beneficial measurement for the shelf life of pork.

However, the impact of IMF, which at increased concentrations has eating quality benefits, is an important issue for the pork industry, especially considering the size of the effect and that the level of IMF in this experiment was low. Thus if the industry is to increase intramuscular fat to improve eating quality and consistency more investigation is required between the interactions of muscle vitamin E and intramuscular fat during long stored pork product.

PROJECTS 3A–111 & 3A–113: ESTABLISHING THE CRITICAL CONTROL POINTS FOR IMPROVING FRESH PORK MEAT QUALITY and A POST MORTEM METABOLISM INVESTIGATION AND THE IMPACT OF ENZYMATIC GLYCOLYTIC/ OXIDATIVE POTENTIAL

Project Leader:
Cameron Jose

Project Participants:
Murdoch University, DAFWA

Aims and Objectives

This project aimed to randomly select commercial entire male carcasses that represent the Australian retail product, to test the following hypothesis:

1] Low ultimate pH is a result of increased glycolytic and decreased oxidative potential in entire male pigs.

2] Fast post-mortem (PM) metabolism rates, as

measured by the production of lactate and pH decline, will result in pork that does not benefit from aging.

The intention of investigating these hypothesis was to identify a number of points along the supply chain which could be used to control or manipulate the quality of pork meat. Furthermore, this project aimed to identify the rates of PSE pork while discussing the use of a quality grade to decrease variation in Australian Pork.

Key Findings

- Two meat quality defects were identified in a modern Australian herd; "Acid meat" (32.8% of carcasses) and "PSE-Like" (16% of carcasses).
- "Acid meat" (low ultimate pH of below 5.4) had lower water holding capacity, protein solubility and was paler in colour.
- "PSE-Like" carcasses expressed fast early metabolism and resulted in no improvement in tenderness once aged.
- Oxidative/glycolytic potential did not predict "acid meat" or "PSE-Like" carcasses.
- "Acid meat" was a result of high glycogen levels at slaughter.
- "PSE-Like" conditions were the result of elevated temperature shortly after slaughter, indicating enhanced metabolism and likely caused by increased stress or stress susceptibility.

Application to Industry

This work illustrates two possible metabolic defects that result in poor meat quality and that the occurrence is very regular (43.9% of 198 carcasses sampled). Since "acid meat" is due to excessive glycogen storage and is a result of a highly glycolytic genotype associated with good efficiency and growth rate, the only real means of control would be to change the genotype, or find a balance between eating quality and efficiency. However, if these carcasses could be identified by routine pH measures then the industry could make informed choices to maintain market integrity and decrease the risk of a poor eating experience. This would involve downgrading or value adding to the product.

The current study has identified that PSE like conditions occur in the modern supply chain, however it is not known if this is a genetic effect (such as the Halothane gene) or simply by increased stress prior to slaughter. Carcasses that present PSE-like conditions would have a greater core temperature shortly after slaughter and a technology would need to be developed to identify these carcasses. Furthermore, PSE-Like carcasses that had a high pH would likely hold moisture infusion and could be value added, while the remainder would need to be downgraded due to the lack of tenderness development.

PROJECT 3A–112: IDENTIFYING PRE- AND POST-SLAUGHTER FACTORS THAT IMPACT FINAL MEAT QUALITY IN HEAVY AND LIGHT CARCASSES REARED IN CONVENTIONAL AND DEEP LITTER FARM SYSTEMS

Project Leader:
Dr Robert Smits
(Rivalea Australia)

Project Participants:
Amy Lealiifano
(Rivalea Australia),
Professor Frank Dunshea
(University of Melbourne),
Dr Darryl D'Souza
(SunPork Farms)

Aims and Objectives

The project aim was to establish a benchmark dataset that compares the multiple pre-slaughter factors of housing (conventional vs deep-litter housed), carcass weight (light (66 kg HSCW) supermarket carcasses through to heavy carcasses (84 kg HSCW), and sex (females vs immunocastrates) within the same genotype, nutritional regimen, slaughter day and post-slaughter conditions.

Research Summaries for Subprogram 3A continued

Key Findings

Housing differences between pigs reared on deep litter housing compared to conventional housed pigs on slatted flooring had the biggest impact on carcass and meat quality. Carcasses from Deep litter housing were 1 mm fatter within each weight cohort and sex group when slaughtered at the same age. In terms of boned meat quality 24 h after slaughter, meat cuts from Deep litter carcasses were more tender (lower shear force), were darker in the loin but paler in the rump and silverside, and redder and more yellow in all three cuts. On the downside, meat from Deep litter carcasses had a higher drip loss.

Weight was also a significant contributor to carcass and meat quality. The heavier the carcass within Housing and Sex cohort, the slower the pH decline and rate of carcass chill. For objective meat quality measures, Weight was inversely related to shear force, so as carcass weight increased, tenderness increased.

Sex (Castrate by Improvac® vs female) had no effect on carcass quality measures within 24 h post slaughter. However, meat cuts from Castrates had a lower drip loss and were less red in colour. There was a tendency ($P<0.06$) for Castrates to have a higher shear force value (less tender) than Females.

Application to Industry

Overall, there were several interactions between the different pre-slaughter factors (Housing, Weight and Sex) on objective carcass and meat quality, and this may be exploited by supply chain managers to select which type of carcasses delivers the "best" overall meat quality outcome. Based on our results, Housing was a significant variable relating to shear force and carcass pH decline, which are major factors related to consumer preference of quality determined by Channon *et al.* (2016). Finally the use of the loin as an indicator muscle for overall meat quality is unreliable and that other meat cuts should be included in objective meat quality testing.

PROJECT 3A–116: DEVELOPMENT OF A GENERIC PORK EATING QUALITY MODEL AND INTERACTIVE TOOL

Project Leader:
Jessica Jolley

Project Participants:
Richard Jarrett and Andreas Kiermeier (SARDI), Heather Channon (APL), Frank Dunshea (University of Melbourne)

Aims and Objectives

The aim of this project was to utilise all relevant Pork CRC data to develop an eating quality predictive model for Australian fresh pork, based on an overall quality score, as part of a non-prescriptive eating quality system.

Key Findings

- A total of 3,564 muscle samples from 626 pigs and 14,208 individual consumer responses were collated for analysis and included four different muscles, loin, silverside, chuck tender and bolar blade by three different cooking methods.
- From the multinomial regression of quality grade results against the recorded sensory attributes of aroma, tenderness, juiciness, flavour and overall liking, a model for the composite pork quality score (PQS) was developed.

  PQS = 0.82*Overall Liking + 0.14*Flavour + 0.07*Tenderness + 0.02*Juiciness – 0.05*Aroma

- The PQS was classified into four quality grade categories: unsatisfactory / below average, average, above average and excellent with the cut-off values of ≤35 (unsatisfactory/below average), 36–65 (average), 66-87 (above average) and ≥88 (excellent).
- 67.2% of the samples were correctly allocated when compared to the opinion score originally given by the consumer.
- The additive terms in the eating quality model were gender, ageing period, cut type x cooking method, endpoint temperature, moisture infusion, electrical stimulation, hanging method and ultimate pH. Significant interactions were found between endpoint temperature and gender, ageing period and cut type x cooking method.
- The key additive factors shown to have the largest influence on the PQS were moisture infusion (with larger effects of moisture infusion identified for loin roast and loin stir fry, compared with the other five evaluated cuts), hanging method and electrical stimulation

(where the effect change was highest for roasts compared to the other cuts).

- The predicted values from the model for the range of samples tested in the various studies ranged from 46.2 to 78.2, indicating that all samples would have been graded as either average (category 3; 36–65) or above average (category 4; 66–87).
- From the predictive model, an interactive spreadsheet tool was developed which predicts the PQSs for 70°C and 75°C, based on the input parameters of gender, ageing period, cut, cooking method, electrical stimulation, moisture infusion, ultimate pH and hanging method.

Application to Industry

This project has enabled the key outcomes arising from the complex multi-factorial studies conducted with Pork CRC support to be modelled and more simply communicated. An interactive spreadsheet tool has also been developed from which the effect of different pathway factors can be estimated.

This project has delivered a solid framework for an eating quality predictive model that needs to continue to be built on to ensure the model is and remains reliable for different cut types x cooking methods and when different combinations of factors are used. The recommendation for more samples will assist in strengthening the estimates of the model and investigating combinations of factors that may result in increasing the quality scores for pork cuts and further assist processors in producing high quality and consistent pork. Areas for potential future work include other pathway parameters such as retail ready packaging and alternative cooking methods or combinations of factors that were only in small studies (such as electrical stimulation and moisture infusion).

PROJECT 3A–118: INVESTIGATION OF TENDERNESS AND WATER HOLDING CAPACITY OF AGED PORK LOINS IN TWO PACKAGING SYSTEMS

Project Leader:
Minh Ha
(University of Melbourne)

Project Participants:
Robyn Warner
and Frank Dunshea
(University of Melbourne)

Aims and Objectives

Investigate the effect of high oxygen modified atmosphere packaging (hiOxMAP) and vacuum packaging (VAC) on objective measurement of tenderness and water holding capacity of pork. In addition, a combination of both VAC and hiOxMAP was also trialled.

Key Findings

- Testing of oxygen concentration in pork packaging from various Victorian Woolworth and Cole's supermarkets revealed hiOxMAP is still the most popular packaging method for Australian pork.
- HiOxMAP had a negative impact on overall colour, shear force, texture and water holding capacity of Australian pork loins compared to VAC.
- The negative influence of hiOxMAP correlated with increased lipid and protein oxidation which is well known to affect colour, texture and juiciness of meat.
- VAC followed by HiOxMAP resulted in toughening of loins compared with VAC only treatment.
- However, pork loins aged in VAC followed by HiOxMAP resulted in improvement (compared with hiOxMAP only treatment) in hardness, chewiness, cohesiveness and protein oxidation without significantly affecting colour and water holding capacity of pork loins.
- Overall, the best results for shear force, texture and water holding capacity of Australian pork loins were in VAC only treatment followed by combination treatment (VAC and hiOxMAP) followed by hiOxMAP only treatment.

Application to Industry

- An increase in usage of alternative packaging methods such as vacuum packaging and the more recent innovation vacuum skin packaging which are already used in Australian meat retail is recommended.
- The use of hiOxMAP should be limited to pork cuts with a high turnover to reduce storage time to less than 5 days due to toughening of pork loins in hiOxMAP.
- Sufficient ageing time (approximately 5 days) of pork loins in VAC prior to hiOxMAP may reduce impact on eating qualities.

Subprogram 3B: Inherent Properties of Australian Pork to Enhance Consumer Health

Research the inherent health properties of Australian pork to address key issues such as obesity, diabetes and understand the role of pork on the health of children and the aged.

PROJECT ID	TITLE
3B–102	Effect of long term consumption of Australian pork for weight loss and weight maintenance on cardiometabolic health, food cravings and cognition and psychological wellbeing in individuals with type 2 diabetes
3B–103	The acute response following the consumption of pork meat: a metabolomic analysis
3B–104	The role of pork in improving muscle mass, body strength and cognitive function in institutionalised elderly people
3B–105	Volunteers' attitudes towards consumption of fresh Australian pork
3B–106	Health benefits of pork consumption in the diets of Australian children
3B–107	Lipemic Index of pork
3A–107	Sensory specific liking and satiety induced by pig meat flavours
3B–108	Exploring barriers to fresh and total pork consumption among children: parental perspectives
3B–109	Consumption of pork by Australians – a secondary analysis of the 2011–2013 Australian Health Survey
3B–110	Pork consumption and serum irisin levels in type 2 diabetes
3B–111	Communicating the health benefits of pork consumption
3B–112	Nutritional composition of pork
3B–113	Effect of a Mediterranean diet (MedDiet) with fresh lean Australian pork on blood pressure, cardiovascular risk factors and cognition, mood and psychological wellbeing in high risk individuals

Research Summaries for Subprogram 3B

PROJECT 3B–102: EFFECT OF LONG-TERM CONSUMPTION OF AUSTRALIAN PORK FOR WEIGHT LOSS AND WEIGHT MAINTENANCE ON CARDIOMETABOLIC HEALTH, FOOD CRAVINGS AND COGNITION AND PSYCHOLOGICAL WELLBEING IN OVERWEIGHT/OBESE INDIVIDUALS WITH TYPE 2 DIABETES

Project Leader:
Dr Karen Murphy

Project Participant:
University of South Australia

Aims and Objectives

Research shows energy-restricted, low fat, high pork-protein diets combined with exercise assists with weight loss, cardiometabolic health and glycaemic control in individuals with type 2 diabetes (T2DM). It is unclear whether such diets can sustain these health benefits during subsequent weight maintenance. Nor is it known if pork-protein based diets impact food cravings and cognition. 61 overweight/obese adults with T2DM were randomised to consume either a high pork-protein diet (HPP) (n=32, ~32% protein) or a lower pork-protein diet (LPP, n=29, ~22% protein) for 24 weeks with 150 minutes of moderate intensity exercise weekly for the study duration.

There was an initial 12-week, energy-restricted weight loss phase followed by a 12-week, energy balance weight maintenance phase. The primary outcome was glycaemic control measured by glycosylated haemoglobin (HbA1c). Secondary outcomes included cardiometabolic risk factors (body weight and composition, blood pressure, plasma lipids, glucose, insulin and C-reactive protein), food cravings, cognitive function and well-being.

Key Findings

44 volunteers completed the study. The population was on average 55±8 years and obese (BMI 34±5kg/m2); had borderline poorly controlled T2DM (HbA1c 8.1±1.4%) with an average duration of disease of 7.2±5.2 years. 75% of volunteers took diabetes medication whilst ~50% were taking cholesterol and blood pressure medication. Dietary and physical activity data indicated participants achieved high compliance to the diet and exercise prescriptions. There were no differences between groups for any outcome measure. Weight loss significantly increased in both groups during the weight loss phase (~8kg reduction), which was maintained during the weight maintenance phase. Glycaemic control including HbA1c, fasting blood glucose and insulin levels decreased by 1.4%, 2.7mmol/L and 8.6mU/L, respectively, during the weight loss phase in both diet groups and remained stable during the weight maintenance phase. Cardiometabolic risk factors including blood pressure, insulin resistance, C-reactive protein, plasma total cholesterol, low-density lipoprotein cholesterol and triglycerides significantly decreased, and HDL significantly increased, during the weight-loss phase in both diet groups and remained stable during the weight maintenance phase with the exception of total cholesterol which increased slightly. Over the course of the study, the use of diabetes medications decreased for both groups during the weight loss phase and remained stable during weight maintenance whilst lipid-lowering medication was reduced in four volunteers. Cognitive function remained steady over the course of the study; whilst general health and quality of sleep improved during the weight loss phase. Diabetes related stress, quality of life, vitality and food cravings decreased significantly during the weight loss phase and remained stable during the weight maintenance phase.

Application to Industry

This randomised controlled trial is considered level II evidence according to the NHMRC, evidence which is likely to be considered for dietary guideline revision and clinical practice. This study is highly relevant to the pork industry as not only is pork an important and nutrient dense protein source, we have provided evidence to alleviate health concerns of higher meat diets.

PROJECT 3B–103: A METABOLOMIC ANALYSIS OF THE ACUTE RESPONSE TO MEALS THAT CONTAIN PORK OR CHICKEN

Project Leader:
A/Professor Samir Samman (Discipline of Nutrition and Metabolism, School of Molecular Bioscience, University of Sydney)

Project Participants:
Dr Ben Crossett (University of Sydney), David Sullivan (Royal Prince Alfred Hospital & University of Sydney)

Aims and Objectives

The aims of this study were to investigate the acute responses to consumption of meals containing either pork or chicken, and to identify relationships between amino acids and markers of glycaemic and lipaemic control. A secondary aim was to explore amino acid predictors of plasma zinc concentrations.

Ten healthy adults (men and women) participated in a post-prandial study on 2 separate occasions. In a randomised cross-over design, participants consumed a meal that contained either pork or chicken as the main source of protein. The concentrations of 21 amino acids, glucose, insulin, triglycerides, non-esterified fatty acids and zinc were determined at timed intervals over 5h post-prandially.

Key Findings

The response of amino acids was influenced by the test meal. The mean concentration of plasma histidine was significantly higher after consuming the pork meal, with consistently higher changes from baseline observed after 60 min. In contrast, higher percent increases were noted at limited time points for valine and leucine+isoleucine in those who consumed chicken compared to pork.

The differences in meal composition did not influence glucose, insulin, triglyceride, non-esterified fatty acids or zinc concentrations. However in linear regression various plasma amino acids predicted the changes in plasma glucose (alanine, lysine and histidine), triglycerides (ornithine, tyrosine), non-esterified fatty acids (valine), and zinc concentrations (arginine).

Application to Industry

Our study demonstrates that a single meal of pork or chicken produces a differential profile of amino acids in the post-prandial state. The sustained increase in histidine following the consumption of a pork meal may have beneficial metabolic effects such as decreasing appetite. There is evidence from the literature that histidine contributes to an improved metabolic profile such as decreased oxidative stress and inflammation, and may be responsible partly for the health benefits of high protein diets that contain pork, e.g. weight loss.

Our results provide opportunities for innovative product development, e.g. selection of specific muscle compartments or other parts of the animal carcass that have high histidine concentrations.

Further research is needed to confirm our novel findings and if confirmed, this information may lead to new evidence-based claims regarding pork and health outcomes.

Research Summaries for Subprogram 3B continued

PROJECT 3B–104: THE ROLE OF PORK IN IMPROVING MUSCLE MASS, BODY STRENGTH AND COGNITIVE FUNCTION IN OLDER PEOPLE

Project Leader:
A/Professor
Karen Charlton

Project Participant:
University of Wollongong

Aims and Objectives

This study aimed to investigate whether a diet in which pork is provided as the main protein source in meals four times a week for 12 weeks resulted in improved muscle mass, body strength and cognitive function in community-living older adults. Cross sectional analyses were also conducted at baseline to investigate the association between dietary intake specifically protein and thiamine, with cognitive functioning and to assess associations between age, body composition, upper (hand grip strength) and lower body strength (sit-to-stand test, get up and go test), functional exercise performance (6-minute walk test) and nutritional status. Three focus groups were conducted with 18 older adults in order to gather information on factors affecting dietary habits and particularly inclusion of pork in their diets.

Key Findings

No significant association was found between protein or thiamine and the tested domains of cognition. Associations were found between vitamin D intake and the Letter Fluency Test and Rey-Auditory Verbal Learning Test (RAVLT), and between both carbohydrate and iron intake and the Geriatric Depression scale. Weight was inversely associated with performance in the sit-to-stand test and body mass index was inversely associated with performance in the 6 minute walk test. Left hand grip strength declined with age in both males and females. Energy intake was positively associated with both right and left hand grip strength. No differences were found between pork and chicken groups for any of the outcome variables, although participants in the chicken group had significantly improved measures on the RAVLT test (verbal learning and memory) at 6 weeks.

Focus groups indicated that quality and price were important considerations for food choices and a preference for Australian sourced foods. Participants expressed a strong desire to remain independent and undertook strategies to positively influence their health status, including making healthy dietary choices.

In a sample of generally healthy, well-nourished older adults, no association was shown in a cross sectional analysis between protein or thiamine intake and the tested components of cognition. A slight increase in thiamine intake was achieved in participants by the provision of four pork meals a week, but this did not result in improvements in cognitive function, nor measures of strength or physical function. Merely changing the type of dietary protein provided by meat did not affect measures of physical and cognitive function.

Application to Industry

The findings of this pilot research provide evidence regarding the positioning of pork and pork products in food-based dietary advice to support healthy ageing. Regulatory agencies require scientific evidence of the health benefits of foods to underpin commercial marketing. This information may add a new marketing opportunity for the pork industry that will address consumer demands for foods that target health and wellbeing over the lifespan. Pork has largely been overlooked in favour of other protein sources, such as red meat and poultry, in nutritional interventions that assess the role of foods in the prevention of loss of muscle mass and maintenance of cognitive function in older adults.

The inclusion of pork as a primary source of protein provides novel information on the benefits of regular inclusion in the diets of older people, an increasingly large sector of the population of Australia. The project methodology has been refined and could be applied to a longer study. Qualitative data has provided insights for the pork industry into consumer food-related behaviour in older adults who represent a key market for expansion of pork meat sales given the shifting demographic.

PROJECT 3B–105: VOLUNTEER'S ATTITUDES TOWARDS CONSUMPTION OF FRESH AUSTRALIAN PORK. CAN PARTICIPATION IN A DIETARY INTERVENTION TRIAL CHANGE PERCEPTIONS LEADING TO GREATER PORK CONSUMPTION?

Project Leader:
Dr Karen Murphy

Project Participants:
Professor Peter Howe,
Professor Jon Buckley,
Courtney Davis
(University of South Australia)

Aims and Objectives

The aim of the present project was to determine if voluntary participation in dietary intervention trials where pork was provided together with pork recipes, cooking advice and education on pork's potential health benefits had altered volunteers' perceptions and consumption of pork.

Key Findings

The major findings that have been identified in this population of consumers are:

- Pork was seen overall quite positively, but more so after participation in the dietary intervention trial.
- Half of the intervention group and a third of the control group reported their pork intake had increased since being involved in the study.
- Participation in a dietary intervention trial where pork was provided together with health information and recipes or where volunteers were exposed to potential health benefits of lean pork, appears to have increased habitual consumption of pork by approximately 29g/wk in low pork consumers.
- Taste, tenderness and juiciness of pork are important attributes considered when purchasing.

- Religion did not impact on consumption in these volunteers.
- Pork was perceived equally healthy as beef and chicken.
- Volunteers were unsure about the saturated fat content of pork in comparison with beef and chicken.
- Volunteers ranked pork as having the least amount of exposure in the media.

Application to Industry

The major opportunity that has been uncovered by this research is the need for a marketing campaign to:

- Promote the health benefits of pork (based on previously funded Pork CRC projects).
- Dispel common misconceptions about pork.
- Provide easy to understand information on preparing and cooking pork.
- Provide healthy pork recipes perhaps together with tasting opportunities in butchers or supermarkets to 'expose' consumers to pork.
- Increase the presence of pork in the media.

This marketing campaign is needed to educate and inform consumers that pork is nutritionally equal to lean beef and chicken, it can be just as versatile and it can be incorporated into meals as part of a healthy balanced diet. It is evident that consumers are not informed and have not been exposed to pork and with attention and pork eating experience consumers may well increase their intakes.

PROJECT 3B–106: HEALTH BENEFITS OF PORK CONSUMPTION IN THE DIETS OF AUSTRALIAN CHILDREN

Project Leader:
Deborah Nolan-Clark

Project Participants:
Landmark Nutrition Pty Ltd, University of Wollongong

Main findings

- In a recent survey of the eating habits of Australian children aged 2–16 years old, approximately half of the children surveyed reported eating some type of pork.
- Of the children who ate pork, most reported eating processed pork such as ham and bacon, with only 7% of children reporting that they ate fresh pork.
- The type of pork eaten in the greatest amount was ham, followed by bacon.
- Children's cultural background may influence pork intake. Fewer children who reported eating pork had a primary carer born in Africa or the Middle East, compared to Australia, Europe and the United Kingdom.
- When considering the type of pork eaten, more children who reported eating fresh pork had a primary carer born in Asia (compared to Australia, Europe and the United Kingdom). In contrast, more children that reported eating processed pork had a primary carer born in Australia, Europe or the United Kingdom, compared to Asia.
- Pork was most commonly consumed at home at lunchtime.
- Vegetable products and dishes were the items eaten most frequently with pork.
- Children who reported eating pork had greater intakes of protein, phosphorous and zinc than children who did not eat pork.
- Pork contributed substantially to the intakes of a number of important nutrients, including protein, thiamine, zinc and niacin.
- Children who ate pork were more likely to meet their nutritional requirements for protein, calcium, iron, thiamine, riboflavin, phosphorous, zinc and iodine than children who did not eat pork.
- Despite finding that children who ate pork had a greater energy, total fat and saturated fat intake than children who did not eat pork, there was no difference in weight, waist circumference, or prevalence of overweight/obesity (categorised using body mass index) between children who ate pork and those that did not.

Research Summaries for Subprogram 3B continued

PROJECT 3B–107: LIPEMIC INDEX OF PORK

Project Leader:
Professor Manohar Garg (University of New Castle)

Project Participants:
Professor Peter Howe, A/Professor Lisa Wood and Dr Melinda Phang (all University of New Castle)

Aims and Objectives

The aim of this project was to compare the impact of consuming a pork meal on plasma lipids (the acute lipemic response) to that of consuming a red meat (lamb) meal with equivalent fat content.

Key Findings

The study showed no difference between the pork and lamb meals in the incremental changes of blood cholesterol (total, LDL and HDL) and triglycerides at 2, 4 or 6 hours.

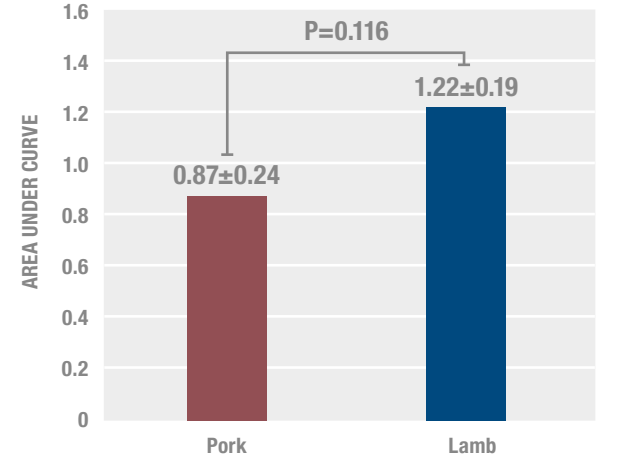
Although statistically insignificant, the Lipemic Index (i.e. the integrated change in plasma triglyceride levels calculated as the area within a trapezoid) tended to be lower for pork than lamb.

The effect size suggests the possibility of a significant difference with a larger sample size.

Application to Industry

The current findings provide a proof of concept that pork is as good as lamb and possibly better with respect to its effects on postprandial lipemia and support the growing evidence that consumption of fresh pork is equally healthy to consumption of alternative meats.

The Lipemic Index (or the Area under the Curve – the integrated change in plasma triglyceride levels calculated as the area within a trapezoid). Values are mean±SEM.



PROJECT 3A–107: SENSORY SPECIFIC LIKING AND SATIETY INDUCED BY PIG MEAT FLAVOURS (PREDICTIVE MODELS BASED ON SUBJECTIVE RATINGS AND BRAIN ACTIVITY MEASURED BY FMRI)

Project Leader:
Dr Eugeni Roura

Project Participant:
University of Queensland

Aims and Objectives

The project involved 18 healthy adults and aimed to study the effect of pork flavoured chewing gum and a pork rich breakfast on appetite for several food categories (meat, fruits, vegetable and cakes), general satiety and pork related SSS. Brain scanning using fMRI was used to study the responses of specific areas such as the OFC to food cues (visual and olfactory). In addition, subjective ratings on hunger, fullness, desire to eat, liking and wanting were assessed.

Key Findings

The principal findings of this preliminary fMRI study confirm our main hypothesis that pork elicited strong satiety ratings based on sensory cues. Pork SSS was strong after breakfast when panellist were exposed to visual cues and the results were enhanced by the addition of olfactory cues in the second fMRI. In addition, our data proves that the subjective ratings are related to the brain activity particularly at the OFC region.

The results provide evidence that pork flavour can be considered as a potential tool for appetite-control.

Application to Industry

The novel fMRI application developed has the potential to evaluate the sensory pleasing of pork and compare it to other foods/meats. Future research could target the development and characterisation of a branded sensory signature unique to Australian pork – which enhances its succulence as well as its health related claims.

PROJECT 3B–108: EXPLORING BARRIERS TO FRESH AND TOTAL PORK CONSUMPTION AMONG CHILDREN: PARENTAL PERSPECTIVES

Project Leader:
Deborah Nolan-Clarke (Landmark Nutrition)

Project Participants:
Elizabeth Neale (Landmark Nutrition), Karen Charlton (University of Wollongong)

Aims and Objectives

Factors influencing children's consumption of total and fresh pork were examined through focus groups with parents of children aged 2–16 years.

Key Findings

- Parents reported that pork was an acceptable meat to include in children's meals and there was an overall perception that fresh pork was a healthy meat, because of its leanness. In comparison, processed pork such as ham and bacon was seen to be less healthy than fresh pork, although it was viewed as being more convenient.
- Family and cultural traditions had a large influence on the type and amount of pork participants served their children. Fresh pork tended to be eaten commonly on special occasions, for example roast pork at Christmas.
- Parents felt they lacked confidence when cooking fresh pork, and many believed that pork needed to be cooked until well-done to avoid food poisoning. A strong desire for easy and fast recipes using fresh pork was discussed. Participants also felt they lacked knowledge of the nutrition contribution of pork compared to other meats.
- Fresh pork was seen to be less visible in shopping outlets than beef or chicken, and was also seen to be advertised less frequently than these meats. This lack of visibility was seen as having a negative impact on the likelihood that parents would serve fresh pork to their children.
- Animal welfare and country of origin concerns were discussed by a small number of participants but did not appear to have a large impact on purchasing patterns. A key finding was that participants did not check the country of origin when buying pork, and assumed that all pork (both fresh and processed) was from Australia.
- Popular children's programs involving pigs could be a barrier to fresh pork consumption in younger children.
- The texture of fresh pork was also discussed as a barrier for younger children, with the inclusion of fresh pork in mixed dishes such as stir-fries discussed as a way of overcoming this barrier and encouraging consumption. Participants also found that involving their children in preparing dishes containing fresh pork (for example dumplings) improved their acceptance of these meals.
- When participants were provided examples of value-added fresh pork products, participants viewed them as being convenient meal options; however they were sceptical of pre-marinaded products, and viewed them to be too expensive to regularly serve them to their families.

Application to Industry

The project provides an insight into the perception and preferences of parents for pork and pork products.

Research Summaries for Subprogram 3B continued

PROJECT 3B–109: CONSUMPTION OF PORK BY AUSTRALIANS – A SECONDARY ANALYSIS OF THE 2011–2013 AUSTRALIAN HEALTH SURVEY

Project Leader:
Dr Deborah Nolan-Clark (Landmark Nutrition)

Project Participants:
Dr Elizabeth Neale (Landmark Nutrition), A/Professor Karen Charlton (University of Woolongong)

Aims and Objectives

The aim of this study was to explore the nutrition and health benefits of pork consumption in the diets of Australians based on the latest available data from the 2011–2013 Australian Health Survey.

The objectives were as follows:

- Describe the current intake of fresh pork and pork-containing products by Australian adults and children.
- Identify target groups for the promotion of fresh pork through an analysis of demographic information relating to both high and low pork consumers.
- Compare the nutritional status of pork consumers to non-pork consumers, using current nutrient reference values (NRVs).
- Explore associations between pork intake and several health characteristics of pork consumers.

Key Findings

- Just over a third (37.4%) of Australians reported eating any type of pork on the survey day evaluated, with 7.70% consuming fresh pork and 32.0% consuming processed pork.
- Ham was the pork variety consumed in the greatest amount, followed by bacon. Within the fresh pork category, pork loin was consumed in the greatest amount.
- Males consumed pork in greater quantities than females.
- A significantly lower proportion of individuals who consumed total or processed pork were born in Australia than other countries. In comparison, a higher proportion of fresh pork consumers were born in a non-English speaking country.
- More pork consumers met their dietary requirements for protein, long chain omega-3 polyunsaturated fatty acids, thiamine, riboflavin, niacin, vitamin B6, vitamin B12, phosphorous, zinc, iron, iodine and selenium than non-consumers.
- Pork consumers consumed significantly higher amounts of protein, fibre, thiamine, monounsaturated fat, iodine and selenium than non-consumers. However, intakes of energy, total and saturated fat, cholesterol and sodium were also higher amongst pork consumers.
- Despite the large sample size from the use of weighted survey data suggesting significant differences between pork consumers and non-consumers in terms of body weight, waist circumference and blood pressure, the lack of an absolute difference in these measures between intake groups suggests that these differences are unlikely to be of clinical relevance.

Application to Industry

This research will contribute to the evidence base surrounding the important position of pork as a core food in the Australian diet. The quantification of intakes of processed, fresh and more recently consumed pork varieties in addition to demographic analyses of consumers and non-consumers may provide important insights for the strategic marketing of pork to Australians. This analysis of the contribution of pork to key nutrient requirements will also be invaluable in terms of providing evidence to support marketing efforts seeking to expose the unique nutritional benefits of consuming pork as part of a balanced diet.

PROJECT 3B–110: PORK CONSUMPTION AND SERUM IRISIN LEVELS IN TYPE 2 DIABETES

Project Leader:
Professor Manohar L Garg

Project Participants:
Dr Rachel Wong &
Professor Peter RC Howe,
Nutraceuticals Research
Group, University of Newcastle

Aims and Objectives

This study explored the potential for consumption of pork, as a source of protein, to enhance irisin production and favourably influence biomarkers of insulin resistance in adults with type 2 diabetes.

Key Findings

1] Regular consumption of pork for 4 weeks does not influence plasma irisin levels in people with type 2 diabetes.

2] Including pork in the diet marginally (but significantly) reduced body fat content and increased muscle percentage.

3] Regular pork consumption does not adversely affect blood measures of "health" i.e. blood lipid levels or glycemic indices or body weight despite an increase in energy intake.

Application to Industry

In conclusion, we provide proof of concept that despite no change in irisin levels, regular consumption of pork does not worsen glycemic control or increase cardiovascular disease risk in people with type 2 diabetes. On a positive note, inclusion of pork in the diet resulted in a small but significant improvement in body composition (muscle mass).

PROJECT 3B–111: COMMUNICATING THE HEALTH BENEFITS OF PORK CONSUMPTION

Project Leader:
Dr Deborah Nolan-Clark

Project Participant:
Landmark Nutrition Pty Ltd

Aims and Objectives

Given the significant investment by Pork CRC towards research that has identified several unique health benefits, it is important that evidence evaluating the effect of fresh pork on health be identified, reviewed and translated to a form easily accessible to a range of individuals including health professionals and the public.

Key Findings

A narrative review was constructed to focus on areas where there was sufficient research on a health outcome associated with fresh pork consumption. The areas where pork was associated with favourable health effects included body composition and cardiovascular health. A discussion of the important contribution of pork to nutrient intakes was also included. Two summary documents were developed, suitable for communicating the findings of the narrative review and other pertinent information about the health benefits of pork to health professionals, and to the general population. Finally, a scoping study was conducted that identified several opportunities for communicating the health and nutrient benefits of pork consumption, including communication to the Dietitians Association of Australia and Royal Australian College of General Practitioners memberships, via partnership opportunities, conference sponsorship, and communication via social media.

Application to Industry

This research and associated components has consolidated the evidence base surrounding the positioning of fresh pork as a healthy meat that may have favourable effects on both body composition and measures of cardiovascular health when consumed as part of a healthy diet. The dissemination of information summaries created within this project will help inform consumers and health professionals of the contribution of fresh pork to a balanced diet and may help to dispel the myth that pork is less healthy than other meats. It is anticipated that the appropriate dissemination of the information created throughout this project may assist with positively raising the profile of fresh pork. Such an approach could assist in driving consumer demand for fresh pork, potentially leading to an increase in sales, which will directly benefit the Australian pork industry.

Research Summaries for Subprogram 3B continued

PROJECT 3B–112: NUTRITIONAL COMPOSITION OF AUSTRALIAN PORK

Project Leaders:
Ken Ng and Frank Dunshea (University of Melbourne)

Project Participants:
Debbie Xu and Jenny Tran (University of Melbourne), Heather Channon (APL)

Aims and Objectives

The aim of the project was to conduct a targeted survey of the nutritional composition of three commonly consumed pork cuts (pork fillets, Scotch fillets and loin steaks) obtained from four different abattoirs from four Australian States (VIC, QLD, NSW, WA), to determine if there had been any changes in the key nutritional composition of Australian pork compared with previous analyses commissioned by Australian Pork Limited in 2006. The objectives were to measure proximate (moisture, ash, nitrogen, protein and total fats), iron and thiamine contents using AOAC Official Analytical Methods. Fatty acids compositions were also determined using analytically established GC-MS method. Direct comparison was made between the three cuts from the current analysis with similar cuts in the previous analysis.

Key Findings

1] Moisture contents were (States Means) 74.2±2.3g/100g (pork fillets), 70.3±1.3g/100g (Scotch fillets) and 67.1±4.1g/100g (loin steaks). Ash contents were (States Means) were 1.177±0.037g/100g (pork fillets), 1.09±0.14g/100g (Scotch fillets) and 1.03±0.11g/100g (loin steaks). Protein contents as total nitrogen were (States Means) were 20.94±0.55g/100g (pork fillets), 18.84±0.48g/100g (Scotch fillets) and 19.7±1.3g/100g (loin steaks). Differences in protein contents of the pork cuts between the current analysis and the previous analysis (Greenfield et al, 2009) were unremarkable.

2] Fats contents were (States Means): 5.56±0.50g/100g (pork fillet), 16.60±0.68g /100g (Scotch fillets) and 17.83±0.91g/100g (loin steaks). Differences in the fats content of the pork cuts between the current analysis and the previous analysis (Sinclair et al, 2010) could not be established, due to variable fats content presented in the cuts as supplied and to differing sample preparation protocol regarding removal of fats in the laboratory before analysis.

3] Total energy as calculated from the protein and fats contents were (States Means): 560±27kJ/100g (pork fillets), 934±33 kJ/100g (Scotch fillets) and 993±55kJ/100g (loin steaks). Comparison with previous analysis could not be made due to variability in fats contents that contributed to the energy calculation.

4] Iron contents were (States Means): 1.62±0.32mg /100g (pork fillets), 1.74±0.15mg/100g (Scotch fillets) and 0.83±0.15mg/100g (loin steaks). There were significant ($p<0.05$) increases in the iron contents in the pork cuts compared to similar cuts from previous analysis (Greenfield et al, 2009). Scotch fillets showed the highest increase (217%), followed by pork fillets (188%) and loin steaks (153%).

5] Thiamine contents were (States Means): 1.217±0.039mg/100g (pork fillets), 0.820±0.071mg /100g (Scotch fillets) and 1.03±0.12mg/100g (loin steaks). Compared to the previous analysis of lean cuts (Greenfield et al, 2009), the thiamine content of pork in the current analysis was higher for loin steaks (122% increase) and Scotch fillets (126% increase). Thiamine content was lower for pork fillets (19% lower) compared to the lean pork fillets in the previous analysis. This could be due to the higher fat content, therefore less lean meat, of the pork fillet in the current analysis compared to the lean pork fillets in the previous analysis.

6] The most prominent saturated fatty acid in all three pork cuts was C16:0 (palmitic acid), followed by C18:0 (Stearic acid) and C14:0 (Myristic acid). For monounsaturated fatty acid it was C18:1 (oleic acid), followed by C18:1t9 (elaidic acid) and C16:1 (palmitoleic acid). For polyunsaturated fatty acids it was C18:2n6 (linoleic acid) followed by low amounts of C18:3n3 (α-linolenic acid).

Application to Industry

- This project has resulted in the compilation of an up-to-date, scientifically robust database of the key nutrient composition of three commonly consumed pork cuts, pork fillets, Scotch fillets and loin steaks. These results can be used to upgrade nutrient composition databases such as NUTTAB, which will allow for communication of pork composition data.
- Comparisons with previous analyses of pork cuts (Greenfield et al, 2009) showed that iron content had increased substantially in pork fillets, Scotch fillets and loin steaks, and thiamine content had increased marginally in Scotch fillets and loin steaks since 2006. These data indicate the successes of several Australian Pork Limited and Pork CRC projects which aimed to influence the iron and thiamine contents of fresh pork.
- The iron and thiamine data can also be used for consumer education and regulatory purposes, including the use of health and nutrient content claims to be displayed on packaging and in advertisements, as a point-of-difference for pork compared to other meats.

PROJECT 3B–113: EFFECT OF A MEDITERRANEAN DIET (MEDDIET) WITH FRESH LEAN AUSTRALIAN PORK ON BLOOD PRESSURE, CARDIOVASCULAR RISK FACTORS AND COGNITION, MOOD AND PSYCHOLOGICAL WELLBEING IN HIGH RISK INDIVIDUALS

Project Leader:
Dr Karen Murphy
(University of South Australia)

Project Participants:
Alexandra Wade,
Professor Jonathan Hodgson,
Professor Richard Woodman,
Dr Hannah Keage
(all University of South Australia)

Aims and Objectives

The project sought to examine the cardiovascular and cognitive effects of a Mediterranean diet modified to include 2–3 weekly serves of fresh, lean pork. A 24-week crossover design trial compared a Mediterranean diet with pork (MedPork) with a low-fat control diet (LF) in 33 men and women at risk of developing cardiovascular disease.

Key Findings

There were no significant differences between diets for blood pressure, lipids, CRP, glucose and insulin.

A small but significant effect of the LF intervention was found for weight, waist circumference, BMI and fat mass.

Sensitivity analyses showed a significant reduction in systolic blood pressure and pulse pressure in participants who were overweight after the MedPork phase.

Processing speed, a cognitive domain of attention improved following the MedPork intervention, but worsened following the LF intervention.

While the study did not detect a significance effect of diet on psychological wellbeing, positive trends were observed across all subscales of the profile of mood state questionnaire following the MedPork intervention, with improvements in Depression and Total Mood Disturbance approaching statistical significance.

Application to Industry

Adding pork to the Mediterranean diet may have beneficial health effects in overweight individuals on vascular function, particularly blood pressure, a key risk factor for cardiovascular disease.

To our knowledge, this research is the first to investigate whether an alternate source of protein can be included in the Mediterranean diet to increase sustainability and feasibility for a non-Mediterranean population. Findings are significant for the prevention of cardiovascular disease and age-related decline, and may inform individuals, clinicians and public health policy. The use of the Mediterranean dietary pattern continues to gain momentum. The American Dietary Guidelines 2015–2020 have adopted the pattern as one of three healthy diets for good health for Americans. Our findings offer a new angle in revitalising the healthy image of pork offering opportunity for it to be part of a healthy dietary pattern such as the Mediterranean dietary pattern and its use in dietary practice and dietary guideline revision.

Subprogram 3C:
Market Demand for High Integrity Australian Pork

Research designed to understand how to more effectively communicate with consumers to change consumption habits of consistent quality Australian pork. As part of this Subprogram, work was conducted in four key Asian markets to better understand how those consumers perceive Australia and, in particular, Australian pork compared with pork from other countries.

PROJECT ID	TITLE
3C–102	Inclusion of lupins in the diets of finisher pigs to reduce the level of cholesterol
3C–103	A comparison of regular consumption of fresh lean pork, beef and chicken on body composition and energy intake
3C–104	Enhancing the iron content of pork to promote human health benefits
3C–105	Defining the relative importance of consumer drivers and perceptions of Australian pork in targeted export markets
3C–106	Eating Quality impacts on consumer perceptions and behaviour

Research Summaries for Subprogram 3C

PROJECT 3C–102: INCLUSION OF LUPINS IN THE DIETS OF FINISHER PIGS TO REDUCE THE LEVEL OF CHOLESTEROL IN PORK

Project Leaders:
Joshua Sweeny and Megan Trezona (DAFWA)

Project Participants:
Matthew Langridge, Karen Moore, Jae Kim and Bruce Mullan (all DAFWA)

Aims and Objectives

To investigate the cholesterol lowering effect of lupins in pig diets to further enhance the healthiness of Australian pork.

To determine how the cholesterol lowering effects of lupins compares with that of soy lecithin.

Immunocastrated pigs were fed diets formulated to be low or high in cholesterol (low and high fat) and to contain 7.5 % soy lecithin or 30% lupins between 40 and 95 kg.

Key Findings

Soy lecithin effectively lowered plasma total and LDL cholesterol levels, however the inclusion of soy lecithin or lupins in finisher pig diets did not significantly lower tissue cholesterol levels. Pork from pigs fed soy lecithin or lupins had a higher PUFA:SFA ratio indicating that lupin fed pigs can produce healthier pork with enhanced nutritional value and fatty acid profile. Inclusion of 30% lupins in the diet increased the PUFA: SFA ratio by 38%–42% in the loin, 23%–44% in the ham and by 25%–49% in belly fat tissue with the greater improvements being achieved in pigs fed the high fat diets. The inclusion of soy lecithin or lupins in finisher pig diets had no negative impacts upon pig growth performance, with the exception of soy lecithin fed pigs, which had lighter LW at Day 42 and lower ADFI (Day 42 and overall). There were also no observed effects of diet type on objective pork quality measurements.

- Lupins can be incorporated into high fat finisher pig diets at levels of up to 30% to supply further advantages other than being a nutrient source for finisher pigs, whereby they can effectively manage the fatty acid profile (PUFA:SFA ratio) of pork to maintain healthier pork product from pigs fed a standard low fat diet.
- Further research, with a larger number of pigs (group housed in a commercial environment) is required to assess whether the inclusion of lupins can effectively lower the cholesterol content of pork when pigs are fed high fat diets.

Application to Industry

These results demonstrated that the dietary inclusion of lupins at 30% effectively manages the ratio of PUFA:SFA in the tissue of pigs fed high fat diets without impacting upon performance.

Lupins possess further advantages other than being a nutrient source for finisher pigs and as they are a commonly utilised feed ingredient, this management strategy can be easily adopted to allow producers to use tallow as a concentrated energy source when alternative feed ingredients that possess low energy densities are utilised.

PROJECT 3C–103: A COMPARISON OF REGULAR CONSUMPTION OF FRESH LEAN PORK, BEEF AND CHICKEN ON BODY COMPOSITION AND ENERGY INTAKE

Project Leader:
Dr Karen Murphy

Project Participant:
University of South Australia

Aims and Objectives

This was a 9 month cross-over intervention project, where 49 overweight adults were randomly assigned to consume up to 1kg of either pork, chicken or beef/wk, in the form of steak or (chicken) breast, diced, mince and stir fry, ad libitum and without energy restriction. At baseline and then at 3, 6 and 9 months weight, body mass index, waist/hip circumference and measures of body composition including % body fat, abdominal fat and lean mass using dual energy x-ray absorptiometry was assessed.

Key Findings

Results showed that regular consumption of lean pork was equally healthy as beef or chicken consumption. After statistical analyses using random effects GLS regression, there was no difference between the pork, beef or chicken diet for weight or any other index of adiposity. Similarly, there was no difference in energy intake or macro or micronutrient intakes. Volunteers reported that pork was the preferred meat to chicken (P=0.229) and had significantly greater satisfaction than beef (P=0.018). The most enjoyed type and cut of meat was pork steak.

Application to Industry

Regular consumption of lean fresh pork is equally healthy as consumption of beef or chicken. Given the increasing prevalence of obesity in Australia, such evidence will reassure consumers that lean pork is a healthy choice, which should strengthen its market relative to its chief competitors.

Research Summaries for Subprogram 3C continued

PROJECT 3C–104: ENHANCING THE IRON CONTENT OF PORK TO PROMOTE HUMAN HEALTH BENEFITS

Project Leader:
Professor John Pluske (Murdoch University)

Aims and Objectives

The iron (Fe) content of pork meat is low in relation to lamb and beef, and currently, Australian pork does not meet the Australian Food Standards Code requirements of being a food that is "a good source" of Fe. Three experiments were conducted to test the propositions that:

a] Pigs raised in deep-litter systems will have more Fe and myoglobin than their counterparts raised indoors (conventional).

b] Feeding diets lower in Fe (to induce mild iron depletion) followed by feeding diets higher in Fe (to induce Fe repletion) will increase muscle Fe levels.

c] There will be differential expression of candidate genes implicated in muscle Fe metabolism in response to (b).

Key Findings

Experiment 1 measured mineral and myoglobin levels in samples of muscle (*longissimus dorsi,* LD; and *rectus abdominus,* RA) from female pigs grown indoors or on deep-litter that were slaughtered at either 7, 10, 13, 16, 20, 24, 26, 30 or 35 weeks of age. There was no housing effect on Fe, Zn or myoglobin contents. The RA was higher in Fe, Zn and myoglobin than the LD. In Experiment 2, female pigs were fed one of two grower diets for 8 weeks that differed in Fe content (High or Low; 239 *vs* 50 ppm) followed by a cross-over design for 7 weeks of further feeding, with half of the High pigs fed a high Fe (248 ppm) finisher diet (High-High) while the other half were fed a low Fe (71 ppm) diet (High-Low). The same design was applied to the Low Fe grower pigs, to create Low-High and Low-Low treatment groups, respectively. Blood samples were obtained through the grower-finisher stages. Pigs were killed commercially at the end of the grower and finisher stages with muscle [*m. longissimus dorsi* (LD) and *m. rectus femorus* (RF)] and organ (liver, heart) samples obtained. Increases in Fe content were only found in the RF at the end of both the grower and finisher stages in response to feeding diets High Fe and Low-High, respectively. Increases in RF Fe content in diet Low-High supports the dietary depletion/repletion model of action. There were no deleterious effects on production indices. Pigs fed diet High-High had less P2 than pigs fed diet Low-High. Muscle LD from High pigs was darker and redder than in pigs fed Low Fe (end of grower), and pigs fed High-High (end of finisher) had redder meat in the LD. The liver, but not the heart, stored Fe in pigs fed diets High and diets Low-High and High-High. Experiment 3 investigated the expression of some candidate genes involved in Fe metabolism and physiological regulation in both the LD and RF muscles at both the end of the grower and finisher stages. Findings confirmed blood and muscle results in Experiment 2, and underscored the physiological regulation of Fe metabolism in muscle. For example, ferroportin levels (ferroportin is a transmembrane protein that transports iron from the inside of a cell to the outside of it) supported the higher Fe concentration in muscle RF and indicated an increased excretion of iron from this muscle.

Data obtained from this project using this particular nutritional manipulation model indicated that it was not possible to manipulate the amount of Fe contained in all muscles of the pig. The redder RF was more responsive to the depletion-repletion model, however and as evidenced by blood Fe, ferretin and haemoglobin levels, the grower-finisher pig has tremendous homeostatic propensity to buffer 3- to 4-fold differences in dietary Fe intake to avoid deficiency or overload.

Application to Industry

1] There is no benefit in feeding additional dietary Fe to increase its content in muscle, except possibly where there might be a specific market niche for higher Fe pork, in which case redder muscle types will deposit more Fe if given in excess.

2] The liver acts as a storage organ for surplus Fe absorbed by the pig.

3] Dietary Fe levels in young pigs should be re-examined to eliminate the possibility that over supply of dietary Fe early in life is not having a detrimental affect on Fe absorption (and hence deposition in muscle) later in life.

4] The decrease in P2 at slaughter in pigs fed diet High-High compared to pigs fed Low-High warrants further examination.

PROJECT 3C–105: DEFINING THE RELATIVE IMPORTANCE OF CONSUMER DRIVERS AND PERCEPTIONS OF AUSTRALIAN PORK IN TARGETED EXPORT MARKETS

Project Leader:
Peter Haydon

Project Participants:
Australian Pork Limited, IPSOS Marketing

Aims and Objectives

The focus of this study was to identify those countries that Australia can target for export; determine perceptions of Australian pork of consumers in these countries compared to domestically produced product and other sources of pork and whether Australia is regarded as a favourable source of pork compared to other sources and the relative importance of potential differentiators including credence values, food safety and quality attributes.

Key Findings

An on-line market research study was conducted by IPSOS Marketing in September 2012 involving 300 consumers in Japan, 200 in Hong Kong and Korea and 800 in China across 4 cities. The major findings from this study were:

- 87% of Korean, 85% of Japanese, 97% of Chinese and 94% of Hong Kong consumers (who were all frequent pork consumers)

were interested in Australian pork.

- For those consumers interested in Australian pork, a higher response for 'definitely would consider' was obtained from China, followed by Hong Kong.
- South Korean and Japanese consumers perceived locally produced/sourced pork to be of higher quality, extremely safer than imported pork and produced with better welfare standards and environmentally friendly practices than imported pork – indicating that there are two different segments – Northern Asia and China/Hong Kong.

- Australian pork was favorably viewed in terms of:
  - Quality – by South Korean, Chinese and Hong Kong consumers.
  - Safety – by South Korean, Chinese and Hong Kong consumers.
  - Welfare – Chinese and Hong Kong consumers considered local product to be produced to lower welfare standards than sources of imported pork.
  - Environment – Australian pork was comparable to Denmark and Canada.
  - Being better than locally produced pork – rated highest for this attribute compared to pork from Canada, Denmark and USA by Chinese and Hong Kong consumers.
  - Overall, 46% and 38% of consumers from China and Hong Kong, respectively, indicated that they'd be prepared to pay a premium of 30% or higher for Australian pork.
- Across all consumers, safety and quality rated higher than country of origin, welfare and environmental standards.

Application to Industry

Strong opportunities for Australian pork were identified for China and Hong Kong, with moderate opportunity in South Korea. Further efforts aimed at understanding market conditions, opportunities and barriers to trade, focussed on obtaining market access for Australian pork into China are required to result in supply of pork to affluent Chinese consumers. Industry delegations are also required from Australia to develop relationships with importers and government officials. Further knowledge of the combination of credence, integrity, traceability as well as quality attributes being developed across the High Integrity Australian Pork CRC is required to establish Australia's position as a trusted source of high quality, safe pork. Furthermore, market research, together with econometric modelling, is also required to both improve our understanding of what makes Australian pork 'special' to differentiate it and make it attractive to consumers for purchase from pork from other imported pork in the marketplace. Understanding of the range of pork products, and delivery formats required to meet consumer expectations and compete effectively against pork from other countries is also required.

PROJECT 3C–106: EATING QUALITY IMPACTS ON CONSUMER PERCEPTIONS AND BEHAVIOR

Project Leader:
Peter Smith (APL)

Project Participant:
Peter Haydon (APL)

Aims and Objectives

The aim of this project was to identify the impact of improved pork cut delivery and cooking instructions on driving increased purchase of pork steaks and recipe habit formation as well as identifying the key marketing levers that can be used to elicit long term consumer behavioural change, resulting in pork gaining a place in consumers' *Core Recipe Repertoire*.

Key Findings

Impact of the Campaign on Sales

The campaign generated a significant increase in the unit sales of pork steak in all 3 of our retail partners during the campaign period.

This increase was incremental to existing pork sales, not at the expense of other pork cuts

Actual sales data provided by both our retail partners was consistent with claimed behaviour of consumers identified in follow up consumer research.

Impact of the Campaign on Reported Behaviour

- Increase in claimed proportion of pork meals consumed overall by key segments.
- Increase in claimed consumption of pork steaks being eaten (avg. per week).
- An increase in proportion of people who pan-fry their pork.

Overall, no major shifts in attitude change toward Pork in general was observed from this campaign – although an improved perception of "Pork is good for steaks" and "good for BBQs" was positively identified within the Ad Tracking data.

Application to Industry

For long term change in behaviour to occur, it is necessary for pork steak to become embedded in meal occasions and purchase patterns.

Communicating the rewards associated with 6-2-2 is the best way to entrench the purchase of pork steak and avoid relying on a continuous advertising push.

The gap between behaviour and specific attitudes will change over time if the behaviour becomes entrenched.

The mix of marketing of marketing activities (above and below the line) should be rebalanced in future campaigns to expand the reach they have with consumers to maximise the impact at the point of purchase.

PROGRAM

4 Carbon Conscious Nutrient Inputs and Outputs

Program 4 aimed to reduce effluent emissions through novel management, offsetting traditional nutrient inputs with alternate sources derived from algae, and restructuring grain breeding and ingredient evaluation programs to complement these new nutrient sources.

SUBPROGRAM 4A	**FUTURE FEEDS FOR FUTURE NEEDS**
SUBPROGRAM 4B	**ENHANCED USE OF TRADITIONAL PROTEIN AND ENERGY SOURCES**
SUBPROGRAM 4C	**CARBON-NEUTRAL PORK PRODUCTION**

Subprogram 4A: Future Feeds for Future Needs

Investigated the use of algae to remediate piggery effluent and provide a potential alternative feed source for the industry whether grown on-farm or from CO_2 mitigation or biofuel systems.

PROJECT ID	TITLE
4A–101	Algae for energy & feed: a wastewater solution
4A–102	Evaluation of algal meal as an energy and protein source in swine diets
4A–105	Aerobic and algal treatment of piggery wastewaters for heat recovery, effluent treatment and water reuse
4A–106	Growth, development and use of algae grown on untreated and undiluted anaerobic digestion piggery effluent (ADPE)
4A–107	Bioprospecting and growth of macroalgae on anaerobic digestion piggery effluent (ADPE)
4A–108	Evaluate different microalgae cultivation systems for treating anaerobic digestion piggery effluent (ADPE)
4A–109	Co-cultivation of microalgae and macroalgae for the efficient treatment of anaerobic digestion piggery effluent (ADPE)

Research Summaries for Subprogram 4A

PROJECT 4A–101: ALGAE FOR ENERGY AND FEED: A WASTEWATER SOLUTION

Project Leader:
Professor Howard Fallowfield (Flinders University)

Project Participants:
University of Adelaide, Murdoch University, Temaplan Group

Aims and Objectives

The objective of this project was to conduct an integrating review that encompassed both the priorities requested under Program *4A Future Feeds for Future Needs* with aspects of *Program 4C Carbon-Neutral Pork Production.* The Program 4A review was of the techno-economic and life cycle assessment of algal growth systems and processes suitable to produce algae as a feed source for pigs; review of pig nutrient requirements and the identification of suitable algal species that meet these nutritional requirements. The Program 4C component was to review current knowledge and future integrated piggery waste management/bio-energy systems and their potential to impact the growth of micro-algae on piggery waste to maximise nutrient and energy recovery from piggery waste streams.

An expert group conducted the review, managed by Flinders University, comprising Neil Buchanan, Dr Natalie Bolton, Ryan Cheng, Dr Ivo Svoboda (Flinders); Prof Michael Borowitzka & Dr Navid Moheimani (Murdoch University); Dr Tim Grant (Life Cycle Strategies), Dr David Batten (Temaplan Group). The review considered current local and international slurry handling & management practices including anaerobic digestion (AD); aerobic treatment which would facilitate algal culture; performance of algal culture systems for feed, wastewater treatment and fuel; pig and human health benefits and risks associated with adoption of wastewater grown algal technologies and a streamlined life cycle assessment (LCA) of integrated wastewater treatment, GHG abatement and algal technologies for feed and fuel. The overarching objective maintained throughout was to inform the future research required to *'turn possibility into reality'*.

Key Findings

Pig slurry should be viewed as a resource rather than a waste management cost and problem within the Australian pork industry. The overwhelming majority of pork producers use lagoon systems for wastewater treatment. A small minority have covered anaerobic lagoons to reduce emissions of the GHG methane from slurry. The LCA analysis indicates that rather than 'flaring' this renewable energy source the industry should be encouraged to exploit biogas for water or space heating or in combined heat and power systems thereby reducing fossil fuel usage and associated GHG emissions. The review identified high ammonia and suspended solids concentrations in slurry as major inhibitors of algal growth; recommending the integration of controlled, closed vessel aerobic treatment to biologically convert the ammonia to nitrate, followed by solids separation to enable microalgal growth on anaerobic digester effluent. The LCA indicates that further wastewater treatment by microalgae, followed by additional energy recovery via co-digestion of the algal biomass with pig slurry is the option most likely to achieve the Pork CRC aspirational GHG emission target of 1kg CO2e kg HSCW-1 by 5% of the Australian pork industry. This approach may also enable subsequent research, on what is a less mature technology, on growing algae for pig nutrition. Improved disinfection of wastewater with reduced ammonia for piggery reuse was realised and highlighted in the review as an additional benefit for pig health and profitability.

Application to Industry

The review clearly articulated the research needs to exploit pig slurry as an energy source, recycle nutrients and water and improve pig health via the practical application of algal technology. The LCA supported this approach to assist in meeting the aspirational target of 1kg CO2e kg HSCW-1 by 5% of the Australian pork industry. Considering the fate of pathogens the reuse of inadequately treated wastewater for shed flushing and washdown exposes both pigs and humans to these and commensal organisms. Evidence suggests that reducing ammonia and pathogens in effluent used for flushing would reduce pig morbidity, decreasing feed costs from the associated lower growth rates which delay attainment of slaughter weight. Preliminary analysis for a 2000 sow farrow-finishing unit suggests, potential reduction in operational costs in excess of $600k per year if wastewater low in ammonia, commensals and pathogens is used for shed flushing and washdown.

Research Summaries for Subprogram 4A continued

PROJECT 4A–102: EVALUATION OF ALGAL MEAL AS AN ENERGY AND PROTEIN SOURCE IN PIG DIETS

Project Leader:
Mr David Henman

Project Participant:
Rivalea Australia

Aims and Objectives

Micro and Macro Algae are now a focus of developing a sustainable resource that can be used to supply a substantial part of the diet of all phases of pig production. The production of Algae is rapidly gaining acceptance as a method of reducing the carbon output of many heavy industries that produce significant carbon output to the environment. The Algal product that is produced as a by-product is available to the animal industries as a feed ingredient. Despite the potential use of algae as a valuable protein source for animals, there has been very little research on the evaluation of algae as a feed ingredient for animals over the past 20–30 years.

80 male weaners (PrimeGro™ genetics) were weaned at an average age of 26 days (average weight 7.2 kg ± 0.89 kg) and transferred into individual weaner pens. Pigs were offered a commercial starter diet for an initial 5-day period to acclimatise to solid feed and the new environment. After this acclimatisation period, all pigs were individually weighed and allocated to one of the test diets:

1] 0% Algal meal control diet.

2] 10% Algal meal diet (Algal meal sourced from Multiculture grown at James cook University).

The 10% addition of the Algae to the diet was a direct replacement for Canola meal in the diet.

Key Findings

The inclusion of algal meal once formulated correctly into the diet is unlikely to have any major negative effects on the performance of the piglets although the higher level of scouring would need to be examined in a commercial environment and with algae formulated into the diet. The high level of chloroplasts in Algae maybe causing this effect and this would be an important area to investigate.

Application to Industry

The potential users of the new information include researchers and nutritionists that are looking at the potential of Algae for animal feed.

PROJECT 4A–105: AEROBIC AND ALGAL TREATMENT OF PIGGERY WASTEWATERS FOR HEAT RECOVERY, EFFLUENT TREATMENT AND WATER REUSE

Project Leader:
Professor Howard Fellowfield

Project Participants:
Flinders University

Aims and Objectives

Algae grow prolifically, in suitable wastewaters while using carbon dioxide. The algal biomass can be converted on-site to energy, offsetting CO_2 emissions from fossil fuel derived electricity and reducing GHG emissions. Anaerobic lagoons are the predominant treatment systems employed within the Australian pork industry. The effluent is reused within the production environment. It is generally of poor quality containing high concentrations of ammonia and microorganisms. These have been shown to have an adverse effect on pig health; potentially increasing time and associated feed costs to achieve slaughter weight. High concentrations of ammonia also inhibit algal growth. Aerobic treatment of effluent from anaerobic lagoons was identified as a technology, which could convert ammonia into nitrate removing its adverse impact on both pig health and algae. The integration of anaerobic – aerobic – algal treatment of piggery wastewater was investigated at Roseworthy Piggery, Adelaide.

A research pilot plant was constructed comprising a 13m3 aerobic reactor with a 1.1 kW aerator. Aeration, to convert ammonia to nitrate, is controlled by continuous monitoring of dissolved oxygen to reduce energy consumption. The aerobic treatment is followed by nutrient removal and disinfection in a 59 m^2, 19 m3 at 0.3 m depth high rate algal pond (HRAP). The HRAP is a single pass raceway, with a maximum operational depth of 0.5m, mixed by a paddlewheel powered by a 0.75 kW motor and gearbox. The pilot plant is operated and monitored remotely using cloud based software.

Key Findings

Unfortunate delays in receiving permissions and leasing agreements significantly delayed construction. The pilot plant was commissioned. The aerobic reactor was commissioned and nitrification of anaerobically pre-treated slurry was clearly demonstrated. Early estimates suggest an energy consumption between 1.4–2.2 kW d -1.

Application to Industry

Further significant evaluation is required to determine treatment performance (nutrient removal and disinfection) and the potential for algal biomass energy recovery. The pilot plant is a unique durable asset to further research to enhance the quality of wastewater reused in piggery operations with the objective of reducing emissions, generating on-site energy and improving pig and occupational health.

PROJECT 4A–106: GROWTH, DEVELOPMENT AND USE OF ALGAE GROWN ON UNTREATED AND UNDILUTED ANAEROBIC DIGESTION PIGGERY EFFLUENT

Project Leader:
Dr Navid Moheimani (Murdoch University)

Project Participants:
Professor Michael A Borowitzka, and Professor John Pluske (Murdoch University), Dr Sasha Jenkins (University of WA)

Aims and Objectives

The main aims of this project were to test:

1] Sustainable cultivation of microalgae on undiluted and non-treated anaerobic digestion piggery effluent.

2] Microalgae growth optimisation as well as nutrient and CO_2 removal.

3] Nutrient composition of produced biomass and test the suitability of grown algae as a protein feed for pigs.

4] Co-anaerobic digestion of produced biomass with piggery effluent.

5] Preliminary techno-economics.

Key Findings

Waste slurry produced from the primary treatment of anaerobic digestion of raw piggery effluent (ADPE) employed in most piggeries is still limited by elevated concentrations of ammonium that can be toxic to most living organisms.

The integration of microalgae cultivation as a subsequent step to anaerobic digestion has been proposed as a potential component of the Australian wastewater management strategy for piggeries to treat ADPE efficiently. In accordance, this project evaluated the growth, development and use of microalgal grown on undiluted and sand filtered ADPE. More specifically, in this work, we studied the long-term cultivation and growth of an isolated microalgal consortium consisting mainly of *Chlorella* sp. and *Scenedesmus* sp. that were capable on growing in undiluted ADPE while simultaneously optimising limiting factors to their growth and productivity. Outdoor growth of the mixed algal culture on ADPE using raceway ponds showed potential for up to 63.7 ± 12.1 mg $N\text{-}NH_4^+$ L^{-1} d^{-1} ammonium removal from ADPE. The microalgal consortium was dominated by *Chlorella* sp. and was stable when grown between 800 and 1600 mg $N\text{-}NH_4^+$ L^{-1} ADPE. Average microalgal biomass productivity at 800 mg $N\text{-}NH_4^+$ L^{-1} ADPE during five weeks of semicontinuous growth was 18.5 mg ash-free dry weight L^{-1} d^{-1}. Doubling the ammonium concentration from 800 to 1600 mg $N\text{-}NH_4^+$ L^{-1} resulted in a 21% reduction of productivity, however when cultures were grown at 1600 mg $N\text{-}NH_4^+$ L^{-1} with the addition of CO_2 at pH = 8 led to a 17% increase in biomass productivity.

Comparison between different algal cultivation systems (i.e. open ponds and closed photobioreactors) and different mixing mechanisms (paddle wheel and jets) were also evaluated to optimise the microalgal growth and increase nutrient removal rate. Two Biocoils, (airlift and submersible centrifugal pump driven) were tested. Despite several attempts in using airlift-driven Biocoil (e.g. modification of the sparger design), no net microalgae growth was observed due to intense foaming and loss of culture. Overall, similar average ammonium nitrogen removal rates in the submersible pump Biocoil (24.6±7.18 mg NH_4^+-N L^{-1} day^{-1}) and raceway pond (25.9±8.6 mg NH_4^+-N L^{-1} day^{-1}) was achieved. The average volumetric biomass productivity of microalgae grown in the Biocoil (25.03±0.24 mg AFDW L^{-1} day^{-1}) was 2.1 times higher than in raceway pond. While no significant differences were detected between the cultivation systems, the overall carbohydrate, lipid and protein contents of the consortium averaged 29.17±3.22, 32.79±3.26 and 23.29±2.15% AFDW respectively, revealing its suitability as animal feed or potential biofuel feedstock.

We also compared the turbulent mixing and nutrient removal efficiency of conventional paddlewheel driven raceway ponds (PWP) with customised jet nozzle mixed raceway pond (JNP) on microalgae grown in ADPE. Overall, the concentration of microalgae consisting mainly of Cyanobacteria and *Chlorella* sp. trended higher in the JNP over the PWP with the visible absence of diatoms in JNP. The ammonium removal rates (%) were also found to be significantly higher in the JNP (36.8 ± 3.93) than the PWP (23.5 ± 4.42).

Also as part of this study, the quality and suitability of grown biomass as a potential feedstock to pigs was assessed. We evaluated the nutritional value, pathogen load, *in vitro* digestibility and potential physiological energy (PPE) of ADPE-grown microalgae as a potential pig feedstock. Pathogen load of ADPE-grown microalgae was within regulatory limits. Crude protein and essential amino acid content was comparable with a number of other vegetable protein sources for pig, but was slightly lower in some essential amino acids than soybean meal (SBM). Fatty acid composition of the microalgae was favourable with an omega-3: omega 6 ratio of ~1.9, which may offer potential for value-adding uses in some diets. *In vitro* digestibility, the digestibilities were higher in faeces than at the ileum and were lower for the defatted microalgae biomass. The (theoretical) net energy values of ground and bead-milled algae samples were found to be comparable to conventional de-hulled sunflower meal used as a feeding ingredient for pigs but were lower than SBM.

The feasibility of co-digesting manure and algae was also evaluated. In particular, we identified pre-treatment requirements for the algae, potential toxicity effect or inhibition of the microalgae grown on ADPE and optimal manure to algal loading ratio involved in the co-digestion process. The results suggested that the unbroken and broken algal sample with lipid removal treatments used did not significantly affect methane production, but broken cells yielded the lowest methane production. This suggests that it would be preferable to use algae unaltered.

The suitability of the ADPE-grown algal biomass as a fertilizer for crops and raw material for anaerobic digestion was also studied. A pot experiment was carried out with the following treatments: microalgae biomass and NH_4NO_3 at five N equivalent levels for 6 weeks. Wheat (*Triticum aestivum* L.) was used as the host plant in a randomised block design in three replicates. Utilisation of the two N sources significantly improved the dry-harvest for wheat plants at the greatest application level compared with the control. The N sources and levels significantly affected the N uptake in shoots. The application of microalgae biomass revealed significant lower N in shoots compared to the NH_4NO_3. Results of this study indicated that microalgae biomass is an available nitrogen source for plants.

Finally, the cost assessment of integrating microalgae cultivation in existing piggeries to treat ADPE was conducted on multiple plausible scenarios to identify the economic viability of the proposed process. We conducted a preliminary techno-economics of microalgae cultures grown in paddle wheel driven raceway ponds and tubular photobioreactors for the treatment of undiluted ADPE at a medium (400 sows) and a large (2,000 sows) sized piggeries. The results indicated

Research Summaries for Subprogram 4A continued

that the lowest production cost was achieved when productivity was highest. The most economical outcome was achieved for a large sized piggery using paddle wheel driven raceway ponds.

Application to Industry

Our findings highlighted the potential use and promise of the isolated *Chlorella* and *Scenedesmus* consortium for the bioremediation of ADPE and biomass production. To the best of our knowledge, this is the first study evaluating the potential of using microalgae to treat undiluted ADPE. Based on the outcome of the current project, raceway ponds can be recommended to the industry. While there is a need for further optimisation at pilot level, successful microalgae growth on ADPE indicates the potential of using these organisms for not only treating ADPE but also as a potential source of animal feed, fertiliser or bioenergy (methane) production. The generated biomass can also be sold as aquaculture feed. We highly recommend the Pork Industry to adopt the outcomes of this project. However, there is a need for further onsite pilot and demonstration before commercialisation.

PROJECT 4A–107: BIOPROSPECTING AND GROWTH OF MACROALGAE ON ANAEROBIC DIGESTION PIGGERY EFFLUENT (ADPE)

Project Leader:
Dr Navid Moheimani

Project Participants:
Murdoch University and Western Australian Herbarium, Science Division, Department of Parks and Wildlife

Aims and Objectives

To evaluate the growth potential of several locally isolated macroalgae in ADPE under outdoor climatic conditions and investigate their nutrient removal rates and biochemical composition.

Key Findings

A consortium of two macroalgae, *Rhizoclonium* sp. and *Ulothrix* sp. were isolated and could efficiently grow in the ADPE with concentration of up to 248.4 mg NH_3. N L^{-1}. Macroalgal consortium growth could not be maintained at higher ADPE concentration. Maximum ammonium removal rate (30.6 ± 6.50 mg NH_4^+-$NL^{-1}D^{-1}$) was achieved at ADPE concentration equivalent to 248.4 mgNH_4^+-NL^{-1}. Mean biomass productivity of 31.1 ± 1.14 g AFDW $m^{-2}D^{-1}$ was attained. Total carbohydrate and protein contents ranged between 42.8–54.8 and 43.4–45.0% (ash-free dry weight), respectively, while total lipid content was very low.

Application to Industry

The findings highlighted the potential use and promise of this *Rhizoclonium* sp. and *Ulothrix* sp. consortium for the bioremediation of ADPE and biomass production. To the best of the researcher's knowledge, this is the first study evaluating the potential of using macroalgae to treat ADPE. While there is a need for further optimisation, successful macroalgae growth on ADPE indicates the potential of using these organisms for not only treating ADPE but also as a potential source of animal feed or bioenergy (methane) production.

PROJECT 4A–108: COMPARISON OF DIFFERENT CULTIVATION SYSTEMS FOR TREATING ANAEROBIC DIGESTION PIGGERY EFFLUENT (ADPE)

Project Leader:
Dr Navid Moheimani (Murdoch University)

Project Participants:
Professor Parisa Bahri, Dr David Parlevliet, Professor John Pluske (all Murdoch University)

Aims and Objectives

Project aims:

1] Design and construct prototypes of inclined thin layer plate photo-bioreactor and inclined open pond systems.

2] Compare the growth, biomass productivity and nutrient removal (C, N and P) rates of isolated microalgae on inclined pond against paddle wheel driven raceway pond.

3] Optimising growth in both cultivation systems for maximum nutrient removal rates.

4] Analyse the nutrient composition of algal biomass.

5] Undertake a cost-benefit economic assessment and CO_2 bioremediation of large scale production.

Key Findings

1] When operated at 1 cm depth, algal culture grown on ADPE in an inclined pond showed higher volumetric biomass productivity and nutrient removal rates compared to culture grown in a raceway pond with the same surface area.

2] Due to large volume of culture in raceway pond, the overall aerial biomass productivity and nutrient removal rate of algal culture grown in raceway pond was significantly higher than inclined pond.

3] *Chlorella* and *Scenedesmus* were the most dominant species in both ponds. During batch growth, *Chlorella* dominated the culture in both ponds. However, when ponds were operated semi-continuously, *Scenedesmus* became the dominant species.

4] Efficiency of Ammonium removal rate in inclined pond was 1.4 times greater than the culture in raceway pond.

5] Algal culture in raceway pond showed significantly higher lipid content compared to the culture in inclined pond.

6] Based on the overall biomass productivity and nutrient removal rate, raceway ponds were found to be a more efficient cultivation system than inclined ponds.

Application to Industry

Our results clearly indicate that both raceway and inclined ponds could be used for treating ADPE. Based on the outcome of the current project, raceway ponds can be recommended to the industry. We have so far treated ADPE using 1 m^2 and 11 m^2 raceway ponds. We are currently assessing the economics and design of a large-scale treatment facility based on the outcome of our studies through Pork CRC 4A–106 project (to be completed by February 2018). A detailed pilot and demonstration study is the next obvious stage towards commercialisation of our proposed process.

PROJECT 4A–109: CO-CULTIVATION OF MICROALGAE AND MACROALGAE FOR THE EFFICIENT TREATMENT OF ANAEROBIC DIGESTION PIGGERY EFFLUENT (ADPE)

Project Leader:
Dr Navid Moheimani
(Murdoch University)

Project Participant:
Dr Ashiwin Vadiveloo
(Murdoch University)

Aims and Objectives

1] Develop a sequential method for the efficient treatment of anaerobic digestion piggery effluent (ADPE) using both microalgae and macroalgae.

2] Evaluate the growth, biomass productivity, photo-physiology and nutrient removal (C, N and P) of microalgal and macroalgal treatment when grown individually and when combined together in sequence.

3] Growth optimisation for maximising biomass productivity and nutrient removal rates.

Key Findings

When grown by its own, the macroalgae Cladophora sp. was able to grow on anaerobic digestate piggery effluent (ADPE) with up to 150mg L^{-1} NH_4^+. On the other hand, microalgae consortium consisting of Chlorella sp. and Scenedesmus sp. was able to successfully grow and treat undiluted ADPE.

Nevertheless, when co-cultivated together, despite the different conditions evaluated, the growth and photo-physiology of Cladophora sp. was found to decline and resulted in culture loss due to the dominancy of the microalgal culture. This was mainly due to microalgal higher efficiency in competing for nutrients and available resources.

Subsequently, based on this outcome, an outdoor inclined reactor was customised to evaluate the potential use of attached macroalgal culture as a way of scrubbing available nutrients and microalgae biomass from ADPE post microalgal treatment. Although, the inclined system was very efficient in scrubbing and harvesting microalgae biomass, nevertheless, nutrient removal rates (i.e. ammonium and nitrate) of the co-cultivated system was much lower than the control which was operated using macroalgae only.

Application to Industry

In this study, despite multiple different approaches and cultivation systems, both algal groups were unable to co-exist for efficient growth in ADPE due to direct competition for available resources and the negative interaction of both algal groups. Nevertheless, through this study, it has been demonstrated that macroalgae could be potentially used for harvesting microalgae grown in ADPE. Thus, there is great potential in exploiting microalgae for the bioremediation of undiluted ADPE and biomass production while targeting the use of macroalgae as a cost-effective harvesting agent/option for microalgae grown in ADPE.

Subprogram 4B: Enhanced Use of Traditional Protein and Energy Sources

Subprogram 4B built on specific outcomes from the first Pork CRC, including development and commercialisation of real–time near infra–red (NIR) analysis of grains and protein meals. Research continued on innovative processing technologies to improve the utilisation of grains and feeds for pigs.

PROJECT ID	TITLE
4B–101	Improved Triticale Production through Breeding
4B–102	Development of adapted field pea varieties for pork producing regions in northern and southern Australia
4B–103	Selection of feed wheat and (or) barley varieties for the Australian pig industry
4B–104	Improving the efficiency of pig feed manufacturing and application of additives
4B–105	Screening of new lines of cereal grains for inclusion in NIRS calibrations for predicting nutritional quality of feed ingredients for pigs
4B–106	Quantification of the variability in the amino acid and reactive lysine content of soybean meal and development of NIR calibration for rapid prediction of reactive lysine content
4B–107	Processing methods of grains – Extension
4B–108	Increasing amino acid digestibility by Subtilisin protease in Australian Protein meals
4B–109	Sulphur amino acid supplementation to improve herd feed efficiency in commercial grower production systems
4B–110	Further development of a reactive lysine NIR calibration for soya bean meal
4B–111	Improving the utilisation of cereals and pulses by pigs: the effect of grain type, milling conditions and processing technology
4B–112	Optimising particle size distribution for grains and protein sources
4B–115	Advancing Berkshire triticale supply for the Australian pig industry
4B–117	Strengthening the AusScan pig DE, DE intake index NIR calibrations *(confidential)*
4B–118	Canola meal NIR calibration implementation
4B–119	AusScan NIR Grain Standards Development & User Calibration Upgrade
4B–120	Commercial validation study for sulphur amino acid (SAA) requirement in finisher pigs
4B–121	Effect of grind size in typical Grower Finisher diets under commercial conditions
4B–122	Predicting the effects of fibre, grain digestion rate and the ileal brake on voluntary feed intake
4B–123	Measurement of grain enzyme diffusion rates and grain threshold particle size calculator
4B–124	Re-engineering of grain grinding/sieving in commercial mills and application of software

Research Summaries for Subprogram 4B

PROJECT 4B–101: IMPROVED TRITICALE PRODUCTION THROUGH BREEDING

Project Leader:
Jeremy Roake

Project Participants:
Plant Breeding Institute, Cobbitty

Aims and Objectives

Triticale is on average 10% higher yielding than wheat, and is much more tolerant to abiotic stresses. These include low pH soils (4.0–4.5) which are high in aluminium, high boron soils, and soils low in zinc and copper. The project had two aims. These were:

1] To evaluate hybrid triticale's produced from the previous project.

2] To evaluate inbred varieties to identify higher yielding, triple rust resistant lines.

Key Findings

The hybrids did not express sufficient heterosis to justify commercial production. Though heterosis levels were 10–20% higher than the old variety Tahara, they were similar or lower than the current top inbred varieties. This was thought to be due to the low levels of diversity present in the triticale germplasm pool. Three inbred lines, ISR936-144, ISR936-263, and ISR936-269 were identified as possible candidate lines for release. Each line had high yield and resistance to stem, leaf, and stripe rust.

Based on results from multi-location trials conducted by AGT, it was decided to increase ISR936-263 as it performed best at evaluation sites in New South Wales, Victoria, and South Australia. The grain quality of the three lines when compared to Berkshire, were equivalent or better for both faecal and ileal digestibility, % starch, Englyst neutral detergent fibre, and insoluble and soluble non-starch polysaccharides.

Application to Industry

The release of a new high yielding, triple rust resistant line will improve the productivity of triticale in areas relevant to the pork industry. This will increase economic returns to grain producers and improve the reliability of supply of triticale to the pork industry.

PROJECT 4B–102: DEVELOPMENT OF ADAPTED FIELD PEA VARIETIES FOR PORK PRODUCING REGIONS IN NORTHERN AND SOUTHERN AUSTRALIA

Project Leader:
Mr Stephen Moore (University of Sydney),
Mr Adrian Russell (Plant Research NZ)

Aims and Objectives

The overall aim of this project was, utilising a targeted crossing, selection and evaluation program, to produce high yielding, disease resistant, regionally adapted varieties with appropriate grain quality characters which could be commercially competitive with alternative pulses and other crops grown in the target regions.

The methods adopted for the implementation of this project were:

a] Germplasm creation & early generation development.

b] Field experimentation – experimental sites for yield, phenology & disease evaluation in both region North and South were selected and representative of the target regions.

c] Grower advanced trials – to evaluate performance under commercial conditions.

d] Extension and communication – a number of methods were utilised to disseminate information to grain growers, pork producers, agronomists, consultants, researchers and marketers.

e] Project management – to comply with reporting requirements of the CRC.

Key Findings

The key outcomes of this project included:

- Two commercially field pea varieties for the north (Maki, 2009 & CRC Walana, 2011).
- A number of high yielding advanced lines which have the potential for varietal release in both the northern and southern regions.
- A significant & diverse gene pool consisting of high yielding, stable, disease resistant germplasm which is adapted for pork producers in both the northern region and South Australia.
- Diverse (and different) early generation progenies from both PRNZL and University of Sydney crossing programs.
- Ongoing phenology experiments which have facilitated the development of agronomy packages and provided comparative yield and gross margin data for pulses in the north.
- Population development of a number of grain quality traits including Trypsin Inhibitor Activity (TIA), High Metabolisable Energy (HME) and a pea albumin deficient mutant (PA2).
- Communication of the results of this project to grain growers, pork producers, agronomists and marketers via advisor and grower updates, field days and crop inspections, articles in rural and popular press, radio and television.

Application to Industry

The key industry benefit of this research has been the development of a diverse set of germplasm with broad adaptation in region north and more specific adaptation in region south. This germplasm has and can continue to be used to produce a commercially viable, locally produced source of protein for the pork industry in northern NSW, Qld and parts of South Australia.

Research Summaries for Subprogram 4B continued

PROJECT 4B–103: SELECTION OF FEED WHEAT AND/OR BARLEY VARIETIES FOR THE AUSTRALIAN PIG INDUSTRY

Project Leader:
Professor John Pluske

Project Participants:
Murdoch University, DAFWA and InterGrain

Aims and Objectives

Improving reliability and consistency in energy and protein supplies for pig diets will benefit Australian pig producers. Such benefits are likely to include:

1] Reduced variation in the annual cost of pig feed.

2] Reduced total cost of pig feed.

3] A wider range of feed ingredients available to more producers.

4] A closer match of diet specifications to pig requirements.

To this end, the CRC for an Internationally Competitive Pork Industry initiated an Innovative Grain Production research program. Expected outcomes of this program focused on delivering commercial quantities of cereals (and pulses) of high yield and high energy content and acceptable nutritional characteristics for pigs, with cost-effective agronomy, and appropriate marketing arrangements for grain and pig producers.

The objectives of this particular project were to determine if breeding varieties of wheat and barley specifically for the pig industry, and with enhanced yield and digestible energy (DE) contents, could be achieved. An additional aim was to gain a greater understanding of the nutritional characteristics of grain, in particular wheat, that affect the DE content.

Methodology

This research project involved the collaborative support of Murdoch University, the Department of Agriculture and Food WA (DAFWA) and InterGrain (IG). Under the guidance of IG, breeding programs for wheat and barley lines were conducted in Southern Australia. These lines were assessed for yield as well as characteristics such as starch, protein, fibre components and DE content (using AusScan) to generate a valuable data set of wheat characteristics important to the pig industry.

Key Findings

Breeding a specific feed wheat or barley to outcompete existing varieties in both yield and DE content was not possible. However, analyses of data from this research indicated that there is an interaction between site and DE indicating that environmental factors contribute to the level of DE in grain. There is also evidence to suggest that varying levels of DE in grain may be determined more by a variety effect than a site effect. Moreover, the findings from this research support the NIRS testing of grain varieties destined for pig feed. In addition, and analysing the NIRS spectrum associated with other grain characteristics, such as hardness, indicated that environmental conditions at a site can have an impact on the grain quality. The main strategy to arise from this research is continued support of NIRS analyses. Results suggested that there is variation in DE in grain and by using AusScan, pig producers could better select their inputs and hence achieve a more cost effective output. With on-going development of the AusScan technology it could be expected that its associated cost will decrease and therefore accessibility should increase.

Application to Industry

Results suggested that DE in grain is determined by genotype and environment and hence it would be rational for pig producers to consider high DE wheat, barley and triticale varieties, subject to assessment with AusScan, when making grain purchasing decisions. By knowing the DE of varieties, producers can make better decisions about what grain to purchase and the effect on DE of mixing different varieties. This information would be relatively simple and inexpensive to obtain and could result in significant cost reductions for producers.

In terms of improving NIRS calibrations methods, the results supported removing the environmental differences to enable a more accurate prediction of grain-traits than that currently available.

PROJECT 4B–104: IMPROVING THE EFFICIENCY OF PIG FEED MANUFACTURING AND APPLICATION OF ADDITIVES

Project Leader:
Dr Peter Sopade

Project Participants:
University of Queensland, Ridley AgriProducts Pty. Ltd., Rivarina (Australia) Pty. Ltd. (formerly Better Blend Stockfeeds), Rivalea (Australia) Pty. Ltd.

Aims and Objectives

1] To reduce production costs for high-quality pork through understanding how commercial processing conditions affect mill throughput, processing energy efficiency, product durability and the nutritional value of pig feed.

2] To develop NIR calibrations and other tools which can be used by feed manufacturers to adjust processing conditions for specific grain samples and ingredient mixtures to improve manufacturing efficiency, product durability and nutritional value for pigs.

3] To determine whether NIR calibrations of the final processed feed can be developed to reliably predict factors that determine animal performance.

Key Findings

- Characteristics of individual grains that influence pellet quality and nutritional value are not additive in mixed diets, and sorghum characteristics can dominate.
- The size of grain particles significantly affected the RVA, *in vitro* starch digestion parameters, pellet hardness and durability, and efficiency of feed use by young pigs.
- Regrinding large particles increased the efficiency of feed use by young pigs by up to 22% with sorghum based diets and 15% with barley based diets.

- Low conditioning temperature for an extended period significantly increased the rate of *in vitro* starch digestion and efficiency of feed use by growing pigs.
- Addition of surfactants to diet mixtures produced small and variable results in mills.
- There were significant differences between the soft, hard and naturally sprouted wheats in energy use during processing, pellet quality and weaner feed efficiency.
- Significantly more energy was used during processing and pellet formation for the soft wheat diets compared with the hard or naturally sprouted wheat diets.
- The sprouted wheat pellets were significantly softer and appeared less durable than either the soft or hard wheat pellets.
- Although feed consumption for pigs offered the sprouted wheat diets was greater than for pigs offered the soft or hard wheat diets, efficiency of feed use was 16% less than the soft wheat diets. There was no difference between the soft and hard wheats in efficiency of feed use.
- Increasing conditioning temperature from 60°C to 80°C significantly reduced the efficiency of feed use in weaner pigs by 16%.
- *In vitro* starch digestion parameters strongly correlated with efficiency of feed use, suggesting the *in vitro* assay can be used to rapidly screen feed products.
- Preliminary NIR calibrations developed from scans of the pellets reasonably predicted Faecal DE content, *in vitro* starch digestion parameters and physicochemical characteristics of the pellets.

Application to Industry

- Process control during pig feed manufacture (milling, conditioning, etc.) have marked effects (10–22%) on the efficiency of feed use by pigs.
- Factors affecting the efficiency of pig feed processing are known, but would be best applied in industry through a spreadsheet model that is being developed.
- Availability of rapid *in vitro* techniques that predict animal performance.
- Confirmation of differences between NIR calibrations for mash and pellet diets.
- Availability of NIR calibrations for pellets to accurately predict animal performance.

PROJECT 4B–105: SCREENING OF NEW LINES OF CEREALS GRAINS FOR INCLUSION IN NIRS CALIBRATIONS FOR PREDICTING NUTRITIONAL QUALITY OF FEED INGREDIENTS FOR PIGS

Project Leader:
Dr Peter Sopade

Project Participants:
University of Queensland, Kelspec Services, Symbio Alliance

Aims and Objectives

To improve the accuracy and robustness of NIR calibrations for predicting the energy content of cereal grains for pigs.

Key Findings

- The diet pelleting process accounted for more than 50% of the non-grain variation in Faecal DE measurements and reinforced the need for partial replication of the pelleting process in pig digestibility experiments.
- Highly significant ($P<0.01$) differences were obtained in Faecal DE values between and within grain types (wheat, barley, triticale, sorghum, maize).
- Natural paddock germination tended to reduce the Faecal DE content of barley and wheat, while artificial germination of sorghum for 24 h increased Faecal DE content by approximately 1 MJ/kg as fed, but continuing germination for 48 h reduced the response to approximately 0.5 MJ/kg.
- Adding grains from the Pork CRC projects to the original set used to develop the NIR calibration in PGLP, increased the accuracy or precision.
- The latest NIR calibrations can predict Faecal DE with a standard error of ± 0.26 MJ/kg as fed compared with ± 0.38 MJ/kg as fed in the PGLP calibration.
- The latest calibration can predict Faecal DE content within 0.52 MJ/kg as fed with 95% confidence.
- There is further opportunity to improve the robustness of the calibration by increasing the PRD value above 3.0. The current RPD of 2.65 is regarded by NIR specialists as being good for predicting values for unknown samples, but should be improved by adding more maize and other cereal grains to the calibration.
- Comparison of calibrations based on whole grain scans with those based on milled grain scans suggests there is little difference in calibration statistics or the mean values predicted by each calibration for all grains used in PGLP and Pork CRC experiments.
- For most grains, different values were predicted from calibrations based on whole grain scans compared with those from milled grain calibration.
- Milled grain calibrations can be removed from the AusScan suite, and whole grain calibrations should be the focus because it is faster, removes milling effects/differences and does not involve additional expense of grain milling.

Application to Industry

The upgraded whole grain calibration should be adopted by AusScan and the milled grain calibration removed from commercial application.

Research Summaries for Subprogram 4B continued

PROJECT 4B–106: QUANTIFICATION OF VARIABILITY IN THE AMINO ACID AND REACTIVE LYSINE CONTENT OF SOYBEAN MEAL AND DEVELOPMENT OF A NIR CALIBRATION FOR RAPID PREDICTION OF REACTIVE LYSINE CONTENT

Principal Investigator:
Dr Jae Cheol Kim (DAFWA)

Aims and Objectives

Lysine in soybean is highly susceptible to heat damage during the oil extraction and significant amount of the lysine in soybean meal (SBM) is delivered in an unavailable heat damaged form. The level of heat damage is dependent on the amount of lysine and reducing sugars in the soybean as well as the degree and duration of heat treatment during the oil extraction process. The heat damaged and unavailable lysine cannot be discriminated from the bioavailable reactive lysine using the conventional total lysine analysis. Therefore, there is a need to establish reactive lysine analysis in an Australian laboratory and determine the variation in reactive lysine in SBM samples. Based on the collected data, the ultimate aim of this project was to develop a NIR calibration for accurate, rapid, and economic prediction for reactive lysine in SBM.

Methodology

1] A reactive lysine assay was successfully established and validated against results obtained from an external laboratory.

2] Sample collection: To collect a wide range of SBM, a total of 155 SBM samples from 31 shipments that originated from Brazil, Argentina, USA, and India were collected at Inchon Port, South Korea. A feed mill in China was liaised with and collected 24 SBM samples (3 weekly samples of 2 kg each from 8 SBM factories). A further 30 SBM samples (weekly aggregated samples for 30 weeks) were collected from a feed mill in WA (Wesfeeds, Welshpool, WA). From this protocol, a total of 209 samples were collected from a range of suppliers.

3] A NIR calibration for reactive lysine in SBM was established using a FOSS XDS NIR spectrophotometer.

4] An *in vitro* ileal digestibility study was conducted with range of heat treated SBM to establish regression equations for apparent, standardised and true ileal digestible reactive lysine content.

Key Findings

1] Identified a 27% variation in reactive lysine content across all samples (21.9 g – 30.1 g/kg as is basis) and 13% variation in within shipment samples, indicating the danger of spot-sampling to analyse reactive lysine content and emphasising a need for rapid prediction tool.

2] Prediction of reactive lysine from total lysine content was unreliable (R^2=0.52).

3] Established a NIR calibration for reactive lysine prediction (R^2=0.86).

4] Prediction includes apparent, standardised and true ileal digestible reactive lysine contents along with total reactive lysine content.

Application to Industry

The calibrations are available through AuNir and AusScan on-line.

PROJECT 4B–107: PROCESSING METHODS OF GRAINS – EXTENSION

Project Leader:
Dr Peter Sopade
(University of Queensland)

Aims and Objectives

Previous research within the Pork CRC demonstrated that 2–4 MJ/kg of energy in cereal grains is not digested in the small intestine, but fermented in the hind-gut with considerable loss of energy to the pig. Material flowing from the small intestine was shown to consist of intact, large grain particles. Enzyme diffusion rates and therefore digestion rates were found to decrease with the square of particle size, with a 2-fold increase in particle size resulting in a 4-fold decrease in digestion rate. Enzyme diffusion rates were also affected by cereal type, with rates being approximately half for sorghum compared with barley particles of the same size.

Conventional hammer-milling of cereal grains results in a significant proportion of large particles. Hence, sieving off and re-milling large particles was shown to increase the efficiency of feed use by 12–22% in weaner pigs and by 8–11% in grower pigs. The

higher values were for sorghum and the lower values for barley.

Grain particle size distribution was surveyed in several commercial feed mills and home mixers to determine the effects of mill type on particle size variability and proportion of large particles in commercial pig feeds. An *in vitro* assay was developed to determine the rate of protein digestion in a range of protein meals including field peas, meat meal, soybean meal, sunflower meal and sorghum.

Key Findings

There were large variations in cereal grain particle size distribution between mills. Most mills produced a substantial proportion of ground grains that had particles estimated to be too large for complete digestion in the small intestine of pigs. Hammer mills produced the widest distribution in particle size, whereas roller mills produced the lowest variation in particle size. Roller mills produced the greatest proportion of large particles. Disc mills tended to produce more fine particles than other mills, but size distribution depended greatly on the gap between discs.

An *in vitro* protein assay was successfully developed. The rate and extent of protein digestion was affected by protein source (greatest for meat meal and least for field peas) and also particle size. Protein digestion rate was also inversely related to the square of particle size, but this relationship did not always apply to the mean sample size as it depended on the actual particle size distribution.

A prototype for a cheap, easy to use hand held sieving device was developed and tested at commercial enterprises. A spreadsheet applicable for smart phones and tablets was developed to guide feed millers in the correct direction to improve the particle size distribution of milled products.

Further research is required to better define the threshold maximum particle size for complete digestion in the small intestines for different cereal grains and protein sources.

Application to Industry

Commercial feed millers and piggery home mixers are already enthusiastic about using the manual sieving devise, because of the large improvements in feed conversion efficiency related to the proportion of large particles in feed mixtures.

PROJECT 4B–108: SUBTILISIN PROTEASE INCREASES DIGESTIBLE ENERGY IN SORGHUM AND WHEAT BASED DIETS

Project Leader:
Dr David Cadogan

Project Participants:
Feedworks,
University of Queensland,
University of Melbourne
and University of Sydney

Aims and Objectives

The main objective was to investigate if the Subtilisin protease can significantly improve protein digestibility and energy availability in Australian grown or produced protein meals and cereals. Protein meals such as meat meal, canola (solvent and expeller), sunflower and cottonseed meal, the legumes field peas and lupins and protein in feed grains such as sorghum generally have inferior essential amino acid availability compared to soybean. If effective the protease would reduce the reliance on imported soybean, and address the outputs for sub-program 4B of Pork CRC.

The second objective was to compare the effectiveness and accuracy of two digestibility makers, Celite (acid insoluble ash) and Titanium Oxide.

Key Findings

The in-vitro protein digestibility studies showed a significant enzyme elicited improvement in all test protein sources, except for soybean meal and canola meal, which exhibited protein digestibility of 91% and higher. There was a significant relationship between digestibility of protein in the tested raw materials and response to the protease, where the lower the protein digestibility, the greater the increase in protein release.

In diets containing the various protein sources the protease had no direct effect on increasing protein digestibility in the protein sources or the two cereals. However, there were trends towards the protease having a greater effect on the pea and meat meal based diets and the diets containing wheat.

The protease did, however significantly increase faecal DE across all treatments, with the largest effect in diets containing soybean and canola protein and sorghum, which is the opposite to the effects on protein digestibility. The protease increased the ileal DE of the sorghum diets containing soybean and canola by 1.05 MJ/kg. The corresponding increase in faecal DE was 0.55 MJ/kg.

Both digestibility markers produced similar means and standard errors.

Application to Industry

The two digestibility markers, Celite and Titanium Oxide were found to produce similar standard errors, with the Titanium Oxide producing slightly lower standard errors in the ileal digestibility coefficients and the Celite produced numerically better standard errors in the faecal digestibility coefficients. The advantage of Titanium Oxide is it is cheaper to add, a lower cost to analyse for and a more rapid procedure.

The protease supplementation costs circa $2.50 per tonne of feed. The average 0.35 MJ/kg increase in DE of the experimental diets (average of 0.44 MJ/kg DE for the sorghum and 0.20 MJ/kg for wheat diets), is worth approximately $8.75 per tonne if the cost of 1 MJ/kg DE is $25. Therefore the protease supplementation to improve DE only, is a 2:1 and 4:1 payback for wheat and sorghum diets, respectively, and there may be some small increases in protein digestibility as observed in the in-vitro study.

Research Summaries for Subprogram 4B continued

PROJECT 4B–109: SULPHUR AMINO ACID SUPPLEMENTATION TO IMPROVE HERD FEED CONVERSION EFFICIENCY IN COMMERCIAL GROWER PRODUCTION SYSTEM

Project Leader:
Dr Jae Kim,
(Department of Agriculture and Food of Western Australia)

Project Participants:
DAFWA and Rivalea Australia

Aims and Objectives

Pigs kept under commercial conditions are continuously exposed to microorganisms, and typically respond to these immune system challenges by elevated release of cytokines, increased metabolic use of protein, and decreased protein deposition. A mild bacterial disease challenge for example, may significantly alter nutrient partitioning from protein deposition to the synthesis of immune molecules, and hence the amino acids used for the synthesis of these molecules may become deficient in diets and limit maximum rates of protein deposition. Sulphur amino acids, especially cysteine, are one of the most abundantly used amino acids for synthesis of immune function-related molecules. A previous study indicated that when the pig's immune system is activated, a significant proportion of sulphur amino acids are re-directed and retained in non-protein compounds such as glutathione, while at the same time muscle protein anabolism is compromised. However, the role of sulphur amino acids on protein utilisation efficiency of finisher pigs grown in commercial production facilities, where pigs are continuously exposed to immune system challenges, has not been explored as yet. Therefore, the rationale for this project was that the current recommendation for SAA requirement based on empirical studies at a hygienic research facility may significantly underestimate the true SAA requirement for finisher pigs housed in less hygienic commercial facilities and significantly reduce herd feed conversion efficiency.

To determine the SAA requirement of finisher pigs housed in commercial pig production systems, two experiments were conducted. The first pilot experiment was conducted in a research facility (Medina Research Station) using an immune system activation model. Pigs (50-100 kg) received twice-weekly intramuscular injection of either sterile saline or E. coli endotoxin, to simulate conditions in a hygienic research facility or continuous pathogen exposure under commercial conditions, respectively, to compare the role of increasing dietary SAA on protein utilisation efficiency. The second experiment was conducted in a commercial farm (Rivalea Australian Pty Ltd), to validate the findings of the pilot study using a dose-response design.

Key Findings

The pilot study clearly demonstrated that SAA requirement expressed as a proportion of lysine for immune system activated pigs was 0.75 and was significantly higher than for healthy pigs at 0.55. Unlike healthy pigs, immune system activated pigs did not achieve maximum protein deposition (67 vs. 59 g/d, respectively) at the current recommended SAA level of 0.55. However, protein deposition rate in immune system activated pigs returned to the pre-infection level of 67 g/d when the dietary SAA:lysine ratio was increased to 0.75. Based on assumption that the E. coli endotoxin model represents the level of pathogen challenges in the commercial facility, the results of this pilot study indicate that increasing dietary SAA in commercial finisher pigs will significantly improve herd feed conversion ratio.

Results of the commercial validation study indicated that minimum feed conversion ratio and maximum carcass gain were achieved at dietary SAA:Lys ratio of 0.73.

Application to Industry

The findings have commercial implications. They suggest the SAA to Lysine ratio of grower-finisher diets probably should be set at a minimum of 0.6:1 and increased in situations where immune challenge is likely to be higher.

PROJECT 4B–110: FURTHER DEVELOPMENT OF A REACTIVE LYSINE NIR CALIBRATION FOR SOYBEAN MEAL

Project Leader:
Dr Jae Cheol Kim (DAWFA)

Project Participants:
Dr Bruce Mullan,
Dr John Black,
Mr John Spragg

Aims and Objectives

To improve prediction accuracy of soybean meal reactive lysine NIR calibration.

Key Findings

- In the current project we included 68 soybean meal samples and 25 soy protein concentrate samples into an updated calibration (total of 309 samples used in the calibration).
- The updated calibration provides the prediction of total and reactive lysine with the standard error of cross validations of ±1.02 g/kg and ±0.96 g/kg (as is basis), respectively, with R^2 of 0.94 and 0.95.
- These values mean that the total and reactive lysine contents of unknown soybean samples should be predicted with 95% confidence to be within 2.04 and 1.92 g/kg of the actual value.
- The RPD values for total and reactive lysine calibrations were improved from 1.59 and 2.32 to 3.35 and 3.94, respectively and the new NIR calibration offers a robust prediction for bioavailable lysine content in soybean meal and soy protein concentrate.
- In addition, the new calibration has the ability to predict apparent, standardised and true ileal digestible total and reactive lysine contents

in soybean meal and soy protein concentrate with similar accuracy.

- The calibration can also be used for soy protein concentrate.

Application to Industry

This calibration can be applied in commercial feed mills, nutrition labs and SBM trading companies to accurately evaluate the quality of SBM. Furthermore, use of predicted standardised reactive lysine content for diet formulation will improve nitrogen utilisation efficiency by the Australian Pork industry. In addition, use of this technology in the Australian pig industry will reduce nitrogen excretion into the environment. The calibrations are available via AusScan on-line.

PROJECT 4B–111: IMPROVING THE UTILISATION OF CEREALS AND PULSES BY PIGS: THE EFFECT OF GRAIN TYPE, MILLING CONDITIONS AND PROCESSING TECHNOLOGY

Project Leader:
Dr Peter Torley
(Charles Sturt University)

Aims and Objectives

Inefficiencies in the conversion of feed grains to live weight gain represent a major inefficiency for a pig industry where profit margins are dictated largely by the cost of feeding. The cost of processing of grain will depend on the number of steps required to normalise particle size and hardness to minimise the flow of particles through to faeces. The techniques discussed herein are designed to meet this goal.

Improving the efficiency with which starch stores in grain is converted to energy substrate to promote growth will lead to improvements in feed conversion efficiency. The need to control the heterogeneity of the size of grain particles without grinding too finely is important for efficient ration formulation to promote growth. The opportunities for the industry emanating from this review to improve grain processing and feeding use current technology but in novel ways.

Key Findings

The capital costs involve investments of up to $2million, which depending on throughput will involve depreciation costs of $0.63 (roller mill-opportunity 1) to $2.52 (extrusion equipment-opportunity 3) per tonne over 20 years while whole grain expansion capability (opportunity 4) may cost more than $1million.

Grain soaking may cost $40/tonne (opportunity 6). The design of multiple outlet interval or meal feeders will require innovative design for both the feeder and pen to maximise feed access around the clock at the time of day when pigs are most active metabolically (opportunity 6).

The goal is to synchronise the supply of amino acids and peptides with the supply of energy substrate at the time of day when they are most efficiently utilised for protein synthesis.

Application to Industry

The project identified cost effective techniques to equalise particle size in processed grains without decreasing it to the point that ulceration of the gastro-intestinal tract occurs. The final report is essential reading for nutritionists, producers and feed millers.

PROJECT 4B–112: OPTIMISING PARTICLE SIZE DISTRIBUTION FOR GRAINS AND PROTEIN SOURCES

Project Leaders:
Peter A Sopade,
Giang T Nguyen
and Michael J Gidley
(University of Queensland)

Aims and Objectives

Previous Pork CRC projects had showed that reducing the amounts of milled grain particles > 1mm in size (for sorghum, or 1.7 mm for barley) improves feed conversion ratios in both weaner and grower pigs. This project built on these findings by:

1] Evaluating the particle size distributions of milled grains currently used in feeds by both large and small producers, using a custom built hand-held sieving device.

2] Testing in the laboratory whether the same underlying particle size mechanism applies to field peas for both starch and protein digestion.

3] Testing in weaner pig trials whether variations in particle size below 1 mm have any effects on FCR or growth rate for field peas or sorghum.

4] Investigating the composition and particle sizes of residual feed at the ileum as a function of passage time using a cannulation model.

Key Findings

For the four target areas described above:

a] There is a wide range of particle size (distributions) for milled grains in current production, including many with a high percentage of >1mm particles. Measurement of particle size distribution can be simple but is rarely carried out.

b] The same diffusion-controlled digestion process found for starch in milled cereal grains also applies for both starch and protein in field peas as a model legume.

c] For mean particle sizes between 0.4 and 0.8 mm, there were no significant performance differences for weaner pigs on sorghum- or pea-rich diets.

d] The cannulation time course study showed very low levels of starch and no large particles (>0.5 mm) at the ileum. Feeds with larger particles had a slower rate of passage, suggesting that the negative effect of large particle sizes on feed efficiency observed previously may be related to passage rate as well as digestibility effects.

Research Summaries for Subprogram 4B continued

Application to Industry

- Particle size management is an important and potentially overlooked aspect of feed quality, particularly by smaller producers. A hand-held on-site sieving device prototype gave essentially the same results as conventional laboratory sieving analysis, and offers the potential for on-site adjustment of milling parameters (particularly to reduce the levels of particles greater than 1 mm in size) with predicted impact on animal performance.
- Starch and protein digestion in field peas follows the same 'outside-in' diffusion process as in cereal grains, offering a potential new approach to nutrient synchrony by combining protein and starch sources with similar enzyme digestion rates.
- For diets containing 49% sorghum or 30% peas with milled grain or legume particle size distributions in the 0.4–0.8 mm range, there is unlikely to be significant differences in animal performance efficiency even though up to 40% of sorghum/pea particles are 1 mm or larger. In contrast, reducing the percentage of sorghum or barley particles larger than 1 mm has previously been shown to improve efficiency in diets containing 72% of the grain. This suggests that larger particles may be more tolerated in diets containing diverse grains than in single grain formulations.
- The current focus on digestion rates as the reason why larger particles reduce animal performance needs to be broadened to include gastric emptying rates.

PROJECT 4B– 115: ADVANCING BERKSHIRE TRITICALE SUPPLY FOR THE AUSTRALIAN PIG INDUSTRY

Project Leader:
Professor John Pluske

Project Participants:
Matthew Sherriff (GrainCorp), Daniel Goussac (Black Swan Nutrition), Andrew Goyder (Grain Link), Chris Heinjus (Rural Directions), Dee Heinjus (Rural Directions), Tony Craddock (Rural Directions), Graeme Pope (Graeme Pope Consulting), Jo Pluske (SciEcons Consulting)

Aims and Objectives

To provide a guide for triticale supply chains that could be economically and environmentally efficient for the Australian pig industry in WA and SA, and to complete an assessment of these chains to determine the likelihood of their success.

Key Findings

Whilst the project objective of facilitating production of up to 10,000 tonnes of *Berkshire* in WA and SA was not officially realised through this project, the assessments of the supply chain provided valuable information. Knowledge gaps were identified and outputs were prepared and distributed to address this lack of information. Generally, communication within the supply chain appeared to be sufficient to facilitate growing and using *Berkshire* within the supply chain. Even so, demand for *Berkshire* is spasmodic with price incentives being limited due to seemingly adequate supply of alternative grains. Further, supply of triticale is irregular and after poor seasons is unlikely to be grown unless the grain producer has ample resources to use it as a break crop or receives a price incentive to grow it. Failure to establish a successful closed-loop supply chain was perhaps due to an overestimation of production risk and an underestimation of price risk. However, in due course when supply of grains for feed is limiting the advantages of a closed-loop supply chain for both pork producers and grain growers will be evident.

To that end, the following recommendations have been made: endorse triticale varieties as energy substitutes for wheat to encourage triticale demand at a market price; should demand increase, encourage feed buyers to communicate with agronomists and triticale growers to stimulate supply; in the short term, to increase the area grown of triticale and specifically *Berkshire*, the focus should be the "Grower-User" market segment involving mixed pork/grain businesses; remove the PBR status from *Berkshire*; follow the progress of triticale as a food grain and use any positive market developments to benefit feed grains; a market awareness campaign for grain bought as feed and a workshop program focusing on price risk management and grain trading be made available for producers and buyers of grains purchased as feed for the pig industry; to ensure security for grain used as feed, there is merit in testing the closed-loop

supply chain concept again with a mainstream commodity such as wheat or barley; the Pork CRC should not be involved in plant breeding of niche varieties.

Application to Industry

Currently the most likely market that exists for *Berkshire* remains with mixed pork/grain businesses where both a grain growing and a pork production enterprise are conducted. Should a new high-energy grain variety become available for use in pig feed (e.g., there are 14 relatively new triticale varieties), it is not likely to be available in all regions nor is it likely to be a requirement in all pig diets. Generally the market is not currently sophisticated enough to ensure that the value of DE is reflected in prices, despite the technology (AusScan) existing. Hence any premiums are likely to arise only by negotiation of individual parties. Should such negotiations arise, supply of a particular variety would be more secure and pig producers may benefit from the higher energy content.

For this reason, and given the substantial cost of variety development, it is recommended that Pork CRC should not be involved in plant breeding of niche varieties. It is envisaged that existing plant breeding programs of mainstream species and varieties will meet the feed grain needs for the pork industry.

PROJECT 4B –118: CANOLA MEAL NIR CALIBRATION IMPLEMENTATION

Project Leader:
John Spragg
(JCS Solutions Pty Ltd)

Aims and Objectives

Previous project work has looked at the effects of heat processing on canola meal quality. Total and reactive lysine NIR calibrations have been developed for predicting variation in meal quality. The previous calibration statistical data identified the need for further samples to be analysed to improve the calibrations.

A total of 53 Canola meal samples were collected from eleven oilseed crushing plants. Additional purposely heat damaged samples were produced through autoclaving. Samples were analysed for total and reactive lysine, as well as wet chemistry parameters. The additional canola meal sample results were added to the NIR calibrations previously developed. New calibrations were developed using a FOSS 6500 NIR spectrophotometer.

Key Findings

Total lysine content ranged from 15.4 to 20.9 g/kg. Reactive lysine content ranged from 14.0 to 19.9 g/kg and was more variable than total lysine.

Crude fat levels ranged from 8.4% to 16.8% in expeller extracted meals and from 0.4% to 3.4% in solvent extracted meals.

The inclusion of more samples, as well as heat damaged autoclaved samples, has provided a greater spread of samples, with improved NIR calibration statistics. The RPD value for both total and reactive lysine has increased. The new calibrations have greater ability to distinguish between low, medium and high results. Wet chemistry data provides further information for industry's use.

Application to Industry

This project work has increased the number of samples the canola meal total and reactive lysine NIR calibration equations are based on. This has provided an improvement in the calibrations statistics and the ability to predict meal quality.

The project has provided more robust NIR calibrations for prediction of total and reactive lysine content. The variability between commercial crushing plant samples identifies the value in utilising NIR calibrations in providing rapid and lower cost meal quality assessment.

It is recommended that the revised calibration equations be released for use by the oilseed, livestock and feed industries. The calibrations are accessible through AusScan on-line.

PROJECT 4B–119: AUSSCAN NIR GRAIN STANDARDS DEVELOPMENT AND USER CALIBRATION UPGRADE

Project Leader:
Peter Flinn (Kelspec)

Aims and Objectives

To develop a new set of sealed whole grain "standards" for standardising a network of near infrared (NIR) spectrometers, and to generate "repeatability" files based on grain samples scanned on different instruments and at different temperatures, in order to improve robustness and stability of the AusScan grain quality calibrations, resulting in improved repeatability among instruments.

Key Findings

A new and representative set of 18 sealed standards was created, and all were scanned on 16 NIR instruments around Australia, with new standardisation files generated for 15 "host" instruments to match the selected "master". The standards will also be available for future standardisation work. Two repeatability files, based on instruments and temperature differences, were successfully incorporated into the grain calibrations, without compromising calibration accuracy and with repeatability values small in relation to calibration error. The calibrations were updated to reflect the new master instrument.

Due to imminent changes in commercial arrangements for AusScan, it was not possible to test and validate the calibration updates across the network through a new ring test.

It is recommended that this be done as soon as possible in order to properly evaluate the performance of the network.

Application to Industry

The outcomes of this project will lead to the AusScan calibrations becoming more stable and robust, through the re-standardisation process which was possible with the production of new whole grain standards, and the use of a repeatability file (or files).

This will result in improved uniformity of analysis across the NIR instruments in the network, and hence improve confidence in the accuracy of the calibrations by licensees in both the research and industry sectors, and hopefully attract further participants to utilise the rapid and efficient NIR technique for assessing feed grain quality for the livestock industries.

Research Summaries for Subprogram 4B continued

PROJECT 4B–120: COMMERCIAL VALIDATION STUDY FOR SULPHUR AMINO ACID (SAA) REQUIREMENT IN FINISHER PIGS

Project Leader:
Dr Jae Kim (DAWFA)

Project Participants:
Dr Bruce Mullan (DAWFA), Dr Cherie Collins (Rivalea Australia)

Aims and Objectives

The aim of this study was to validate the hypothesis that finisher pigs raised in a commercial facility will have a 26% higher SAA requirement for minimum FCR than the current dietary recommendation of 0.58 SID SAA:Lys ratio.

Key Findings

The previous endotoxin model study (4B–109) demonstrated that pigs whose immune system is activated require approximately 26% more sulphur amino acids than healthy pigs (SID SAA:Lys ratio of 0.73 in comparison to NRC recommendation of 0.59) due to decreased protein utilisation efficiency. To validate this finding in commercial farms, two independent commercial validation experiments were conducted (4B–109 and present study) using a range of diets containing varying levels of SID SAA:Lys ratios. A combined data set, which was statistically adjusted for differences in the two experimental batches, was fitted in a quadratic-plateau prediction model to estimate SAA requirement in commercially-housed finisher pigs.

The results are similar to the previous finding and the optimum SID SAA content for maximum feed utilisation efficiency was 71% of the SID lysine in a finisher diet for commercially reared pigs. Considering current NRC recommendations of 56% of lysine for 50kg pigs to 59% of lysine for 100kg pigs, it is a 27% to 20% greater SID SAA requirement to negate the chronic exposure to stressors and bacterial/viral pathogens.

From the results of this research, a recommendation is made to formulate diets for finisher pigs to contain more than 70% of standardised ileal digestible sulphur amino acids in relation to standardised ileal digestible lysine content.

Application to Industry

It is concluded that under the experimental condition where pigs are continuously exposed to chronic immune system activation, SID SAA requirement for finisher pigs should be 20–27% higher than current NRC recommendations of 56% of lysine for 50kg pigs to 59% of lysine for 100kg pigs, (i.e., SID SAA:Lys ratio of 0.71).

Increasing SID SAA may not improve daily gain or feed intake, however, it will ensure maximum feed conversion efficiency in immune system compromised pigs.

PROJECT 4B–121: EFFECTS OF GRIND SIZE IN TYPICAL GROWER/ FINISHER DIETS UNDER COMMERCIAL CONDITIONS

Project Leader:
A.C. Edwards ACE Livestock Consulting Pty Ltd

Project Participant:
Australian Pork Farms Pty Ltd

Aims and Objectives

To explore the effects on animal performance of reducing the average particle size from 1100 to 600 micron, in commercial pelleted diets.

A survey of commercial feed mills and home mixers in 2013 revealed a wide range in grain particle sizes. Many samples recorded average particle sizes well above the suggested optimum of 700 micron. This trial explored the effects on animal performance of reducing the average particle size from 1100 to 600 micron, in commercial pelleted diets.

This project involved 3 separate trials using the same protocol and employing 3168 pigs. The diets involved were based on wheat, barley, peas and canola meal and were fed as a grower diet (30–60 kg Live weight) 14.2 MJ DE and 0.70 gm Avail. Lysine/MJ DE) and as a Finisher diet (60–100 kg live weight, 14.0 MJ DE and 0.60 gm Avail. Lysine/MJ DE).

The treatments applied involved grinding common diets over a disc mill at different settings to create a “fine” product (500–600 micron) and a “coarse” product (1000–1100 micron). A third treatment was created by blending the fine and coarse versions in a 50:50 mix. The diets were fed ad libitum as pellets.

Key Findings

Reducing the grind size from 1100 to 600 micron had no effect on ADG but reduced feed intake resulting in a 2.6% improvement in FCR in the grower phase and 5.6% improvement in the finisher phase.

An interesting artefact of the series of experiments was that one batch of “fine” grower feed was in fact ground to an ultrafine state (440 micron) and this depressed performance.

One of the cautions of finer grinding is the increased risk of gastric lesions but the excellent performance of the pigs in this series of trials and the associated low loss rate (<1.5%) would suggest that this was not a major issue at the particle sizes tested, nor with the combination of grains used.

Application to Industry

Many producers in Australia are milling feeds to an average particle size of 1500+ micron which implies there is a huge potential to improve feed efficiency and lower the cost of production by simply adjusting the milling equipment to achieve closer to optimal particle size.

PROJECT 4B–122: PREDICTING THE EFFECTS OF FIBRE, GRAIN DIGESTION RATE AND THE ILEAL BRAKE ON VOLUNTARY FEED INTAKE

Project Leader:
Professor Mike Gidley

Project Participants:
University of Queensland

Aims and Objectives

The overall project aim was to quantify relationships between feed intake, fibre amount / type and grain starch digestion rate. This was achieved through three animal trials with the specific objectives of:

1] Establishing the effects of partially fermentable (wheat bran) and largely non-

fermentable (oat hulls) fibres offered with highly digestible starch-based diets on feed intake and large intestinal (LI) fermentation in pigs.

2] Determining feed intake and efficiency of nutritionally balanced diets based on grains (milled wheat and sorghum; steam-flaked wheat and sorghum) with widely different starch digestion rate at 5% insoluble fibre level, and their effects on LI fermentation.

3] Identifying the effects of the same four grain-based diets, as influenced by insoluble fibre level (0, 5 and 20%), on the gastrointestinal tract passage rate, expressed as cumulative mean retention time in the stomach and small intestine (SI), determined with indigestible markers.

Key Findings

1] Inclusion of insoluble and non-fermentable fibre in diets (e.g. oat hulls) at low levels (ca 5%) can increase feed intake. Even partly fermentable insoluble fibre such as wheat bran depresses intake in a dose-dependent manner.

2] Faecal pH is a potential indicator of the extent of SI digestion, as undigested starch at the end of the SI is fermented in the colon to short chain fatty acids and results in a lower faecal pH. This could be a useful on-farm check that feeds are efficiently digested, if data are collected over time to monitor feed processing batch variation effects.

3] Hydration capacity of feeds is a predictor of intake, particularly for highly digestible diets. The greater the hydration capacity, the lower the feed intake. This results directly from gastric structuring (increasing residence time) and/or indirectly from the enhanced microbial fermentation of more swellable fibres.

Application to Industry

Strategies to increase FI include (all of) the following:

1] Ensuring that all milled grain particles are below 1.0 mm (wheat/barley) or 0.8 mm (sorghum) to have a limited effect on gastric retention and rapid/complete digestion in the small intestine.

2] Addition of small quantities of non-fermentable fibre to stimulate passage rate (e.g. 5% oat hulls).

3] Avoiding dietary components with high hydration capacity and/or fermentability.

Strategies for decreased FI include (all of) the following:

1] Larger milled grain particle sizes to slow gastric emptying.

2] Addition of large amounts of insoluble fibre irrespective of whether fermentable or not (e.g. 20% oat hulls or wheat bran), particularly for wheat-based diets.

3] Addition of other dietary components with high water holding capacity.

PROJECT 4B–123: MEASUREMENT OF GRAIN ENZYME DIFFUSION RATES AND GRAIN THRESHOLD PARTICLE SIZE CALCULATOR

Project Leader:
Professor Mike Gidley

Project Participants:
University of Queensland, Ridley Agriproducts Pty Ltd

Aims and Objectives

Grain particles not digested in the small intestine (SI) and fermented in the lower gut reduce efficiency of feed use (15% energy lost as heat, methane and microbes) and intake (activation of ileal brake). Rate of grain digestion depends on enzyme diffusion rate (EDR), which varies widely with structure and composition of grains and processing (milling, heat, exogenous enzymes). Threshold particle size, where all grain is digested in the SI, is determined primarily by EDR. This project aimed to measure EDR for a range of grains/processing and develop a threshold particle size calculator.

Key Findings

1] Enzyme diffusion rates can be determined for a wide range of grains (wheat, barley and sorghum) through laboratory analysis of first-order kinetic rate constants as a function of milled grain particle size.

2] Wheat and barley have faster enzyme diffusion rates than sorghum, consistent with relative in vivo digestibility.

3] Particle size cut-offs for efficient small intestinal digestion can be predicted from EDR.

4] Fibre can affect the relationship between EDR and ileal digestible energy, probably through effects on passage rate. Fibre-adjusted ileal DE correlates reasonably with EDR.

5] NIR shows promise as a tool to determine EDR non-invasively, but more calibration samples are needed to validate.

Application to Industry

Recommendations include:

- The particle size distribution of milled grains should be routinely assessed.
- For efficient use in feeds, it is predicted that milled wheat/barley should not contain particles greater than 0.8–1.0 mm to ensure digestion in the small intestine.
- For sorghum, the particle size cut-off is predicted to be lower at about 0.6–0.8 mm.
- Multi-pass milling should be considered as a route to assuring the absence of over-size particles without generating fines.
- Further work should be carried out to generate a NIR calibration for amylase diffusion coefficient and link this to particle size specifications for maximal feed efficiency from grains.

Research Summaries for Subprogram 4B continued

PROJECT 4B–124: RE-ENGINEERING OF GRAIN GRINDING/SIEVING IN COMMERCIAL MILLS AND APPLICATION OF SOFTWARE

Project Leader:
Robert Parkes

Project Participants:
Ridley St.Arnaud,
Ridley Mooroopna,
Rivalea Corowa,
SunPork Murray Bridge

Aims and Objectives

This project comprised two parts:

1] A desktop study of options available and cost/benefit analyses for four stock feed plants in Victoria, NSW and South Australia.

2] Evaluation of software and algorithms arising from two integrated projects through University of Queensland.

Key Findings

It has been identified that (a) thorough engineering reviews at selected commercial feed mills illustrate that reengineering the grinding capabilities of commercial feed mills is largely cost prohibitive. This is based on individual mill setups and by species feed supply mix requirements and also the mill down time that would be needed to make the necessary changes. Robust monitoring of feed mill grinding capabilities and establishing standards that reduce/minimise grain particles above 1mm for creep through grower feed are achievable in feed mills. The application of project 4B–123 threshold particle size calculator has merit as a particle size and energy grain availability monitoring tool for feed mills, and further work to establish a sieving protocol using 9–10 sieves and selection of the curve of best fit is required.

Application to Industry

This project has identified alternatives to retrofit conventional feed mills to better manage grain and feed particle size. In all circumstances, the costs of completing this work are considerable and for alternative options such as replacing grinding equipment, are cost prohibitive from both an equipment (capital) and mill down time for the work to be completed. The cost benefit analysis for the mills included in this project also relates to the volume of pig feed manufactured and the volume of alternative species feeds manufactured. Each mill included in the project are best placed to complete this assessment.

Completing the review of particle size identified that there is benefit to the pig industry through feed suppliers or home mixers being able to manage better particle size depending on the stage of pig production. The reduction in energy available to the pig ranged from 1–12% depending on the type of grinder and distribution of particles above 1000 microns. At this higher end of this range (where many samples sit) there is potential to halve the reduction in energy through reducing the quantify of large particle above 1mm. Factoring in a reduction from 10% to 5% improves energy availability from the grain component of creep through grower feeds by 0.60 to 0.70 MJ of DE.

Further, the variation in grinding results from this analysis identified that from the same grinding equipment, operations management (grinder set up and monitoring) strategies can substantially influence the level of energy reduction. Do feed mills need to change equipment, add in additional sieving or adjust current equipment to better manage grain or feed particle size? The results from the ground grain analysis indicates that grinding equipment set up and monitoring provide the quickest and most cost effective method for improving pig performance. Feed manufacture is a specialised skill and should be considered a technical aspect of all pig production systems be they internal or external suppliers. Pig producers are encouraged to have a close working relationship with their feed supplier or look more closely at their own grinding systems set up and monitoring if they home mix their feed.

Subprogram 4C: Carbon-Neutral Pork Production

The subprogram involved highly novel research to maximise methane production from effluent ponds so that collection and use of gas is economically viable. Alternative approaches to waste management were also studied to develop solid-waste pork production systems that mitigate carbon outputs.

PROJECT ID	TITLE
4C–101	LCA of waste treatment and additional pork supply chains
4C–102	Piggery biogas capture and energy generation feasibility study
4C–104	Bioenergy Support Program
4C–105	Assessing stimulation and inhibition of anaerobic lagoons
4C–106	Impact of pig gut microbiology on pig nutrition and health
4C–107	Potential Pathways to Carbon Neutrality
4C–109	Enhanced methane production from pig manure in covered lagoons and digesters
4C–110	Bioenergy Support Program – Operational
4C–111	Anaerobic treatment for emissions reduction from solid manure residues
4C–112	On-farm evaluation of a pond-less piggery effluent treatment system using novel flocculation and filtration techniques
4C–113	Enhanced methane bioenergy recovery at australian piggeries through anaerobic co-digestion
4C–114	Options for cost-effective and efficient use of piggery biogas energy
4C–115	Bioenergy support program – Transition (Research)
4C–116	Bioenergy Support Program – DAF Transition
4C–117	Benchmarking the performance of Australian pork with life cycle assessment
4C–121	The Low emission future of pork
4C–122	Installation of instrumentation for remote monitoring of biogas composition and operational data at commercial piggeries

Research Summaries for Subprogram 4C

PROJECT 4C–101: LIFE CYCLE ASSESSMENT OF WASTE TREATMENT AND ADDITIONAL PORK SUPPLY CHAINS

Project Leader:
Mr Stephen Wiedemann
(FSA Consulting)

Aims and Objectives

The report presented research on the environmental intensity of pork production, focussing on greenhouse gas (GHG) emissions, energy and water use. It was conducted with the Australian public, the research community and the pork industry in mind. This project aimed to extend pork LCA research in Australia to investigate the GHG emissions for a range of effluent treatment systems and waste management practices, across five pork supply chains in three states. These included a small–medium supply chain comprised of five, closed herd farrow-finish piggeries located in south east Queensland, a Western Australian large conventional piggery, a large outdoor breeder unit and a deep litter grower-finisher unit in WA, a large conventional farrow-finish piggery in Queensland and a conventional breeder, deep litter wean-finish enterprise in southern NSW.

The study was an ISO 14040/14044 compliant LCA covering GHG, energy use and water use for the pork supply chain from 'cradle to processor gate'. Supply chains consisted of either 1 large piggery or a series of smaller piggeries selling to a similar market. Inputs and production data were collected from a total of 13 piggeries (~23,000 sow places) over a 12 month period. Inventory data were collected from three meat processing plants. A comprehensive water and energy inventory was collected from each piggery and meat processing plant. GHG emissions were determined using a mass balance modelling approach based on feed intake and animal production to predict manure excretion, and emission factors from the Australian inventory (NGGI) and literature sources. Emissions and impacts from alternative manure management systems were modelled based on a desktop review of alternative emission factors and (as relevant) energy generation potential.

Key Findings

- Total GHG ranged from 5.0 ± 0.7 kg $CO_{2\text{-}e}$/kg to 8.7 ± 1.2 kg $CO_{2\text{-}e}$/kg Retail Pork, with the range in values mainly driven by differences in the manure management system.
- Total embodied energy ranged from 18.8 ± 1.0 MJ/kg to 22.1± 1.2 MJ/kg Retail Pork, with differences largely related to diet and production efficiency.
- Consumptive fresh water use ranged from 50.3 ± 4.4 L/kg to 252.8 ± 39.4 L/kg Retail Pork. Several factors contributed to the large range in water use, including housing type, inclusion of irrigated feed products in the diet and losses associated with water supply.
- Stress weighed water use ranged from 16 ± 1.4 L $H_2O_{\text{-}e}$/kg to 62± 2.0 L H_2O-$_e$ /kg Retail Pork.
- A number of GHG mitigation options are available to the pork industry. Of these, on-site energy generation via anaerobic digestion provided the greatest reductions in GHG and energy demand. Alternative GHG reduction strategies include rapid irrigation of effluent (short hydraulic retention time) or alternative housing (i.e. on litter or outdoor).
- This study provides data and methods that may be used to benchmark industry performance, though this should be done with reference to a larger sample of the industry or a complete industry inventory. Doing so would provide the CRC with a sound benchmark from which to measure practice chance in the future. Such measurement of progress is important for the industry in order to 'keep pace' with changed production systems and levels of productivity, both of which drive impacts.

Application to Industry

The project outcomes provide valuable information for different users.

- The pork industry – to provide a benchmark for environmental performance across a number of pork production systems, and to provide insight into strategies to reduce impacts.
- Researchers in the pork industry and potentially in the food supply chain – Researchers may use the data and results here to guide future research.
- Pig farmers – who can use the energy and water use data for benchmarking and can use the GHG information to assist in understanding how to minimise their environmental impacts.
- The general public – at the discretion of Pork CRC, this information may be valuable for members of the general public who are concerned about the environmental impacts of pork.

PROJECT 4C–102: PIGGERY BIOGAS CAPTURE AND ENERGY GENERATION FEASIBILITY STUDY

Project Leader:
Mr Eugene McGahan
(FSA Consulting)

Aims and Objectives

The Pork CRC is currently involved in research that will develop commercially viable effluent management systems for pig production that significantly reduce the net carbon footprint of piggeries. In particular, the research program will establish pork production systems that are carbon neutral through novel research such as the development of anaerobic digestion techniques. The research program will transform the Australian pig industry by specifically addressing critical environmental and economic issues that confront its sustainability and by investigating the most effective method(s) of reusing biogas to minimise the piggery's reliance on electricity from the grid and/or imported fuels such as diesel and liquefied petroleum gas (LPG).

The project was divided into a staged process for each of the five piggeries investigated, which provided the operators with advice on: initial investigations regarding layout of the system; the most appropriate anaerobic digestion technology; biogas use and conditioning; digestate management; and financial modelling of the most appropriate biogas use options.

The methodology is described as follows:

- Site visit and data collection.
- Modelling – Technical feasibility modelling of expected biogas production and potential energy production and financial modelling of the most appropriate biogas uses. Investigations into maximising co-benefits of the system.
- Reports and presentation.

Key Findings

- The findings from this research indicate that there is potential of capturing and utilising biogas to minimise piggeries' reliance on electricity from the grid and/or imported fuels such as diesel and liquefied petroleum gas (LPG).
- The five case studies have all been shown to be economically feasible with each piggery having short payback periods between 1.8 and 7.2 years and delivering a substantial positive return on investment over a 10-year project life. At present, there are also biogas capture and utilisation systems currently been successfully undertaken by other producers across Australia.
- The research indicates that biogas capture and utilisation technology can be successfully adopted at piggeries. However, all piggeries are different and care should be taken when interpreting these results. Each piggery would require an individual cost benefit and feasibility analysis before any biogas utilisation system was installed due to the variety of factors that affect both the practical and economic feasibility of such a system. These factors include but are not limited to piggery size and energy demand and cost. There may however be other drivers for piggeries to capture and destroy biogas, such as for odour reduction.

Application to Industry

The project outcomes provide valuable information for producers, researchers and the general public.

PROJECTS 4C–104 & 4C–110: BIOENERGY SUPPORT PROGRAM (BSP) PROJECTS

Project Leader:
Dr Stephan Tait

Project Participant:
University of Queensland

Aims and Objectives

The Bioenergy Support Program (BSP) aimed to facilitate biogas uptake to reduce emissions from pork to less than 1 kg CO_2-e/kg pig meat.

Objectives:

1] A central source of reputable information on biogas.

2] Understand and promote the true economic and technical feasibility of biogas.

3] Establish Pork CRC biogas demonstration sites.

4] Identify and investigate /address barriers to biogas uptake.

5] Build longer-term industry capacity via a postgraduate research project.

Key Findings

- Pork industry uptake of biogas is now at 13.5% of the national Australian herd, with 11.8% (89.4%) adoption since the inception of the BSP, and only 1.7% (10.6%) uptake in the 20 years prior to the BSP.
- Three key demonstration sites operational with extensive information collected and published in technical dossiers. These have become active research piggeries to trial and develop cost-feasible technology options. Case study visits and data on biogas systems have been collected from an additional six other piggeries.
- One-on-one contact/ assistance to >15% of the pork sector, with over 300 individual enquiries addressed. Technical support during feasibility enquiries, approvals and odour, start-up of covered lagoons, sludge management.
- Key influence on Emissions Reduction Fund legislation (formerly the Carbon Farming Initiative or CFI). Led to documented reduction in emissions of 207,617 tonnes CO_2-e and an estimated $2.96M in carbon credit income. Piggery biogas projects committed to a further 698,750 tonnes CO_2-e of future emissions savings under government auction, to earn an additional $8.76M of carbon credit income to the pork industry.
- Using biogas energy at Australian piggeries has to date saved an estimated $2.2-2.8M in energy costs.
- As much as 75%–82% of odour emissions from piggeries originate from uncovered manure treatment lagoons (Smith et al., 1999; Camp Scott Furphy Pty Ltd., 1993), so the capture of biogas has reduced piggery odour considerably.
- The BSP together with APL has developed a Code of Practice for on-farm biogas safety, which is proposed by Victorian and Queensland gas safety regulators for future expansion into an Australian Standard in fuel gas legislation.
- Industry-based masters research project by Mr. Alan Skerman, Principal Environmental Engineer at DAF QLD, and building longer-term biogas support to the industry.

Application to Industry

The project has been central to the uptake of Biogas capture and use by the Australian pork industry.

Research Summaries for Subprogram 4C continued

PROJECT 4C–105: ASSESSING STIMULATION AND INHIBITION OF ANAEROBIC LAGOONS

Project Leader:
A/Prof Damien Batstone

Project Participants:
University of Queensland, University of Western Australia

Aims and Objectives

To promote the widespread use of inhibition testing in assessing anaerobic digestion of pig manure, this project develops and validates a simplified and unified inhibition test protocol. The method development was performed on two very distinct inoculum sources, one being sludge from a covered piggery lagoon, and using two inhibitors, namely ammonia nitrogen and sodium. Attention was given to important details of the test method which were extensively validated with experiments.

Key Findings

Key findings include a clear definition of optimum/preferred test conditions. It was observed that it is necessary to pre-dilute sludge sample to 10g.L^{-1} volatile solids content upon receipt before carrying out inhibition testing, and then to provide sodium acetate as a carbon source at around 2gAcetate.L^{-1}. A simplified version of the test assay was also developed and was shown to perform equally well to the full version. The simplified method is targeted for reduced complexity and cost to promote routine inhibition analysis. In the simplified method, as few as two sampling events over 1.5 days provide a reliable measure of activity in the presence of an inhibitor, and this method is expected to achieve costs as low as the target of $250/sample. The inhibition response was observed to differ slightly (as expected) between the two trial inoculums and was found to be largely consistent between the simplified and the full-test method (multiple sampling events).

Application to Industry

This project defined and validated, via extensive experimental work, a simple yet robust inhibition test assay. For producers, this test assay will be able to quickly quantify how much of a particular chemical or agent can be tolerated in their shed flush effluent before significant inhibition of a covered lagoon will occur (a threshold test).

The test assay is of a general nature, being potentially applicable across anaerobic digestion in many industries, including pork production. This is significant, because such a unified assay has not been previously reported, even in the broader anaerobic digestion community, and therefore the test technique developed in this project also has broader general implications for anaerobic digestion studies. Various test assay conditions were assessed through the project to fully define the assay method. To promote widespread adoption, a simplified and unified test assay was targeted with a cost potentially as low as $250/test without compromising data quality.

The test technique is well-documented in the final report / in the associated journal paper and can accordingly be promoted for adoption by NATA accredited test facilities across Australia. The inhibition test method will be integral part of the analyses toolbox for Project 4C–111 *Anaerobic treatment for emissions reduction from solid manure residues* and Project 4C–109 *Enhanced methane production from pig manure in covered lagoons and digesters*.

PROJECT 4C–106: IMPACT OF PIG GUT MICROBIOLOGY ON PIG NUTRITION AND HEALTH

Project Leader:
Damien Batstone

Project Participants:
Advanced Water Management Centre (UQ), Australian Centre for Ecogenomics (UQ), Qld Department of Agriculture, Fisheries and Forestry (DAFF)

Aims and Objectives

- Identify optimal methodology for extraction of DNA from manure samples.
- Conduct large scale next generation sequencing on 95 PigBal trial samples using the optimal extraction technique and identify linkages between microbial community characteristics, feed and other factors, and nutritional outcomes.

Key Findings

- Optimal extraction technique identified. Mismatch of sample-technique results in null rather than false outcomes.
- Gut community dominated by firmicutes (common anaerobic bacteria).
- Diet and age major predictor of gut community, with wheat diets clustering and having lower diversity.
- Community diversity decreased with age and metabolism shifted towards carbohydrate and lipid capability.
- Nutritional outcomes (weight gain) strongly correlated with microbiome, but there was no unexplained impact apart from those due to age and diet.
- Hence microbiome is an excellent **predictor** of nutritional state, but is not a direct **factor** in comparison with diet or age.
- Predictors of low weight gain included *Clostridia*.
- Antibiotics cause measurable change in specific microbial populations, but does not act as overall driver.
- Pig sample size (16 pigs across 4 feeds) was too small to identify correlation between microbiome and health indicators.

Application to Industry

- It is unlikely that microbiome can be directly manipulated to achieve better nutritional outcomes (due to lack of unexplained correlations).
- Microbiome markers help explain mechanism of diet on nutritional outcomes and may be better used to better design optimal feeds, particularly across pig age. An example may be using the identified markers of positive nutritional outcomes as evaluated in this study, and varying feed to enhance these measures, particularly at different ages.

PROJECT 4C–107: POTENTIAL PATHWAYS TO CARBON NEUTRALITY

Project Leader:
Stephen Wiedemann
(FSA Consulting)

Aims & Objectives

Reducing greenhouse gas (GHG) emissions is a key priority for the CRC for High Integrity Australian Pork, which has set targets to substantially reduce greenhouse gas emissions from pork production, to a target level of 1 kg CO_2-e/kg pork. This project builds on previous research using life cycle assessment (LCA) to quantify the GHG emissions from pork production to the farm gate. The project aimed also to show the process that a pig farmer would follow to lower their GHG emissions per kilogram of pork.

The study conducted a detailed LCA analysis of pork production for a case study farm in Victoria. Emissions were modelled from the production of feed inputs, energy inputs, staff transport and manure management on the farm. Manure emissions were modelled using mass balance principles and emission factors from the Australian GHG Inventory and literature values. A series of GHG mitigation strategies reviewed from the literature and were screened for applicability to the Australian industry by a farmer advisory group established for the purposes of the study. Suitable mitigation strategies were modelled to show the emission rates that could be achieved.

Key Findings

The carbon footprint of the case study piggery was 4.86 kg CO_2-e/kg LW. Mitigations were modelled using a combination of strategies as follows:

1] CAP-CHP with standard production.

2] CAP-CHP with optimised effluent storage and utilisation.

3] CAP-CHP with optimised diet (low GHG feed ingredients).

4] CAP-CHP with optimised diet, effluent storage and utilisation, soil carbon sequestration and tree planting.

The final emissions from the four scenarios ranged from 0.6–2 kg CO_2-e/kg LW.

Reductions to meet the Pork CRC target (1 kg CO_2-e/kg pork) required application of several approaches together. We found that emissions could be reduced by 59% by installing CAP-CHP units and this was both the most likely and the most effective mitigation option.

The qualitative cost-benefit analysis suggests that covering ponds may be cost effective for a reasonable proportion of the industry. Changes to effluent management may also be cost effective, though these may have fairly long payback times. Other options such as modification of ration components or reduction of dietary CP are likely to increase costs making this less attractive.

Application to Industry

Providing a pathway to reducing GHG emissions in the industry. Researchers in the pork industry, and potentially in the food supply chain, may use the results to guide more detailed investigation into mitigation opportunities.

Pig farmers can use the report to identify strategies they can follow to reduce GHG from their farms.

At the discretion of Pork CRC, this information may be valuable for members of the general public who are concerned about the environmental impacts of pork and the potential to reduce impacts.

Research Summaries for Subprogram 4C continued

PROJECT 4C–109: ENHANCED METHANE PRODUCTION FROM PIG MANURE IN COVERED LAGOONS AND DIGESTERS

Project Leader:
Dr. Stephan Tait

Project Participants:
Stephan Tait, Sergi Astals, Shao Dong Yap, Paul Jensen and Damien Batstone (all University of Queensland)

Aims and Objectives

Manure methane is increasingly used at Australian piggeries to produce heat and generate electricity, with current adoption of biogas covered 13.5% of total Australian pork production. The performance of a covered pond (CAP) or in-vessel anaerobic digester in terms of methane production, is dictated by: design and operation of the CAP or digester; methane potential of the waste(s) being treated; and health of the micro-organisms responsible for anaerobic digestion. This project researched the latter two aspects, with the aim to enhance methane production. A targeted literature review was conducted on co-digestion opportunities and considerations, specifically to boost methane production in the Australian pork sector. A number of experimental studies were carried out to quantify the potential effects of CAP desludging on methane yields, to study the effects of chemical inhibitors/response of microbial communities to try and to identify engineering intervention that could promote inhibition resilience.

Key Findings

There are considerable opportunities for anaerobic co-digestion in the pork industry, where two or more wastes are simultaneously digested to boost methane production. Abroad, a number of carbon-rich wastes are regularly co-digested with animal manures. Co-digestion needs careful management to prevent unsafe organic loading rates. The availability of co-digestion wastes is an on-going challenge and transport costs dictate cost feasibility. A major future incentive would be revenue from gate fees when wastes are diverted away from landfill to produce methane for beneficial use.

Settled sludge eventually displaces active covered pond volume and requires extraction. There are now ways to do this by pumping of sludge via sludge extraction pipes, whilst the CAP remains in full operation. Experiments measured the residual methane potential in sludge samples extracted from covered ponds at Pork CRC demonstration piggeries. The results showed that the sludge was reasonably stable, with over 50% of the organic matter already converted into methane. This was also the case for ponds with very short desludging periods of 1 year. It could be beneficial to decrease desludging frequency to every 2 years to allow more time for conversion of manure into methane. However, some piggeries may instead elect to desludge more frequently to manage water balances during wet/dry seasons and to sustainably apply sludge nutrients to cropland.

Inhibition resilience and adaptation of microbial communities were assessed using inoculum samples from full-scale and pilot scale digesters, and separately by subjecting microbes in continuous digesters to chronic high levels of inhibitor. The results showed that inhibition resilience varied moderately between different inoculum sources, with some microbial communities being more resilient than others. Subjecting microbial communities to chronic inhibitor stress showed clear acclimation. These results were encouraging, because they indicated that microbial communities could adapt to inhibitors. However, no statistical links could be found between intervention strategies and inhibition resilience, so acclimation occurs naturally and unfortunately cannot be greatly encouraged by targeted intervention.

Application to Industry

Overall, there is considerable opportunity for co-digestion in Australia. Future research should explore the effects of temperature and organic loading rate on co-digestion performance. It would be worthwhile to advocate for consistent landfill levies across Australia, because this would be a key driver for future profitability of anaerobic co-digestion. Desludging of covered ponds could be extended to every 2 years to allow further conversion into methane. However, well-operated CAPs would unlikely lose more than 10% of manure methane potential with extraction of sludge. Instead, desludging strategies could be based on pumpability of sludge, water balances during wet/dry seasons and nutrient load management to crop lands. Adaptation of microbial communities to chemical inhibitors is best done gradually. For example, a site where salinity gradually increases because of high effluent recycle rates, low rainfall and high evaporation rates, is unlikely to have issues with salt inhibition until salinity reaches very high levels. This is because enough time is given for the AD microbiology to adapt to the gradually increasing salinity levels.

PROJECT 4C–111: ANAEROBIC TREATMENT FOR EMISSIONS REDUCTION FROM SOLID MANURE RESIDUES

Project Leader:
Professor Damien Batstone

Project Participants:
University of Queensland, Australian Pork Limited, Quantum Power Limited, Australian Egg Corporation Limited

Aims and Objectives

This project researched anaerobic treatment of solid manure residues as an alternative to usual manure handling practices, with the aim to reduce emissions and value-add on-farm by recovering energy and nutrients.

Key Findings

Manure characteristics:

1] The manures analysed contained significant

amounts of phosphorus, nitrogen and potassium, highlighting their value as a fertilizer.

2] The manures contained complex consortia of microorganisms, highlighting the impact of carbon and potential future benefits from manures applied to cropland.

Stockpile emissions simulation model:

3] A mechanistic simulation model tool was developed to aid the future design and operation of manure stockpiles for reduced emissions and decreased nutrient losses. Anaerobic treatment technology.

4] Energy (as methane) and nutrients in solid manure residues are recoverable by anaerobic treatment. Specifically, in pilot testing of the project, 50% of the maximum methane potential was recovered. Further, it was possible to up-concentrate phosphorus by 10 times using practical means, which would considerably reduce the costs to transport nutrients to cropland where they are most needed.

5] For pigs, high capital cost presently limits the economics of anaerobic treatment at small to medium production sizes, and future development should target cost-feasible variants.

6] For eggs, high ammonia is a major limiting factor for anaerobic treatment, requiring future work to develop feasible solutions.

Application to Industry

The project tested and developed anaerobic treatment technology. This provided an illustrated example of manure handling practices that may become widespread in the future.

PROJECT 4C–112: ON-FARM EVALUATION OF A POND-LESS PIGGERY EFFLUENT TREATMENT SYSTEM USING NOVEL FLOCCULATION AND FILTRATION TECHNIQUES

Project Leader:
Hugh Payne (DAFWA)

Project Participants:
Brad Cole, Clinton Rampal, Riccardo Pivali, Guy Forget, Paul Kingston (Z-Filter Pty Ltd), Neil Ferguson (Westpork), Stephan Tait (University of Qld)

Aims and Objectives

The Z-Filter, a novel de-watering and filtering system, developed in Western Australia to treat waste streams in the mining, municipal waste and food processing industries. This project was undertaken to evaluate the use of a Z-Filter to treat piggery effluent and to assess the extent to which it could replace ponds in treatment systems. The Z-Filter was used to treat effluent from a single grower-finisher shed with the TS concentration varying from 1.3% to 2.4%.

Key Findings

The average removal rates were 58% for TS, 73% for VS, 35% for total N and 50% for P. The average dry matter content (TS) of the separated solids was 22%.

Data from the trial were used to calculate the capital, operating and chemical costs of operating the Z-Filter which were then combined with output from PigBal 4 simulations of 200 and 2,000 sow farrow-to-finish piggeries to estimate the cost of operating a Z-Filter on a commercial scale. The estimated cost ranged from $50 to $132 per tonne of TS treated, depending on herd size and the TS concentration of the effluent. This equated to $0.04 to $0.12 per kg HSCW of finisher pigs sold. However, this did not take into account any revenue from by-products or potential savings in capital investment in other parts of the treatment system.

The PigBal 4 model was also used to quantify the nutrient content of the separated solids to which a fertiliser unit price was applied. The net value of these nutrients was conservatively estimated to be equivalent to about 20% of the operating cost of the Z-Filter.

Application to Industry

Removal rates achieved by the Z-Filter were higher than most values reported for other types of separation systems in common use. However, the Z-Filter, in common with other mechanical systems, was unable to remove colloidal and aqueous phase solids from the filtrate, necessitating its further treatment in an anaerobic pond. Nevertheless, removal of 75% of the VS would decrease the required pond size by about 60%, resulting in considerable savings in capital expenditure which may offset that incurred by the Z-Filter.

This project was conducted with a prototype Z-Filter which performed reliably during the trial. The manufacturer is confident the commercial model of the Z-Filter, with regular maintenance, will have a lifespan of about 20 years. However, the long term performance of the commercial model of Z-Filter is yet to be determined. Day to day operation of the Z-Filter was relatively easy, requiring a medium degree of maintenance and supervision. Some degree of operator training would be required.

Some producers may view the Z-Filter as complex to operate and outside the competency of their staff. Unless considerable economic benefits can be demonstrated or environmental constraints prevent the use of traditional systems, producers may be reluctant to replace traditional pond systems with more sophisticated alternatives.

Research Summaries for Subprogram 4C continued

PROJECT 4C–113: ENHANCED METHANE BIOENERGY RECOVERY AT AUSTRALIAN PIGGERIES THROUGH ANAEROBIC CO-DIGESTION

Project Team:
Dr Stephan Tait, Dr Sergi Astals, Prof Damien Batstone and Dr Paul Jensen, Advanced Water Management Centre, University of Queensland

Project Participants:
Pork CRC, Australian Meat Processors Corporation, Queensland Urban Utilities and Melbourne Water Corporation

Aims and Objectives

This project investigated anaerobic co-digestion (AcoD), whereby two or more wastes are co-treated in a covered pond or digester to boost biogas production and/or provide gate fee income from receiving and treating wastes from other industries at a piggery. The microbial health of a digester or covered pond is important, because poor AcoD performance instead reduces biogas, causes odour, and increases residues to post-handle and dispose of. Pond or digester health is maintained by NOT adding too much manure/other wastes, in terms of volumetric and organic loading. It was not known how waste mixture composition and low operating temperatures in ambient covered ponds (15-25°C) would influence loading limits for AcoD. These knowledge gaps were addressed in the project via fundamental laboratory analysis by two PhD projects, lab-scale AcoD testing of various wastes and tracking of two full-scale co-digestion trials.

Key Findings

1] Carbon to Nitrogen (C/N) ratios are commonly used to select balanced waste mixtures for aerobic composting. However, this research found that C/N is not adequate to predict AcoD performance. Instead, AcoD performance is reasonable when essential nutrients are available, and inhibition thresholds and loading limits are not exceeded. Loading limits depend on carbon type (carbohydrate vs. lipids vs. protein) in waste mixtures. Lipid/fat is generally preferred, followed by carbohydrates, and protein is ranked last because of high ammonia inhibition risk. Settling/floating behaviour of lipids/fat and complex lignocellulosic carbohydrates (e.g. straw) was not assessed in the project and may negatively affect covered pond operations.

2] AcoD is generally slower at colder temperatures. A decrease in temperature affects some biological reactions more than others do. This increases the risk of microbial imbalances in AcoD at cooler temperatures.

3] Thirty wastes were ranked as candidates for AcoD. Glycerol and Fat Oil and Grease (where available) ranked highest, with high concentrations and good biological performance, but their addition needs to be carefully controlled to prevent organic overload. Macerated food waste and food industry wastes were also strong candidates because of rapid digestion, low impact on residual solids and low inhibition risk. However, such wastes are relatively dilute and may have volumetric loading constraints. Agricultural wastes had mixed rankings, with energy dense wastes such as Dissolved Air Floatation sludge or protein and lipid-rich animal screenings being suitable, but lower energy wastes, such as paunch, waste activated sludge and pig manure ranking poorly unless produced and digested at the same site (not transported over long distances for treatment). Low energy wastes can be co-digested with high-energy wastes.

4] Two full-scale co-digestion trials were tracked during the project, one at a municipal wastewater treatment plant and one at a piggery co-digesting pig manure and paunch in a mixed vessel. The results from the full-scale trials agreed with the laboratory test findings.

Application to Industry

With ambient temperature covered ponds, maximum loads of other wastes can occur during warmer temperatures of Spring-Summer, potentially including minimal amounts of protein. Other wastes should be reduced during cooler months of Autumn-Winter and protein-based wastes and soluble sugar-based wastes avoided. Complex cellulosic wastes may be applied, but at roughly 50% lower loading in cooler months than in warmer months. Lipids are generally

slow to digest and require long treatment times, especially at cooler temperatures.

Increased biogas revenue/savings should be balanced with increased residue disposal costs (nutrient value can be a benefit if used as fertilizer). There may be opportunities to receive and treat wastes for a gate fee, but wastes with recalcitrant contaminants (e.g. heavy metals or pesticides) should be avoided. Purchasing wastes from other industries is generally not economically feasible and it does not make economic sense to pay for transport of wastes over extended distances.

PROJECT 4C–114: OPTIONS FOR COST-EFFECTIVE AND EFFICIENT USE OF PIGGERY BIOGAS ENERGY

Project Leader:
Alan Skerman

Project Participants:
Department of Agriculture and Fisheries, Simons Green Energy

Aims and Objectives

To investigate and evaluate the feasibility of implementing a range of alternative uses for biogas generated by Australian piggeries, focusing on biogas-fuelled tri-generation systems to provide electrical power, heating and cooling.

Key Findings

- Whilst site specific assessment is recommended, annual methane (CH_4) capture by covered anaerobic lagoons (CALs) at Australian piggeries is conservatively estimated at 19 m^3 CH_4 per standard pig unit (SPU), assuming that the raw effluent is screened prior to discharge into the CAL.
- This CH_4 volume can provide 177 kWh (637 MJ) of primary energy per SPU annually, which may be converted to approximately 142 kWh of thermal energy in a hot water boiler (80% efficiency), or 53 kWh (191 MJ) of electrical energy (30% efficiency) and 88 kWh (318 MJ) of thermal energy (50% efficiency) per SPU annually, in a cogeneration system.
- To maximise the benefits from the growing adoption of biogas capture, treatment and use systems, producers will require access to a range of robust, practical, cost-effective technologies and appliances, which can be tailored to match on-farm energy production and use, and cost-effective export of any excess energy.
- Hot water boilers and cogeneration (CHP) systems are likely to continue to be the main biogas use options used at many piggeries.
- The current lack of cost-effective absorption chillers within the required energy range and their unsuitability for large-scale space cooling applications may limit industry uptake of tri-generation systems, in the medium term.
- Feasibility studies identified several alternative biogas energy use options including chilling sow drinking water, sow cooling and tallow tank heating, in addition to current uses such as piglet nest and shed space heating.
- The biogas use options recommended in the Feasibility Studies employed a combination of hot water boilers and cogeneration units, resulting in overall return on investment (RoI) ranging from 12 to 25% and payback periods of 4 to 8 years.
- The use of biogas as a fuel for pig transporting trucks and farm tractors does not appear to be financially viable currently, given the technical and operational demands associated with biogas upgrading and compression for on-board storage.
- There appears to be limited scope for Australian piggeries to supply biomethane into a centralised natural gas grid, given the cost and level of technology required for upgrading biogas to the required standard.

Application to Industry

The research findings from this project are expected to assist pork producers and industry service providers in planning biogas capture and use systems, and in selecting a range of practical, cost-effective uses for the available biogas. Adoption of the options outlined in this report will mitigate the economic risks associated with implementing biogas use systems, resulting in reduced farm energy and production costs, and lower greenhouse gas emissions from individual farms and the wider industry.

Research Summaries for Subprogram 4C continued

PROJECT 4C–115: BIOENERGY SUPPORT PROGRAM – TRANSITION (RESEARCH)

Project Leader:
Dr. Stephan Tait

Project Participant:
University of Queensland

Aims and Objectives

Biogas is increasingly used at Australian piggeries to produce heat and generate electricity, with current uptake of biogas by about 13.5% of total Australian pork production. The present project facilitated further uptake of biogas, by conducting targeted biogas-related research.

Solids separation can be used to reduce volatile solids (VS) loading on a covered anaerobic pond (CAP), thereby decreasing the propensity for scum/sludge formation and reducing the pond size required. However, separation of manure solids also removes organic matter and with it methane potential. Australian piggeries installing biogas systems were interested to understand the impact of solids separation. Manure samples were collected from these piggeries before and after solids separation to quantify methane potential losses.

High concentrations of hydrogen sulphide (H_2S) in piggery biogas (500–3000ppm) currently discourages biogas use in Australia. H_2S at these concentrations is extremely hazardous and highly corrosive. There is a lack of practical and cost-effective H_2S removal options, because the many commercially available H_2S removal methods have limited applicability because of high cost, complexity and potential safety issues. To develop practical and cost-effective options, the present study carried out piggery field trials of a simple biological oxidation concept and separately chemisorption using an iron-rich red soil.

Key Findings

Results of the solids separation study confirmed that VS removal by solids separation also reduced methane potential (an unwanted effect), specifically by 17–31% for a screw press and by 22% for a static run-down screen. Methane yield loss was approximately proportional to the extent of VS removed by the solids separation.

H_2S removal by biological oxidation in an simple external vessel was very effective, removing over 90% of the H_2S and reducing H_2S concentrations from a high 4,000 ppm to <400 ppm. Chemisorption using red soil also removed H_2S, but substantially less than a commercial iron-oxide pellet media. Therefore, red soil would only be feasible for final polishing of biogas after an initial biological oxidation step had removed most of the H_2S.

Application to Industry

For covered ponds, it is recommended that a static screen or a similar, mild method of solids separation, be considered to reduce the potential for float layers/crust under the pond cover. This solids separation would reduce methane potential near equivalent to the extent of VS removed.

It is recommended that H_2S be removed from piggery biogas using biological oxidation in an external treatment vessel and using covered pond effluent as nutrient source, because it is simple, cost effective, and performs very well. However, the safety aspects of mixing small amounts of air with biogas (for the biological oxidation) should be made clear and widely advertised, to prevent hazardous scenarios with explosive gas mixtures in the Australian pork sector. Chemisorption with iron-oxide media can be used to remove any H_2S that remains after the initial biological oxidation step. This would ensure that biogas is treated to a consistent high quality for on-farm use.

In the future, food by-products unsuitable as a pig feed will likely be increasingly co-digested with pig manure to boost methane production. However, it is recommended that food by-products instead be used as a pig feed wherever nutritionally, legislatively and economically appropriate. This is so that energy production does not compete with food production, and because the value of pig feed far exceeds the value of biogas methane that can be produced from organic matter in the feed.

PROJECT 4C–116: BIOENERGY SUPPORT PROGRAM (BSP) – DAF TRANSITION

Project Leader:
Alan Skerman (DAF)

Project Participants:
Dr Stephan Tait, AWMC, University of Queensland

Aims and Objectives

1] To effectively extend the outcomes from research Projects 4C–104, 4C–109, 4C–111 and 4C–113 across the pork industry and contribute to meeting Pork CRC Milestones 4.5.2, 4.5.3, 4.5.5, 4.5.6, 4.5.7.

2] To continue to promote adoption of biogas by offering technical support to early adopter producers, and keep Pork CRC biogas-related extension materials up-to-date as an information resource to support biogas adoption.

3] To provide the Pork CRC with up-to-date information about on-going activities and adoption of new technologies at the Pork CRC biogas demonstration sites.

Key Findings

Biogas systems are currently operating at 21 piggery units across Australia. Effluent from approximately 15% of the total Australian pig herd is currently directed to biogas systems which include 14 covered ponds (CAPs), 4 hybrid mixed/heated CAPs and 3 engineered vessel digesters. This is equivalent to 29% of the national herd housed in accommodation currently considered 'suitable' for biogas capture (exclude deep litter housing, outdoor production and smaller piggery units). Producers who have adopted biogas systems have reported significant financial benefits from energy cost savings, sale of surplus electricity to the grid, and returns from the sale of carbon credits and renewable energy certificates (RECs). In several cases, farm

energy costs for the supply of electricity, LPG and diesel have been eliminated and capital expenditure payback periods less than three years have been reported. However, the majority of piggeries currently benefiting from biogas systems have capacities greater than 10,000 SPU (1000 sows farrow to finish), highlighting a need for continued development of biogas options for smaller piggeries, so they can also benefit. During the project term, the BSP assisted many producers, industry service providers and consultants with enquiries regarding piggery biogas system feasibility, planning, design, and even construction, commissioning and operation of biogas systems. The publications produced by the BSP have contributed substantially to reference/extension material available to support the ongoing safe and technically sound development of on-farm biogas systems. Scientific publications also evidenced the rigor of Pork CRC research in biogas. A national biogas survey indicated there were a substantial number of smaller producers interested in biogas and needing further information to assist adoption. The greatest concerns identified by producers with existing biogas systems were depleted biogas production, red tape, sludge management in CAPs, lack of industry support personnel and suppliers, and expensive generator maintenance.

Application to Industry

Based on the project findings, the following future needs/ opportunities are worthy of further exploration to enhance biogas benefits to industry and individual producers:

- Apparent market failure of service providers to cost-effectively deliver the whole range of services required by producers.
- The viability of co-digestion of piggery effluent with various off-farm waste or by-products supplied by nearby industries to maximise returns from biogas systems.
- Smart electricity grid monitoring, spot price checks on grid electricity, and negotiations with grid owners, could enable sale of biogas-derived electricity during higher demand/spot price periods to increase the financial gains from biogas.
- Onerous and inconsistent gas safety standards and legislation should be addressed, as these are discouraging biogas adoption.
- Biogas safety risks should be reinforced, and employees should be well informed at piggeries that capture and use biogas.

PROJECT 4C–117: BENCHMARKING THE PERFORMANCE OF AUSTRALIAN PORK WITH LIFE CYCLE ASSESSMENT

Project Leader:
Stephen Wiedemann
(Feedlot Services Australia)

Project Participants:
Eugene McGahan
(Feedlot Services Australia),
Caoilinn Murphy (FSA Consulting)

Aims and Objectives

1] To benchmark greenhouse gas emissions from Australian pork production using life cycle assessment.

2] To determine emission hotspots in the production system and supply chain.

3] To determine the mitigation potential of alternative manure management systems.

Key Findings

- This study provides the first benchmark of greenhouse gas emissions from Australian pork across the full production system. This included emissions from feed production, housing, manure management and meat processing. Average impacts at the farm-gate are 3.6 kg CO_2-e / kg live weight pork, or 6.36 +/- 1.03 kg CO_2-e / kg wholesale (processed) pork.
- There is a broad range of impacts between different sized operations and different housing /manure management systems.
- Substantial opportunities exist for industry to reduce emissions.
- Biogas capture with heat and power generation resulted in a 31–64% reduction in GHG from conventional housing.
- Deep litter housing resulted in a 38% reduction in GHG compared to conventional housing.
- The lowest modelled emissions from Queensland pork production (1.5 kg CO_2-e / kg LW) were similar to Queensland chicken meat production (1.3 kg CO_2-e / kg LW*).
- When manure management systems are the same, 88% of the variability in GHG can be predicted from differences in herd FCR, demonstrating that FCR is the most important production related indicator of GHG emissions.
- Installation of covered anaerobic ponds or digesters across 50% of the industry is expected to result approximately 30% lower GHG from pork.

Application to Industry

- Most emissions arise from manure management, followed by feed, housing and meat processing.
- GHG emissions can be reduced by changing housing / manure management systems – with the biggest improvements achieved by installing biogas and combined heat and power.
- Deep litter housing and outdoor production will also generate lower GHG than conventional housing.
- Apart from manure management, feed conversion ratio is the most important production parameter that influences emissions, and this can be used to predict GHG from conventional housing systems.

* Comparison study – Wiedemann et al. 2016 – resource use and environmental impacts from Australian chicken meat production, Journal of Cleaner Production, in press.

Research Summaries for Subprogram 4C continued

PROJECT 4C–121: THE LOW EMISSION FUTURE OF PORK

Project Leader:
Stephen Wiedemann

Project Participant:
Integrity Ag Services

Aims and Objectives

The project aimed to determine the greenhouse gas emissions (carbon footprint, CF) from the expanding pork production using the best technology for low CF emissions, demonstrating improvements achieved by the industry and the pork CRC for the year 2015 and projected to the year 2020.

Objectives:

1] To quantify the CF impacts from marginal suppliers of Australian pork.

2] To provide LCA data on Australian marginal suppliers and demonstrate an application of consequential LCA modelling.

3] To assess CF emission trends of marginal suppliers in 2015/16 and projections of the CF emission impacts from the pork industry in 2020/21.

Key Findings

This study revealed that future marginal Australian pork production generated substantially lower CF impacts across three scenarios, compared to previous benchmarks for average Australian pork. Excluding land use change (LUC), the impacts approached the CF of average Australian chicken meat. In the present study, significant improvements were observed in herd performance compared to the industry average in 2010. When combined with changes in the proportion of different housing types and the increase in use of biogas, this resulted in 44% lower impacts for marginal pork production in 2015/16 and 63% for 2020/21 compared to the average benchmark (2010), excluding LUC. These results showed substantial progress towards the goal to reduce the CF of Australian pork to 1.0 kg CO_2-e kg LW^{-1}.

Key factors contributing to the substantial improvement in CF for projected, future Australian pork is the change in herd performance and manure management system. Biogas production was found to be a common feature of the larger, new conventional piggery developments. The cost effectiveness of biogas installation is supported by the market for Australian Carbon Credit Units (ACCUs), which provides a revenue stream from gas used to generate electricity, and excess, flared gas. This has substantially improved the cost-effectiveness of biogas installation in Australia and is a key policy feature assisting the industry transition to lower emissions in the future.

Application to Industry

The authors investigated several mitigation strategies the industry could use to further reduce the environmental burden associated pork production, including: optimised biogas, optimised diets and increased turnoff weight.

The increase in the use of manure for energy production by means of biogas generation could significantly reduce the CF and environmental impacts of pork production. Additionally, the use of pig feed formulated from crops with lower cultivation impacts, and local production of the feed components could significantly reduce the environmental impacts of Australia pork production. Interestingly, an increase in turnoff weight would allow the industry to expand with the low environmental impacts. A mixture of these strategies could be applied to the pork industry to reduce GHG emissions even further and potentially achieve the Pork CRC target to reduce the CF of Australian pork to 1.0 kg CO_2-e kg LW^{-1}.

PROJECT 4C–122: INSTALLATION OF INSTRUMENTATION FOR REMOTE MONITORING OF BIOGAS COMPOSITION AND OPERATIONAL DATA AT COMMERCIAL PIGGERIES

Project Leader:
Alan Skerman (Department of Agriculture and Fisheries)

Project Participants:
Dr Stephan Tait (Advanced Water Management Centre, University of Qld)

Aims and Objectives

To facilitate and provide incentives for producers to install instrumentation to enable Pork CRC Bioenergy Support Program (BSP) officers and piggery managers to remotely monitor biogas composition and other operational data at up to three existing on-farm biogas systems operating at commercial piggeries.

Key Findings

New instrumentation was installed to closely monitor the operation of an existing hybrid covered anaerobic pond (hybrid CAP) at Piggery A, from April to June 2018. Over this period, the average biogas production from the hybrid CAP was 5,601 m^3/d and the resulting biogas and methane yields were 523 m^3 biogas and 287 m^3 CH_4, respectively, per tonne of volatile solids (VS) discharged into the hybrid CAP. The recorded methane yield indicated that the hybrid CAP was achieving a high methane recovery of 88% of the biochemical methane potential (BMP). Approximately two-thirds of the biogas produced by the hybrid CAP was used to run two 250 kWe combined heat and power (CHP) generator units, while the remaining third was burnt in a shrouded flare. The two CHP units generated an average of 6,490 kWh/d over the monitoring period (average output 270 kWe). Thirty-six percent (36%) of the electrical power generated by the CHP units was used in the pig sheds, predominantly running cooling fans, lights and heat lamps, 26% of the power was used to operate the on-site feed mill, and 26% was exported to the electricity grid. The remaining 12% (34 kWe) was used to run the hybrid CAP and onsite biogas production and use infrastructure. Piggery shed power consumption decreased and grid exports increased from April to June, reflecting the lower usage of the evaporative cooling fans as the weather became cooler. Based on the average power generation of 1.73 kWh/m^3 biogas and the average biogas methane content of 55%, the average electrical efficiency of the generator engines was 34%, which is typical for reciprocating biogas engines.

The average hydrogen sulphide (H_2S) concentration in the biogas extracted from the hybrid CAP (223 ppm H_2S) was much lower than levels typically observed in raw piggery biogas and only marginally higher than the recommended maximum of 200 ppm for many generator engines. However, this reduction in H_2S concentration, which was achieved by biological oxidation inside the hybrid CAP headspace, was not sufficiently consistent for safe operation of the generator engines. Further biogas treatment in the external biological scrubber reduced the H_2S concentrations to very low levels (average 18 ppm) which rarely exceeded 200 ppm. Occasional spikes in the H_2S concentration generally coincided with generator stoppages which resulted in stoppages of the biological scrubber, biogas blower and air dosing pump. In general, the combined biological oxidation in the hybrid CAP and external biological scrubber was effective at removing H_2S from the biogas.

Application to Industry

Installation of monitoring instrumentation, similar to that installed at Piggery A, has considerable potential for improving the management of on-farm biogas systems. More specifically, the high quality, real-time data provided by such installations assists piggery managers to promptly diagnose operational irregularities and system faults, and thereby avoid costly damage to system components, such as generator engines. The output data can also be used in evaluating a range of operating strategies and biogas treatment methods to maximise economic benefit. The installation of the monitoring instrumentation at Piggery A provides a model for the further development and more widespread deployment of similar systems across the industry.

PROGRAM

5 Improving Sow Reproduction

The research reported under Program 5 completes that commenced as part of the CRC for Internationally Competitive Pork industry to enhance the reproductive efficiency of the Australian industry by providing better means of detecting pregnancy, increasing litter size and ultimately volume.

SUBPROGRAM 5A **IMPROVING SOW REPRODUCTION**

Subprogram 5A: Improving Sow Reproduction

The research completed work commenced as part of the CRC for Internationally Competitive Pork industry and will enhance the reproductive efficiency of the Australian industry by providing better means of detecting pregnancy, increasing litter size and ultimately volume.

PROJECT ID	TITLE
5A–101	Improving sow reproductive output through dietary manipulation in late lactation
5A–102	Reducing stillbirth & preweaning mortality rates through better gestation feeding
5A–103	Determining the effects of season on timing of ovulation and luteal function
5A–104	Pre-farrowing prediction of litter size
5A–105	Improving embryo quality in pluriparous sows
5A–106	Improving reproductive performance in pigs
5A–107	Dietary ractopamine supplementation
5A–108	Impact of temperature on sow productivity

Research Summaries for Subprogram 5A

PROJECT 5A–101: IMPROVING SOW REPRODUCTIVE OUTPUT THROUGH DIETARY MANIPULATION IN LATE LACTATION

Project Leader:
Professor Paul Hughes (SARDI)

Aims and Objectives

There is now a wide body of evidence to show that sows place the highest priority on milk production during lactation and will normally attempt to maximise the output of milk nutrients for their offspring regardless of maternal nutrient intake. Hence, in many situations lactating sows are compelled to rapidly mobilise maternal tissue to provide substrates for milk production to compensate for deficiencies in lactation feed intake. Even so, in many first lactation sows the rate at which they catabolise their own body reserves is not fast enough to prevent reductions in milk nutrient output. The literature suggests that those sows that are forced to mobilise maternal tissue at or near the maximum rate are most at risk of reproductive failure post-weaning (see Thaker & Bilkei, 2005). This effect is particularly noticeable in late lactation when the quality (and possibly number) of oocytes to be released at the post-weaning ovulation is determined. This project asked two questions:

1] How nutrient intake can be increased in late lactation when the sow would normally already be on an *ad libitum* or high allowance regimen.

2] Will any additional nutrient intake in late lactation actually be partitioned to maternal tissue (hence benefitting oocyte development & quality) or will it simply enhance late lactation output.

The project involved 36 sows allocated to one of three treatments. Two treatment groups of sows were fed 4 kg /day of a standard lactating sow diet throughout a 24 day lactation while a third positive control group were fed 6 kg /day throughout lactation. One treatment group receiving 4kg/day of feed was also given a daily supplement of 1 kg/d of a top dressing (comprising a mixture of glycerine, sugars, starches, oils & quality proteins) for the last 7 days of the lactation. To assess the impact of the feed intake & dietary supplement on the sow's lactation, milk samples were collected from each sow on days -7, -3 and -1 pre-weaning. After weaning all sows were checked twice daily for oestrus in the presence of a boar. At detection of oestrus sows were slaughtered & oocytes harvested from their ovaries. The size of the presumptive ovulatory follicle pool was counted and the oocytes aspirated from these follicles were matured in vitro to assess their developmental competence and ability to progress through the early stages of embryonic development.

Specifically, aspirated oocytes were matured in vitro for 44 hours (IVM), at which point the number and proportion of oocytes at each stage of meiosis were determined and recorded. Those oocytes reaching metaphase II were fertilised in vitro (IVF) and the stage of embryonic development achieved after 7 days of in vitro culture recorded.

Key Findings

Contrary to the available literature, this study demonstrated that either:

1] Oocyte developmental competence, as measured by blastocyst formation in vitro, is impaired by high level feeding during late lactation.

2] Or alternatively, that blastocyst development is not impaired by restrictive feeding.

We conclude that either:

1] Feeding level in late lactation does not affect litter size via changes in oocyte development.

2] Or that the current measure of oocyte development is not appropriate.

The major benefit of additional nutrients for the lactating sow in late lactation appears to be enhanced milk output.

Application to Industry

Unfortunately, this project failed to identify a commercial outcome. The main users of these findings will be reproduction research scientists.

PROJECT 5A–102: REDUCING STILLBIRTH & PRE-WEANING MORTALITY RATES THROUGH BETTER GESTATION FEEDING

Project Leader:
Professor Paul Hughes (SARDI)

Project Participants:
University of Adelaide,
Sun Pork Farms SA

Aims and Objectives

It is clear that stillbirth & pre-weaning mortality rates are too high in Australian herds at a total value of approximately 18% (Australian Pig Annual, Target 25). For an individual piglet its two major risk factors for being stillborn are its birthweight & the duration of the farrowing of the litter in which it's born (Knol et al, 2008). Similarly, while much has been written about how to maximise pre-weaning piglet survival rates (e.g. see Hughes, 1993; Varley, 1995) the facts remain that the drivers of early piglet death are facility design (overlays & chilling), undernutrition (low birthweight/ vigour, poor milk supply) & disease. More recently it has been recognised that piglet activity/vigour in the hours immediately following birth is fuelled by liver glycogen stores. This is critical as most neonates possess limited energy reserves (Seerley et al, 1974) & this may well explain the observation of Knol et al (2008) that piglets with the best survival expectations had the heavier livers. One likely way to reduce stillbirth rates is to increase the sow's energy status at farrowing to permit greater exertion & thus reduce total farrowing time. Equally, now that it is recognised that a strong positive relationship exists between pre-weaning survival rate & piglet liver glycogen stores at birth, the latter may be modified by maternal nutrition during gestation. Since the foetus develops the ability to deposit glycogen in the liver from approximately day 80 of pregnancy it may prove optimal to increase nutrient supply from 5-6 weeks pre-partum onwards. Such a move should also increase average piglet birthweight (see Pluske et al, 1995).

Three studies were conducted to evaluate effects of gestation feeding & hygiene on stillbirth rate, piglet birth weight and pre-weaning piglet mortality.

Experiment 1 used 240 sows at a commercial piggery. The four treatments used were:

1] Sows fed 2.3kg/d of a Dry Sow Diet throughout gestation.

2] Sows fed 2.3kg/d of a Dry Sow Diet for days 1–93 of gestation then 3kg/d of the same diet for the remaining 21 days of gestation.

3] Sows fed 2.3kg/d of a Dry Sow Diet for days 1–72 of gestation then 3kg/d of the same diet for the remaining 42 days of gestation.

4] Sows fed 2.3kg/d of a Dry Sow Diet throughout gestation with an additional 0.7kg of a dietary supplement fed on top of the standard diet for the last 21 days of gestation.

Experiment 2 used 123 sows at the Roseworthy piggery. These were allocated to high (3.3 kg/d) or low (2.3 kg/d) feeding and standard v. high accommodation hygiene regimen for the last 4 weeks of gestation.

Experiment 3 used 658 sows at a commercial piggery & fed either 2.3 kg/d or 3.0 kg/d over the last 4 weeks of gestation.

Key Findings

All three studies found there was no benefit to be gained by increasing nutrient supply to sows over the final weeks of gestation. Additionally, study 2 indicated that the sow's nutrient requirements in late gestation were not significantly altered by the hygiene status of the accommodation provided.

Application to Industry

These data indicate that increased feeding for sows in late gestation is not necessary.

Research Summaries for Subprogram 5A continued

PROJECT 5A–103: DETERMINING THE EFFECTS OF SEASON ON TIMING OF OVULATION AND LUTEAL FUNCTION

Project Leader:
Dr William van Wettere

Project Participant:
University of Adelaide

Aims and Objectives

1] To determine the effect of season (summer/early autumn versus winter) and moderate nutritional restriction on the developmental competence of peri-ovulatory oocytes collected from cycling gilts. The effect of moderate nutritional restriction was included in the trial to mimic the effect of elevated temperatures on feed intake in group-housed gilts.

2] To extend our previous data demonstrating that progesterone release during early gestation differs between summer and winter by determining the effect of season (summer/autumn versus winter) on the timing of ovulation and peri-ovulatory profiles of luteinising hormone (LH) and progesterone (P4) in weaned sows.

Key Findings

There was no effect of season or reducing feed intake from 2.5 to 1.5 times maintenance on oocyte developmental competence (as measured by capacity to reach metaphase II). However, the dynamics of the peri-ovulatory follicle pool did differ between summer/autumn and winter, with fewer follicles growing beyond 6 mm in summer. Interestingly, no effect of moderate nutritional restriction on oocyte competence was observed. When combined with previous studies, this finding suggests a severe restriction in nutrition (feeding at maintenance levels) must occur before the ability of oocytes to reach metaphase II is impaired.

The second study confirmed the negative effect of summer/early autumn on basal LH release, and confirmed our previous finding that P4 levels were significantly higher in summer compared to winter, with levels increasing more rapidly from 72 hours post-oestrus detection onwards.

Sows weaned during summer ovulated approximately 10 hours earlier during oestrus than those weaned in winter, resulting in alterations in the interval from insemination to ovulation (there was no difference in WOI). Assuming oestrus detection occurs every 24 hours, and sows are inseminated at first detection of oestrus and again 24 hours later, the first insemination would, occur therefore 18 hours prior to ovulation, with the second one occurring after ovulation. It could, therefore, be suggested that this alteration in the timing of ovulation and hence inseminations occurring outside the optimal period relative to ovulation (i.e. 0–12 hours pre-ovulation) could be partly responsible for the reduced fertility and fecundity of sows mated during summer

Application to Industry

Gilt reproduction appears unaffected by moderate reductions in feed intake, and seasonal effects on oocyte competence (which determines litter size) appear to be subtle in gilts.

During summer, producers, which experience a summer/early autumn depression in fertility, should consider modifying their insemination protocols to account for the earlier ovulation relative to first oestrus detection.

PROJECT 5A–104: PRE-FARROWING PREDICTION OF LITTER SIZE: TOWARDS IMPROVING SOW METABOLIC STATUS DURING THE PERI-PARTUM PERIOD

Project Leader:
Dr William van Wettere (University of Adelaide)

Project Participant:
Sun Pork Farms SA

Aims and Objectives

To reduce costs of production it is vital that nutrient intake is closely matched to sow requirements for optimal body composition and reproduction. The development of optimal feeding strategies for gestating sows is complicated by the need to satisfy maternal and fetal nutrient requirements, as well as prepare the sow for the demands of lactation. Failure to achieve these targets can have negative consequences for sow lactation performance, reproduction and longevity, as well as progeny survival and performance. The effect of increasing feed intake during the last three weeks of gestation on sow performance and piglet birthweight and survival is controversial. Recent Australian data indicates that sows gestating large litters have impaired subsequent

performance, while in another study late gestation feeding level did not affect progeny or sow performance. Consequently, the current study had two overall aims: one, to determine whether plasma oestrone sulphate could be used to accurately predict litter size; and two, to determine the effect of gestated litter size, parity and feeding level on sow and progeny performance.

In this project plasma samples were collected from 959 pregnant sows on day 23 of gestation and analysed for oestrone sulphate. Total litter size of these sows was recorded, and used to develop an equation for predicting total litter size based on oestrone sulphate. Using 841 sows, a 2 x 2 x 2 factorial experiment was conducted, incorporating two parity groups (gilts vs sows), two predicted litter size groups (LARGE, >12 piglets vs SMALL, < 12 piglets) and two feeding levels from day 85 of gestation until farrowing shed entry (LOW vs HIGH). Daily feeding levels were 2.2 kg and 2.3 kg for LOW gilts and sows, respectively, with an additional 0.6 kg/day being offered to sows and gilts in the HIGH treatment groups.

Key Findings

There was a significant, positive correlation between oestrone sulphate on day 23 of gestation and total litter size ($r^2 = 0.143$; $P < 0.05$). However, the accuracy with which oestrone sulphate predicted large and small litters was only 60.5% and 63.5%, respectively and based on this prediction accuracy, and the extra labour and assay costs, the commercial application of this technology to accurately predict subsequent litter size appears limited.

Although increasing feed intake in late gestation by about 0.6 kg/day failed to significantly improve overall sow reproductive or piglet performance, the higher feeding level during late gestation exerted subtle, yet potentially beneficial, effects on piglet birthweight and survival. Specifically, the number of vulnerable (< 1 kg birthweight) piglets and stillborn piglets tended to be lower and the variation in piglet birthweight was lower for HIGH fed sows. These findings indicate that higher feeding levels in late gestation may promote growth of the smaller foetuses. However, these potential beneficial effects need to be balanced against the additional feed costs associated with HIGH level feeding in late gestation.

Gilts which gestated and suckled a large litter had a smaller second litter size, suggesting that strategies to reduce the metabolic drain on first litter sows during lactation should be explored.

Application to Industry

These data indicate that increased feeding for sows in late gestation does not necessarily result in overall improved piglet and sow performance, but may have subtle effects, particularly on the smaller piglets.

These results along with other nutritional studies with gestating sows should be presented to the Australian pork industry to identify in which situations, if any, increased feeding during late gestation may be beneficial.

PROJECT 5A–105: EXTENT AND TIME OF EARLY EMBRYO LOSS AND EFFECTS OF NUTRITION ON EMBRYO QUALITY

Embryo survival at day 9, 21 and 35 of pregnancy in intact and unilaterally oviduct ligated multiparous sows

Project Leader:
Pieter Langendijk
(SARDI Livestock)

Aims and Objectives

Embryo mortality in pigs ranges from 10 to 50%, and losses are high predominantly in multiparous sows. Because embryo losses are related to the available uterine space, it is often assumed that embryo survival at the end of the embryonic phase (d 35–40 of gestation) is limited by uterine capacity. Most studies, however, have assessed the extent of embryo mortality at this stage and hence it is not clear at what time during early gestation the losses actually occur and to what extent the losses at various stages of the embryonic phase are space related. This project investigated when embryo mortality occurs and how available uterine space affects it.

Multiparous sows were mated and sacrificed at day 9, day 21, or day 35 of gestation to measure the number of ovulations, embryo survival, and a number of placental and uterine characteristics. In a subsample of sows one oviduct was ligated to reduce the number of embryos entering the uterus by 50% on average, and hence double the available space for the embryos. These sows were sacrificed at day 21 or day 35.

Key Findings

In conclusion, in multiparous sows about 40% of embryos are lost during the first month of gestation. Two thirds of this loss is between day 9 and day 21, so before and around implantation of the embryos. Embryo loss during this critical stage was not due to crowding and is likely to be due to intrinsic embryo quality, interaction between embryos and/or the uterine environment, or a combination of these factors. There was less loss of embryos between day 21 and 35 where uterine space appears to become limiting.

Ovulation rate still limits embryo survival in multiparous sows and efforts should be continued to increase ovulation rate in sows, particularly through management of younger sows and more genetic efforts in this area.

Ways to increase ovulation rate through management:

- Replacement gilts should be mated at second or third heat.
- Flush feed breeding gilts (2.5 kg per day or more) prior to mating. To be effective flush feeding should start at least two weeks before expected mating.
- In first litter sows, body weight loss during lactation needs to be minimised by:
  - Maximising feed intake during lactation, which requires good climate control in the farrowing shed, and avoid over-conditioned gilts during late gestation (don't feed more than 2.5 kg/day).

Research Summaries for Subprogram 5A continued

  - Limit suckling litter size to 10–11 piglets.

- In first litter sows, first post weaning mating can be delayed by one week of Regumate treatment. Preferably use a double dose (2x20 mg per day).

Application to Industry

The findings of this project are not immediately applicable at a commercial level, but provide strong direction for further research that aims to increase litter size.

PROJECT 5A–106: IMPROVING REPRODUCTIVE PERFORMANCE IN PIGS

Project Leader:
Dr Sean O'Leary

Project Participants:
University of Adelaide, Roseworthy Piggery and Australian Pork Farm group

Aims and Objectives

The project used a three-prong approach to increase farrowing rates, increase litter size, decrease the number of NIPs and reduce the use of boars in the mating shed. The project consisted of 3 subprojects to address these aims:

1] Fixed-time AI (FT-AI) using Gonavet using only one insemination to increase farrowing rates.

2] Increasing progesterone levels during early pregnancy to increase litter size.

3] Development of an early pregnancy test strip to detect pregnancy as early as day 19 post mating and reduce the number of NIPs and empty days in the herd.

Key Findings

Protocols for using FT-AI were developed and tested in a series of experiments using research and commercial herds. The preferred FT-AI protocol was an injection of equine chorionic gonadotrophic hormone (eCG) 24 hours after weaning, followed by a gonadotrophin releasing hormone analogue (GnRHa) 96 hours after weaning. Insemination with one dose of 3 x 10^9 spermatozoa followed 24 hours after the GnRHa injection. This FT-AI protocol with one insemination maintained subsequent litter size, but increased pregnancy and farrowing rates without requiring boar stimulation and synchronisation of heat.

Several experiments were conducted to develop progesterone (P4) implants that were capable of releasing sufficient progesterone to increase circulating levels of P4 in early gestation to improve embryo survival. Progesterone levels in blood samples collected from the jugular vein were increased by P4 implants inserted on day 10 of pregnancy but this was not associated with an increase in subsequent litter size.

In the third component of the Project, a nitrocellulose (NC) test strip based on lateral flow technology was suggested as a technology to detect pregnancy in sows within about day 20 after insemination. Pregnancy detection using blood and urine samples from day 19 pregnant gilts and sows was possible using established laboratory-based oestrone and progesterone radioimmunoassay. However, although pregnancy was able to be detected by the NC strips containing the appropriate antibodies that were developed within this project, it was not anywhere near the level of accuracy required for a commercial product.

Application to Industry

The standard FT-AI protocol of eCG 24 hours after weaning, followed by GnRHa 96 hours after weaning and then insemination 24 hours later with one dose of 3 x 10^9 spermatozoa does provide at least equivalent performance to the standard oestrus detection and mating procedures. This FT-AI protocol should be evaluated in further field studies, particularly under conditions where fertility may be compromised.

The findings from the progesterone implant studies cannot be directly applied to commercial pork production because the progesterone response from implants was inconsistent and not sufficient to evoke an increase in early embryo survival.

A Pork CRC commercialisation project was initiated with a Belgium company to examine whether the NC technology could be commercially developed to the stage of being able to accurately diagnose pregnancy at about day 20 after insemination.

PROJECT 5A–107: DIETARY RACTOPAMINE SUPPLEMENTATION TO IMPROVE THE PRODUCTIVITY OF SOWS

Project Leader:
Dr Will van Wettere
(University of Adelaide)

Project Participant:
Australian Pork Farm Group and Elanco

Aims and Objectives

Previous pilot studies demonstrated that dietary ractopamine (RAC) supplementation of lactation diets for first litter sows reduced weight loss, decreased anoestrus rates post-weaning by 20% and resulted in a 1.4 increase in the number of piglets born alive at the second farrowing. Two comprehensive commercial studies were conducted in this Project to extend the knowledge about RAC supplementation of lactation diets and to determine whether RAC supplementation of lactation diets may offer an economic response.

Key Findings

Almost 800 first litter sows were allocated to three treatments. The treatments were; Control (0 ppm RAC during lactation), RACD2W (20 ppm RAC from day 2 of lactation to weaning), and RAC10W (20 ppm RAC from day 10 lactation to weaning). An additional study using a total of 464 first litter sows examined similar treatments, but with a RAC dose of 5 ppm instead of 20 ppm.

Both studies demonstrated that RAC supplementation during lactation, regardless of the supplemental dose, duration and timing relative to farrowing significantly reduced sow weight loss by between 3 and 7 kg during lactation. Despite these changes in body weight loss, there was no significant effect of RAC supplementation on piglet performance during lactation or subsequent reproduction performance of the sows.

The failure of RAC supplementation to improve subsequent reproductive performance may be attributed to the relatively low weight loss during lactation and excellent reproductive performance of first litter sows within this herd. The average live weight of sows after their first farrowing was in excess of 200 kg and 190 kg in the two studies. Furthermore, the minimal sow weight loss during lactation indicates relatively high feed intakes during lactation. Consequently, across all treatments, over 85% and 93% of sows exhibited oestrus within 7 days of weaning in the two studies.

Application to Industry

Ractopamine (RAC) supplementation of lactating sow diets may reduce bodyweight loss during lactation. However, where voluntary feed intake during lactation is relatively high and weight loss in first litter sows is limited, RAC supplementation had no significant effect on lactation or reproductive performance of first litter sows.

Supplementation of lactation diets with RAC may be a useful strategy to reduce lactation weight loss and improve subsequent reproduction within herds with a problem of high lactation weight loss, particularly in first litter sows. However there are likely to be other more easily implemented strategies that should be explored to improve voluntary feed intake during lactation, body condition at first farrowing and the consequent reproductive performance.

PROJECT 5A–108: IMPACT OF TEMPERATURE ON SOW PRODUCTIVITY

Project Leader:
Dr William van Wettere

Project Participant:
University of Adelaide

Aims and Objectives

The intention was to use data loggers to record and collate the fluctuations in temperature and humidity experience by breeding sows during the breeding cycle. Specifically, data loggers (i-buttons) were installed in four commercial facilities, two in Queensland and two in South Australia. The data loggers were set up to record at 4 hourly intervals each day and were installed in farrowing sheds, mating sheds and dry sows sheds. It was intended to record the actual temperature and humidity experienced by the sow. Temperature and humidity data was to be used in conjunction with farm records to evaluate the effect of temperature on the day of mating, and during key periods of gestation, on pregnancy outcomes, litter size data and incidences of stillbirths.

Key Findings

Unfortunately, due to logistical and technical reasons, the proposed study was not completed, and no data was recorded. This was for two main reasons, failure of the i-buttons to continue recording and the diversion of research capacity towards other projects.

Application to Industry

The problems experienced meant there were no implications from the project for industry.

PROGRAM

6 Nutritional manipulations to enhance the performance and feed efficiency of growing pigs

Feed intake and feed efficiency are the two factors most affecting the performance of growing pigs and this research completed work commenced as part of nutritional innovations in the CRC for an Internationally Competitive Pork Industry.

SUBPROGRAM 6A	**NUTRITIONAL MANIPULATIONS TO ENHANCE THE PERFORMANCE AND FEED EFFICIENCY OF GROWING PIGS**

Subprogram 6A: Nutritional manipulations to enhance the performance and feed efficiency of growing pigs

Feed intake and feed efficiency are the two factors most affecting the performance of growing pigs and this research completed work commenced as part of nutritional innovations in the CRC for an Internationally Competitive Pork Industry. The research established the extent chemosensory factors, or components of ingredients, might be used in diet formulations to manipulate feed intake, and to establish the extent nutrient asynchrony may play in preventing pigs exhibiting their genetic potential under commercial situations. The research established the extent nutrient availability is affected by ingredients and grain processing, and the extent nutrient asynchrony may play in determining animal performance.

PROJECT ID	TITLE
6A–101	Peripheral chemosensing & feed intake in pigs
6A–102	Influence of nutrient asynchrony on finisher growth performance and feed efficiency

Research Summaries for Subprogram 6A

PROJECT 6A–101: PERIPHERAL CHEMOSENSING AND FEED INTAKE IN PIGS

Project Leader:
Dr Eugeni Roura
(University of Queensland)

Aims and Objectives

The main objective of the project was to identify potential feed ingredients/additives with high preference and high appetite stimulation that may enhance post-weaning feed intake in piglets.

Key Findings

1] The four non-bitter primary tastes (sweet, umami, sour and salty) were found to have preference thresholds in pigs a bit lower (sucrose and citric acid) or slightly higher (MSG and NaCl) than the equivalent identification threshold in humans.

2] Glucose polymers such as maltodextrin, were found to be highly preferred in pigs but only at higher concentrations than classical primary tastes.

3] In addition, the project identified other highly taste-active compounds including organic acids (different from citric acid), L-amino acids (different from glutamic acid) and high intensity sweeteners (other than Na-saccharin). These results are worth further investigation.

4] The project also outlined the need of looking beyond the preference concept and paid particular attention to the concept of sensory-motivated intake. In addition to a good preference value, compounds need to show a high consumption significantly in excess of the water consumed during the double choice.

5] Where the research project showed the highest potential in both sensory-motivated intake and preference was in some of the binary combinations of different taste enhancers tested such as MSG with acids or even sugar. As a result there is a commercialisation project (Pork CRC 8C-002) already ongoing.

6] Equally relevant for the pig industry are other compounds (see key finding 3) that have just been reported with preliminary results here which warrant further investigation before entering into a commercialisation project.

Application to Industry

The results have identified one binary taste combination which is already in a product development phase under the commercialisation scheme of Pork CRC with code number 8C-002.

A novel application for industry would come with further development of taste-active L-Amino acid binary combinations. The development will take a 1 year research project before entering into a commercialisation phase.

Research Summaries for Subprogram 6A

PROJECT 6A–102: INFLUENCE OF NUTRIENT ASYNCHRONY ON FINISHER GROWTH PERFORMANCE AND FEED EFFICIENCY

Project Leader:
Dr Cherie Collins

Project Participants:
Jae Cheol Kim[2], Peter Sopade[3], M.J. Gidley[3], Hugh Payne[2], Bruce Mullan[2], and David Henman[1]

[1]Rivalea (Australia) Pty Ltd; [2]Department of Agriculture and Food of Western Australia; [3]Queensland Alliance for Agriculture and Food Innovation, Centre for Nutrition & Food Sciences, University of Queensland

Aims and Objectives

Maximising the efficiency for which pigs utilise nutrients for weight gain is critical for profitable pork production. There is evidence that the asynchronous supply of amino acids and glucose in the small intestine may reduce protein utilisation and therefore the efficiency for which feed nutrients are utilised for lean tissue deposition. The aim of this investigation was to determine if finisher feed efficiency could be altered by selecting ingredients with differing rates of starch and protein digestion resulting in diets with synchronous or asynchronous nutrient supply.

Key Findings

An initial screening study was undertaken to select ingredients that differed markedly in their starch and protein digestion rates. Based on these results, combinations of three starch sources (slowly digestible starch (SDS, sorghum), moderately digestible starch (MDS, wheat) and fast digestible starch (FDS, barley)) and two amino acid sources (highly digestible amino acids (HDAA, casein) and moderately digestible amino acids (MDAA, vegetable protein – soyabean/canola meal)) were used to create 6 diets differing in their synchrony of glucose and amino acid supply to the small intestine.

A nitrogen balance study was conducted to determine the influence of nutrient synchrony on nitrogen retention rate, with the results indicating a combination of fast digestible starch and highly digestible amino acids improved nitrogen retention rate compared with the combination of slowly digestible starch and moderately digestible amino acids.

A follow up study investigated the impact of these diets on finisher performance. Pigs were individually housed and the diets offered in two meals per day to 95 % of *ad libitum* intakes. Growth performance and feed efficiency was improved when pigs were offered the moderately digestible starch/highly digestible amino acid diet (wheat/casein based diet). The most commercially relevant combinations of fast- moderate- or slowly digestible starch with moderately digestible amino acids (soyabean/canola meal) revealed that rate of gain, feed efficiency and change in P2 back fat was numerically superior (not significant) when pigs were offered the MDS +MDAA diet.

Application to Industry

The combination of fast digestible starch and highly digestible amino acids improved nitrogen retention rate compared with the combination of slowly digestible starch and moderately digestible amino acids. However, superior growth performance and feed efficiency outcomes were obtained with the use of moderately digestible starch (wheat) with either the highly digestible amino acids (casein) or the moderately digestible amino acids (canola meal/soyabean meal).

Based on these results and the unlikely commercial use of casein in finisher pig diets, the MDS+MDAA diet combination is recommended to minimise any negative effects of nutrient asynchrony on the performance of finisher pigs. It is also recognised that the effects of asynchronous nutrient supply is likely much less in animals that are offered feed *ad libitum* and graze continually throughout the day.

Notes

www.porkcrc.com.au