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How to stop the kids from eating you out of house and home: Unravelling factors affecting weaner transition to reduce cost of production in the Australian pig industry

Final Report
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Executive Summary

This project investigated how pre-weaning management influences pig performance after weaning, with the overall aim of identifying practical strategies to improve piglet performance after weaning to reduce cost of production (COP) in the Australian pig industry. There is a large opportunity in the Australian pork industry to improve a piglet's ability to cope with weaning for improved survival, growth, feed efficiency and whole-of-life performance. We aimed to understand which early-life factors most strongly affect post-weaning outcomes to give evidence-based recommendations for producers to manage pigs and ease the weaning transition under commercial conditions.

We aimed to combine retrospective analysis of large commercial datasets with targeted experimental studies to understand how these factors impact post-weaning performance. Historical and recent production records from JBS Pork Australia's Corowa farm were analysed to compare performance before and after a herd depopulation (for control of respiratory pathogens) and to quantify the influence of factors such as weaning age, fostering, birth weight, line, sex and parity on post-weaning survival and lifetime growth (Objective 1). Weaning age spread was a determining factor of lifetime performance seen in the first stage of the project, the impact of which we then aimed to quantify in the second phase. We carried out commercial and intensive evaluations of weaning age spread, including studies in the weaner phase and followed through until sale (Objective 2). We then used the outcomes from these studies to understand the cost benefit of increasing weaning frequency in a large commercial system from once to twice per week, to reduce age spread post-weaning (Objective 3).

The results showed that early-life management has measurable and lasting effects on pig performance. Older weaning age was consistently associated with improved post-weaning survival and lifetime growth, supporting pigs in their weaning transition. Fostering practices also influenced outcomes, with later fostering generally associated with poorer performance than either no fostering or fostering within the first day. Pigs from tighter weaning age spread groups showed improved growth, better feed efficiency and improved carcass weight, indicating that greater uniformity at weaning can support more efficient production when mixing pigs of different developmental stages at this crucial stage.

Importantly, many of the influential factors identified in this project are management-related and therefore potentially actionable on-farm. While some sources of variation, such as sow-related effects, are difficult for the producer to directly influence, strategies that optimise weaning age, avoid unnecessary late fostering, and reduce weaning age spread represent realistic opportunities to improve post-weaning pig performance, feed efficiency and hence COP outcomes in Australian herds.

Overall, this project provides new evidence that improving the consistency of the weaning transition can deliver benefits that extend well beyond the weaner period. A simple indicative cost–benefit analysis suggested that the economic value of tightening weaning age spread is most likely to arise from improved pig uniformity, feed efficiency and carcass weight, rather than from the additional weaning event itself. In large production systems, even small gains in value per pig may be sufficient to offset the extra labour and operational costs of increasing weaning frequency from once to twice per week, provided weaner rooms are filled and pig flows can be maintained. However, the net benefit will depend on system-specific factors including herd size, labour availability, weaner accommodation (e.g., pen and room size) and the extent to which tighter age spread can be achieved in practice.

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1. Background to Research

The potential for influencing health and whole of life feed efficiency by improving a piglets' ability to cope with weaning can have large impacts on lifetime feed costs and overall cost of production (COP). Weaning of domesticated pigs occurs as an abrupt event, differing to the weaning in the wild where the sow's milk supply gradually declines, whilst the piglets foraging and feeding behaviour increases (Budzynska and Weary, 2008; Weary et al., 2008; Blavi et al., 2021). Consequently, domesticated piglets have to develop new strategies to adapt to the new feeding, environment and social structure, in hours rather than weeks. The complexity of this transition frequently affects piglets' growth and productivity (Brooks and Tsourgiannis, 2003).

To improve the weaning transition in commercial production, an holistic approach to weaning is required, including an understanding of social, environmental or physical, and other management factors that impact this process. For pigs in commercial conditions, the abrupt weaning process not only involves mother-piglet separation, but also a profound modification of piglets' feeding, feeding habits, environment, and social interactions (Brooks and Tsourgiannis, 2003; Colson et al., 2006). This complex period leads to stressful changes for piglets (Brooks and Tsourgiannis, 2003; Colson et al., 2006; Lallès et al., 2007).

Although several modifications have been made in the last decades around weaning, a high percentage of piglets present a considerable period of anorexia/under-nutrition, diarrhoea, limited-thermoregulation, and increased aggressive-behaviour (Brooks and Tsourgiannis, 2003; Colson et al., 2006; Lallès et al., 2007). Some studies have investigated individual factors that could be affecting the outcomes of this transition. For instance, researchers have investigated factors such as nutrition (Lallès et al., 2007), type of feed and use of probiotics (Zhang et al., 2019), lighting patterns (Dong and Pluske, 2007), creep-feed pellet formulations (Middelkoop et al., 2019; Craig et al., 2021), and socialisation opportunities before weaning (D'Eath, 2005). Although some studies reported positive results, none of these individual factors have shown enough effects to be considered as a significant solution for the existent challenges around weaning. This may indicate the need to investigate and implement management strategies that consider multiple factors affecting piglets during this transition, i.e. management, nutritional, environmental, and social factors, in order to significantly influence COP.

The purpose of this research was to:

a) Provide a complete understanding of the current challenges around weaning, by identifying the key pre-weaning factors that greatly affect post-weaning performance of pigs.

b) Providing a comprehensive comparison of the productive and economic impacts of these factors between low and high health herds;

c) Quantify the impact of the most important pre-weaning factors on post-weaning performance, feed efficiency, feed costs, and overall production costs in commercial piggeries to assess the potential impact on COP; and,

d) Provide science-based management recommendations that can be used to develop guidelines that allow producers to improve post-weaning performance, reduce HFC, and consequently reduce COP.

2. Objectives of the Research Project

This project set out to identify the critical factors contributing to post-weaning performance in an Australian production system. We had the following objectives for this project:

2.1 Objective 1: Retrospective big data analysis and identification of risk factors

Data collected from JBS Pork Australia's Corowa farm was used to perform big data analysis:
a) We aimed to analyse historical data collected during 2019-2020 ('low-health status') to identify the most important pre- and post-weaning factors that impact lifetime growth (birth to finisher) of pigs.

b) To analyse real-time data from the same farm, but with an improved health status after a Swiss depopulation we used retrospective data records, collected during 2023-2024 ('high-health status') to identify the most important pre-weaning factors that impact post-weaning survival and lifetime growth (birth to finish) of pigs.

With these aims, we hoped to evaluate the importance of farm management procedures (e.g. weaning age, fostering), environmental characteristics (e.g., ambient temperature), and individual characteristics of pigs (e.g., piglet birth weight, dam and nurse sow parity), based on their influence on productive indicators (i.e., survival rate and growth) in the post-weaning phase, and hence evaluate their overall economic impact on the production system. We aimed to use a series of statistical models, including generalized linear mixed models to identify the pre-weaning risk factors that impact on post-weaning survival and growth performance of pigs after weaning.

2.2 Objective 2: Quantification of risk factors

Given the outcomes from Objective 1, we aimed to focus on determining the impact of weaning age spread on lifetime performance in commercial herds. Objective 2 sought to quantify this effect using two controlled studies focusing on common weaning age spreads seen in Australian production systems, based on weaning twice per week (3 day weaning age spread), once per week (7 day weaning age spread) or > once per week (>7 day weaning age spread).

2.3 Objective 3: Development of recommendations for management strategies

Based on the results observed in Objective 1 and 2, we aimed to develop a set of recommendations in order to provide APL and Australian producers with guidelines that will allow producers to adopt effective, low-cost strategies to manage the weaning transition, which promote lifetime growth performance and feed efficiency.

3. Introductory Technical Information

The weaning stage is arguably the most stressful stage of the pig's life, affecting its growth and performance for the rest of its finishing life (Wolter and Ellis, 2001; Huting et al., 2021). Weaning is recognised as a challenging period from both an animal welfare and animal nutrition perspective (Campbell et al., 2013; Blavi et al., 2021). In addition to the separation from the sow, there are changes in the weaner pigs' physical and social environments, as well as a shift from highly digestible sow milk to a less digestible dry solid feed. Voluntary feed intake around weaning is typically low and extremely variable (Kobek-Kjeldager et al., 2021). The largest and most mature piglets at weaning are likely to have higher feed intakes and, thus, be more resilient to weaning stress compared to younger and smaller piglets (Kobek-Kjeldager et al., 2021), particularly if the latter are not managed separately post-weaning to the older, heavier pigs (Huting et al., 2019). In addition, the immunological status of piglets at this age is characterised by a gap in the protective immune system due to lack of maternal immunity and an immature immune system (Moeser et al., 2017). Having a large age spread at the time of weaning likely contributes to the variability in feed intake.

In commercial pig production, piglets are weaned mostly at 3 to 4 weeks of age, but their actual age and weight at weaning can be variable, depending on how frequently the enterprise undertakes the weaning process. Some enterprises may wean twice a week, some weekly, while others may wean every 10+ d. In addition, given natural variation in gestation lengths, on the day of weaning, the many litters weaned on the same day may be of variable age and weight. Larger wean age spreads are more likely to have groups of pigs which thrive less due to different ages and immune status being mixed and sharing the same space. The younger pigs within these large wean age spread groups are likely to be more susceptible to disease and consequently more at risk of death (Gottschalk and Lacouture, 2015). In addition, these younger pigs would also have a less developed gut microbiome, making the transition to the weaner phase more stressful on their gut, leading to a lower feed efficiency (Tang et al., 2022), which can also make them more susceptible to intestinal issues such as ileitis and scours (Gresse et al., 2017; Tang et al., 2022; Guitart-Matas et al., 2024).

A review of factors affecting weaning weight, such as litter size, birth weight, age at weaning, sow parity, and creep feeding, can be found in our previous report (APL Project 2026/0036; Johnson et al., 2026). This literature review was conducted as part of Kristen Johnson's honours thesis (Charles Sturt University, 2026). During this review of the literature, and from the early stages of this analysis, we found that the impact of weaning age spread is seldom reported, and the economic impacts of weaning more frequently (twice vs. once per week) was not well reported. Hence, we aimed to examine the impact of weaning age spread on lifetime performance of pigs in commercial production and make recommendations to farmers on the ideal frequency of weaning in large production systems.

4. Research Methodology

4.1 Objective 1: Identify pre-weaning risk factors that have the greatest impact on post-weaning survival and performance

The aim of this part of the project was to use retrospective data to compare the effect of management processes and other factors on post-weaning survival until day 70 and finisher performance traits before and after a herd depopulation for *Mycoplasma hyopneumoniae* and Bungowannah virus (unique porcine pestivirus causing Porcine Myocarditis – PMC – syndrome) to provide guidance for risk factors to investigate for the next phase of the project.

We aimed to evaluate the importance of farm management procedures (i.e., weaning age, fostering, and testing age), environmental characteristics (i.e., season), and individual characteristics of pigs (e.g., piglet birth weight, dam sow parity, nurse sow parity, total born in birth litter, genetic line, and sex) have on economic and productive indicators (i.e., survival rate and growth) in the post-weaning phase.

The data from two maternal lines (Large White: LW, and Landrace: LD) and one terminal line (Duroc: DC) were collected from a single farm in southern New South Wales, Australia. Data was extracted from the farm management system (PigFM) and included a total of n = 72,269 individual pig records of piglets born (survival analysis) or finisher pigs tested (growth efficiency analysis) in the two years between 2019 and 2020 (pre-depopulation). We collected similar data set with a total of n = 66,750 individual pig records collected in the two years between 2022 and 2024 (post-depopulation).

The traits investigated were average daily feed intake (ADFI) during the finisher phase (ADIntake), average daily gain (ADG) during the finisher phase (ADGtest), ADG over the lifetime (ADGlife), back fat (BF), feed conversion ratio (FCR), calculated as the ratio between ADFI and ADG over the finisher phase and survival of piglets from weaning until day 70 (PostWS70). The finisher phase ranged from approximately 16 weeks of age until 22 weeks of age. Feed intake data in the finisher phase included only entire male pigs and was only recorded in the second phase of this study after depopulation and repopulation of the herd. Start weight and end weight were recorded, and back fat was measured at the P2 position, which is 65 mm down the left side from the midline at the level of the head of the last rib. The following data cleaning steps were undertaken: Firstly, feed intake data was visually assessed for outliers caused by feeder outage, and sick animals were removed from the data set; secondly, for each trait within the genetic lines defined above, outlier records were identified as being -/+ 1.5 times the predicted interquartile range.

Management processes included fostering (3 levels: 1. Fostered after day 1, 2. Fostered between day 0 and 1, 3. Not fostered), weaning age (3 levels: 1. Less than 24 days, 2. Between 24-28 days, 3. Above 28 days of age) and weaning age spread (3 levels: 1. Less than 8 days, 2. Between 8 and 14 days, 3. Above 14 days) and other factors included dam parity (2 levels, Gilt vs Sow) and piglet birth weight grouping (3 levels: 1. Less than 1.3 kg, 2. Between 1.3-1.5 kg, 3. Above 1.5 kg), genetic line (3 levels, LW, LD and DC) and sex (2 levels, Female vs Male). To account for change in management year month of finisher testing and testing type (Conventional group vs Electronic feeder group) were fitted as combined variable for finisher traits and year month born for post-weaning survival. Fixed effects were selected based on the Wald Test (Buse, 1982).

A series of statistical models were performed as part of this analysis, including generalised linear mixed models to identify the pre-weaning risk factors that impact on post-weaning survival, and linear models to identify the pre-weaning risk factors that affect the growth performance of pigs during and after weaning. Random variables were included in models if significant ($P < 0.05$) based on a log-likelihood ratio test. Random effects for each growth, leanness, survival, and feed intake traits included the permanent environmental effect of the birth litter, and the residual effect.

4.2 Objective 2: Quantifying the impact of weaning age spread on lifetime performance

All experimental procedures described for Objective 2 were approved by the JBS Pork Australia Animal Ethics Committee (Protocol numbers 25-002, 25-010 and 25-013) before commencement.

4.2.1 Experiment 1: Commercial evaluation

Experimental Design

The commercial evaluation experiment was carried out at the Research and Innovation unit at Module 1, Corowa NSW. Thirty female and 30 male pens (n = 17-18 pigs per pen) were allocated to two weaning age spread treatments: (A) 3 day age spread; or, (B) 7 day age spread. Pigs were recruited for the study before weaning based on the parity of their birth dam (parity 1 to 7, mean 2.1 ± 2.0 SD) which was allocated evenly between treatments. At weaning (24 ± 1.4 days of age) a maximum of 4 males or 4 females were taken from any one litter (2 males and 2 females per litter, on average), and litter mates were spread between different pens in the weaner facility to remove confounding effects of the litter.

The weaner facility was broken up into 6 separate 'rooms' sharing the same airspace, separated by a solid wall and an aisleway. Each room included 30 treatment pens and 2 hospital pens (for pigs taken off trial). Treatments were blocked by room to allow for nose-to-nose contact between pigs of the same weaning age spread treatment, as would be the case in the commercial environment. Both treatments were housed in the same airspace; however, from previous data collected in this shed there was no significant impact of room on pig performance, and hence we did not expect this to confound any treatment effects due to weaning age spread (data not shown).

Pen weights were taken at entry to the facility (weaning; day 0), at day 7, 14 and 35 at exit, to calculate ADG for the first 7 days and the total weaner period (day 0 to 35). Feed delivered to each pen was recorded and ADFI and feed conversion ratio (FCR) were calculated for each pen over the time periods from days 0 to 7, and days 0 to 35.

At day 35 (approximately 9 weeks of age) pigs were moved into the commercial grower-finisher facility (n = 31-37 pigs per pen), with two pens from the weaner facility combined in this facility, where possible. As such, 14 pens per treatment (7 per sex) were represented in this facility. Pens were weighed at entry to the facility (9 weeks of age), at the mid-point between the grower-finisher stage (15 weeks of age) and again at sale (20.5 weeks of age). Pigs were individually tattooed depending on their pen, sold out over a 2-day period and sent to an on-site abattoir for slaughter.

At the abattoir, hot standard carcass weight (HSCW), P2 backfat and loin depth (LD) were measured from each carcass. Dressing percentage was then calculated from average HSCW of each pen and sale weight.

Housing and Diets

The commercial weaner facility was fully enclosed and cross-ventilated, heated by gas heating and evaporative cooling system. Each pen was fitted with drinker nipples and group feeders for *ad libitum* feed access. The system was fitted with an air-fed Tewe Airfeed automatic feeding system (Tewe Elektronic, Vreden, Germany). Pigs were fed a standard wheat and canola meal-based commercial weaner 1 diet (from day 0 to 14) and switched to a standard weaner 2 diet from day 14 onwards (fed to budget).

The commercial grower-finisher facility was an open ventilation system with blinds either side of the shed regulating air flow and internal temperature. The facility was fitted with a Big Dutchman DryExactPro automatic feeding system (Big Dutchman, Vechta, Germany). Pigs were fed a common grower diet until 15 weeks of age and then switched to a finisher diet until sale. Each pen was fitted with individual nipple drinkers and *ad libitum* access to feed was provided.

Statistical Analysis

Statistical analysis was performed using R (version 4.3.2) in RStudio (version 1.4.1106). Least-squares means were estimated using the *emmeans* package, and figures were produced using *ggplot2*.

Linear mixed model analysis was used for all continuous variables, with fixed factors weaning age spread treatment (3 vs. 7) and sex (male vs. female), and random factors and covariates as appropriate. As there was a significant treatment difference in average piglet weight at day 0 (weaning; $P < 0.001$) before the treatments had been applied, this was used as a covariate in the model.

Two female pens were removed from the analysis in the weaner phase (one from each treatment) due to there not being enough pigs to fill these pens. Similarly, two female pens in the 7 day age spread group were removed from the grower-finisher analysis due to a small number of pigs entering the pen at the beginning of this period. These pens were not an accurate representative of the rest of the group, with pen space per pig being significantly increased in these pens and hence skewing the data (all pens were the same size; 3.6 x 1.5 m).

Given that the number of pigs per pen (and hence space allowance per pig) was variable in the grower-finisher period, the number of pigs per pen was tested as a covariate for each measure in this period (all pens were the same size; 8.5 x 3.3 m). This did not have a significant impact on any of the measures studied and was hence left out of the overall model. Average weaning weight was calculated for each pen in the grower-finisher facility by finding the average between the two weaning weights for the corresponding weaner pens. This was then used as a covariate for measures in this period. Measures around sale (sale weight, carcass data) were corrected for days from 9 weeks until sale as a covariate, to correct for different sale ages.

4.2.2 *Experiment 2a: Intensive evaluation – weaner phase*

Experimental Animals

Piglets recruited for this study were selected from the farrowing houses at JBS Pork Australia's Corowa site. The selection criteria was dependent on a number of variables, the progeny type of the piglet itself, being either gilt or sow (Landrace x Large White (F1) x Duroc composite terminal sire, JBS Pork Australia genetics), and which age spread category it was designated to, based on where its associated date of birth fell into the age spread ranges. The age spread range for each treatment group was worked out based on the average age of weaning once all sows and gilts had concluded farrowing. A maximum of three male piglets were tagged from each litter from a total of 168 litters, consisting of approximately 50% gilt and 50% sow litters.

Once all farrowings had completed and a wean date was set by the production team the average age of wean could be calculated based on the farrowing distributions and their correlated ages, and from this each wean age spread group. Piglets were then tentatively assigned a treatment based on where their date of birth placed them in each range and once weaning was closer, day 21 live weights were measured and recorded to further select pigs for use in the trial and to ensure the recruited piglets were approximately the same size (approximately between 6-8kg) and of quality in terms of fitness and health.

Pigs were pre-allocated to respective pens based on treatment, with a total of three pigs of the same treatment being housed together. The average wean age for each pen was also kept the same as the total batch's age to accurately reflect the mean wean age both for the total experiment and each pen. When wean day arrived the number of piglets had been further reduced from the 491 born alive to the required 288 pigs for this study. While the piglets were housed in the farrowing house they were monitored daily and records made of any deaths, treatments or cross-fostering.

Based on six treatments, sow or gilt, 3 day wean age spread (Treatment A), 7 day wean age spread (Treatment B) and > 7 day wean age spread (Treatment C), 16 replicates and 3 pigs per pen, a total of 288 pigs were recruited for the study. Records were routinely maintained at the farm, including sow identification, parity, farrow date, litter size, number of piglets born alive, and for this project, birth weights of individual piglets of the selected gilts and sows were recorded and used as selection criteria for the piglets ultimately selected for inclusion in the trial. Based on the parity of the sow, farrow/birth date, and weaning age spread category, the recruited piglets were allocated to their respective treatment group.

Data Collection

The timeline of events and sample collection is presented in Figure 1. The pigs were weighed using a portable scale on days 0, 7, 14, 21, 28 and 35, and at days 0, 7, 14, 35 a faecal sample was collected by trained farm staff from one of the three pigs within each treatment pen (the ear tag number of the selected pig was recorded). The collected faecal samples were appropriately labelled and stored frozen until subsequent microbiome analysis (based on 16s rDNA sequencing).

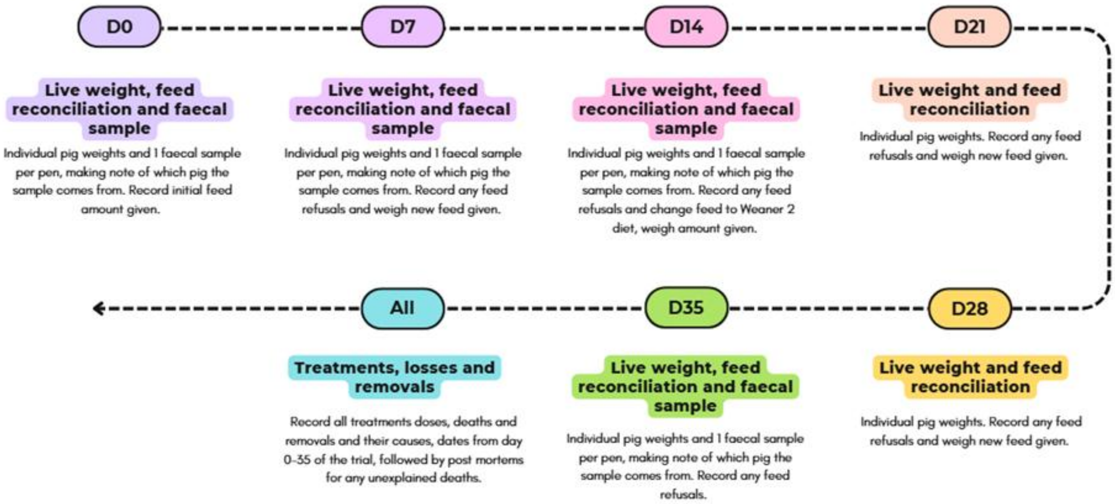

Figure 1. *Infographic outlining timeline of events and samples collections.*

Faecal samples were collected directly from the pigs to ensure no contamination from the pen environment or other contaminants that could affect the samples. This was done by holding a sample jar to the pig so the faeces would fall directly into the jar, preventing any exogenous contamination. Trained staff wore sterile gloves, which were changed after each sample was collected. When required, a clean sterile wooden stick was used to break the faecal sample into smaller pieces for storage. These were also disposed of and replaced after each use to avoid contamination.

Housing and Diets

The pigs were housed within the JBS Pork Australia specialised weaner research facility, the Weaner Discovery Centre (WDC), with each pen representing a treatment replicate. The WDC had 100 pens, and 96 of these pens were used for the project (based on six treatments and n = 16 pen replicates per treatment). Each pen housed 3 pigs for the duration of the trial. The WDC is a climate-controlled shed which is maintained between 20-30°C. This temperature was gradually lowered each week as the pigs aged to ensure they remained comfortable. Heat lamps were also provided for each pen with these having two temperature settings (high and low) and an adjustable chain so the height could be adjusted as the pigs grew. From 6am to 6pm the shed automatically turned on lights to simulate day and night phases. The shed was fitted with fans for ventilation to maintain fresh airflow. Sawdust was provided to the pigs as bedding at the start of the experiment. The effluent system consisted of rows of pits underneath the rows of pens which collected any waste that fell through the grating on the back half of the enclosures. These were filled with water to help control odour and flushed and refilled with fresh water at least weekly. Each pen was also provided with a Porcichew™ (East Riding Farm Services, UK) which is a hard plastic toy used as a form of enrichment.

Pigs were all fed the same diet for the duration of the experimental period, with a two-phase weaner diet regime employed, changing from a first stage weaner diet to a second stage weaner diet at 2 weeks after weaning. The amount of feed delivered to the feed trough was recorded, as was the weight of any uneaten feed remaining in the trough on days 7, 14, 21, 28 and 35 to enable determination of average feed intake per pen over each period.

Nipple water drinkers were present in each pen which the pigs could access water from, and the feed trough featured a depressed bowl designed to prevent feed from spilling into the pen and effluent system below, so feed intake was reliable as to what each pen consumed within each period.

Microbiome Sequencing Data and Community Analysis
All extracted faecal samples were subjected to 16s rDNA sequencing at the Australian Genome Research Facility (AGRF) in Brisbane, Australia, targeting the V3 and V4 hypervariable regions for library construction. All samples passed the quality control protocol used at the AGRF sequencing facility. Raw sequenced data was filtered and spliced to obtain clean data, and subsequently DADA2 (Callahan et al., 2016) was used to reduce noise and filter out the sequences with abundances less than 5, resulting in the final data comprised of amplicon sequence variants (ASVs). Quantitative insights into microbial ecology (QIIME2) (Bolyen et al., 2019) was then used to annotate ASVs with taxonomic information, and this data were then used to infer relative abundance at different taxonomic levels.

Statistical Analysis
Statistical analysis was performed using R (version 4.3.2) in RStudio (version 1.4.1106). Least-squares means were estimated using the *emmeans* package, and figures were produced using *ggplot2*.

Linear mixed model analysis was used for all continuous variables, with fixed factors weaning age spread treatment (3 vs. 7 vs. >7 days) and progeny group (gilt vs. sow progeny), and random factors and covariates as appropriate. The interactive effect of weaning age spread treatment and progeny group was included in the model where significant ($P < 0.05$), otherwise the fixed factors were modelled alone without the interaction. In the analysis of the individual growth performance data, litter and pen were tested as random factors and left in the model where significant ($P < 0.05$). Litter was significant for all traits in the weaner period ($P < 0.05$; days 0-35). As there was a significant treatment difference in average piglet weight at day 0 (weaning) before the treatments had been applied, this was used as a covariate in the model. Extreme outliers were removed from the data set where appropriate if they were >4 SD from the mean and when they did not make biological sense.

4.2.3 *Experiment 2b: Intensive evaluation – lifetime performance*

Experimental Animals and Data Collection

Animals from Experiment 2a were followed into the Grower Discovery Centre (GDC) individual grower-finisher facility at the Module 1 R&I unit at Corowa, NSW. Pigs stayed in the same groups that they were housed in for the WDC weaner period. Pigs were individually weighed at entry to the facility (exit of the weaner facility, described above) and again at 15 weeks of age at sale at approximately 22 weeks of age. Pigs were then transported to an on-site abattoir where carcass data was collected for individual pigs that retained their RFID tags. Unfortunately, only n = 138 pigs retained their tags and were able to have carcass data correlated with their lifetime data. At the abattoir, HSCW, P2 backfat and LD were measured from each carcass. Dressing percentage was then calculated from average HSCW of each pen and sale weight.

Housing and Diets

Pigs were all fed a common grower diet until 15 weeks of age and switched to a common finisher diet which they were then fed until sale. The GDC was fully enclosed and fitted with fans for ventilation and to maintain temperature and fresh air flow. The effluent and flushing systems were similar to the WDC and each pen was again provided with a Porcichew™ (East Riding Farm Services, UK) for enrichment.

All pigs were fed the same diet for the duration of the experimental period, with a two-phase grower-finisher diet regime employed, changing from a grower diet to a non-medicated finisher diet at 15 weeks of age. The amount of feed delivered to each pen was recorded, as was the weight of feed refusals in the trough at 15 weeks of age and at sale to enable determination of average feed intake per pen over each period. Nipple water drinkers were present in each pen for water access.

Statistical Analysis

Statistical analysis was performed using R (version 4.3.2) in RStudio (version 1.4.1106). Least-squares means were estimated using the *emmeans* package, and figures were produced using *ggplot2*.

Linear mixed models analysis was used for all continuous variables, with fixed factors weaning age spread treatment (3 vs. 7 vs. >7 days) and progeny group (gilt vs. sow progeny), and random factors and covariates as appropriate. The interactive effect of weaning age spread treatment and progeny group was included in the model where significant ($P < 0.05$), otherwise the fixed factors were modelled alone without the interaction. As there was a significant treatment difference in average piglet weight at day 0 (weaning) before the treatments had been applied, this was again used as a covariate in the model for the grower-finisher period measures. For measures taken at sale, days from entry to sale was used as a covariate to account for the pigs being sold out over 2 days. Extreme outliers were removed from the data set where appropriate if they were >4 SD from the mean and when they did not make biological sense. Finisher performance data were removed from the analysis for a number of pens (n = 9) for the analysis of ADFI and FCR, as mortalities and/or wasting of feed in these pens impacted the accuracy of measurement of these variables.

4.3 Objective 3: Recommendations for management of pigs after weaning based on weaning age spread

The results from the above studies were then used to calculate a rough cost benefit of increasing from 1 wean per week to 2 weans per week, in order to reduce weaning age spread from 7 to 3 days of age. Factors considered for this analysis include:

- Direct labour cost (i.e., time spent physically weaning pigs, number of staff involved, whether this is ordinary time, overtime, or casual time);
- Additional costs arising from a second weekly wean (i.e., additional shed preparation, washing or movement time, transport/internal pig movement time, e.g., for additional trucks, additional administration and recording costs, a more fragmented workflow for farrowing and weaner teams – e.g., mating twice per week and flow on effects on sow reproduction, for example);
- Capacity / infrastructure constraints (i.e., pig space, room filling efficiency, biosecurity or batching requirements);
- Production benefits seen from Objectives 1 and 2 (i.e., improved uniformity, better ADG, ADFI, FCR or survival, impacts on carcass value).

PigEV (Hermesch et al., 2012) was then used to calculate the value of these improvements to include in the cost benefit analysis.

5. Results

5.1 Objective 1: Risk factors

5.1.1 Health status impacts on lifetime growth performance

Table 1 summarises the data characteristics following cleaning, across all three genetic lines by dataset (2019–2020 vs. 2022–2024). It should be noted that the 2022–2024 dataset was collected following a herd depopulation event aimed at eliminating *Mycoplasma hyopneumoniae*, a strategy widely recognised as an effective approach for pathogen eradication in pig populations, although *Actinobacillus pleuropneumoniae* (APP) remained present. Across the two cohorts, modest but consistent differences in growth were observed. Lifetime ADG (ADGlife) was greater in the 2022–2024 cohort (0.631 ± 0.077 kg/day; n = 40,784) compared with 2019–2020 (0.609 ± 0.071 kg/day; n = 42,984). Backfat thickness at the P2 position was also higher in the more recent cohort (10.0 ± 2.09 mm; n = 40,753) relative to 2019–2020 (8.94 ± 2.27 mm; n = 42,103), which is consistent with the observed increase in growth and associated body weight. In contrast, piglet birth weight (PWT) was similar between periods (1.56 ± 0.36 kg vs. 1.57 ± 0.33 kg), indicating minimal temporal change in early-life traits. The proportion of animals recorded as surviving post-weaning (PostWS) was slightly higher in the 2022–2024 dataset (0.96 ± 0.20; n = 66,750) compared with 2019–2020 (0.93 ± 0.26; n = 72,269). Additional performance traits were only available for the 2022–2024 cohort, with ADG during the finisher period (ADGtest) of 0.978 ± 0.141 kg/day (n = 1,899), ADFI of 2.62 ± 0.32 kg/day (n = 1,900), and FCR of 2.68 ± 0.26 (n = 1,848). Overall, the later cohort demonstrates improved growth performance, while early-life traits remained largely unchanged.

Table 1. *Data characteristics for lifetime average daily gain (ADGlife), average daily gain over the finisher test period (ADGtest), age test end, piglet birth weight (PWT), post-weaning survival (PostWS), back fat thickness at the P2 position (P2), average daily feed intake (ADFI) and feed conversion ratio based on the ratio between ADFI and ADGtest. The data characteristics are displayed by dataset (2019-2020 vs. 2022-2024) after depopulation to eliminate Mycoplasma hyopneumoniae.*

Trait	2019–2020	2022–2024
ADGlife (kg/day)	0.609 ± 0.071 (n = 42,984)	0.631 ± 0.077 (n = 40,784)
ADGtest (kg/day)	–	0.978 ± 0.141 (n = 1,899)
P2 (mm)	8.94 ± 2.27 (n = 42,103)	10.0 ± 2.09 (n = 40,753)
ADFI (kg/day)	–	2.62 ± 0.32 (n = 1,900)
FCR (kg/kg)	–	2.68 ± 0.26 (n = 1,848)
PWT (kg)	1.57 ± 0.33 (n = 71,794)	1.56± 0.36 (n = 66,604)
PostWS (0/1)	0.93 ± 0.26 (n=72,269)	0.96 ±0.20 (n= 66,750)

Table 2 summarises the significance of fixed effects within each dataset, highlighting both consistent and dataset-specific influences on performance traits. In the 2019–2020 dataset, most fixed effects significantly influenced ADGlife, including PWT, fostering, weaning age, sex, line, parity group, age, and contemporary group (CG) (all $P < 0.001$), whereas weaning age spread was not significant ($P > 0.10$). Similarly, in 2022–2024, ADGlife remained strongly affected by the majority of fixed effects

(P < 0.001), although foster and weaning age spread were not significant, indicating a largely consistent structure of effects across datasets. For P2, fewer effects were consistently significant, with PWT not significant in 2019–2020 but becoming significant in 2022–2024 (P < 0.001), while sex, line, and CG remained important drivers in both datasets. Traits available only in the 2022–2024 dataset showed more variable patterns: ADGtest was significantly influenced by weaning age, line, and CG (P < 0.001), with parity group and age showing borderline or non-significant effects; ADFI was influenced by weight into the testing period, and CG (P ≤ 0.03), but not by several other fixed effects; and FCR was significantly affected by weaning age spread, line, weight into the testing period, and CG, but not by age. Post-weaning survival (PostWS) showed a highly consistent pattern across both datasets, with all fitted effects remaining significant (P < 0.001). Overall, contemporary group (CG) and line effects were consistently highly significant across all traits and datasets, while the importance of early-life management factors, particularly fostering and weaning-related variables, varied depending on the trait and time period.

Table 2. *Summary table of the fixed effects for each trait, which included average daily gain life (ADGlife), average daily gain over the finisher test phase (ADGtest), back fat (P2) average daily feed intake (ADFI), FCR defined as the ratio between ADFI and ADGtest and post-weaning survival (PostWS) by data set (2019-2020 vs 2022-2024).*

Trait	Dataset	PWTgr	Fost	WAgeGr	WSpreadGr	Sex	Line	DParityGr	WgtIn	WgtOut	Age	CG
ADGlife (kg/day)	2019–2020	<0.001	<0.001	<0.001	0.03	<0.001	<0.001	<0.001	–	–	<0.001	<0.001
	2022–2024	<0.001	<0.001	<0.001	n.s.	<0.001	<0.001	<0.001	–	–	<0.001	<0.001
ADGtest (kg/day)	2022–2024	*	*	n.s.	<0.001	n.e.	<0.001	n.s. (0.09)	–	–	n.s. (0.07)	<0.001
P2 (mm)	2019–2020	n.s.	0.002	<0.001	n.s. (0.17)	<0.001	<0.001	n.s.	–	<0.001	0.022	<0.001
	2022–2024	<0.001	n.s.	n.s.	0.049	<0.001	<0.001	0.004	–	<0.001	<0.001	<0.001
ADFI (kg/day)	2022–2024	*	*	0.03	n.s. (0.12)	n.e.	n.s.	n.s. (0.15)	<0.001	–	n.s.	<0.001
FCR (kg/kg)	2022–2024	*	*	n.s.	0.0007	n.e.	<0.001	n.s.	<0.001	–	n.s.	<0.001
PostWS (0/1)	2019–2020	<0.001	<0.001	<0.001	n.s.	<0.001	<0.001	<0.001	–	–	–	<0.001
	2022–2024	<0.001	<0.001	<0.001	n.s.	<0.001	<0.001	<0.001	–	–	–	<0.001

n.s. not significant (P > 0.05)
n.e. contrast does not exist in data set (e.g. only male pigs with feed efficiency data recorded)
CG = management group (test month and test station ESF vs Non-ESF or year month of born for PostWS)
PWTgr = Piglet Birth Weight group
Fost = fostering group
WAgeGr = Weaning Age Group
WspreadGr = Weaning Age Spread Group
DParityGr = Dam Parity Group
WgtIn = Weight into the finisher testing period
WgtOut = Weight out of the finisher testing period

5.1.2 Management factors influencing lifetime performance – fostering and weaning age

The impacts of weaning age spread and fostering on some key traits were investigated further and the results are shown in Figure 2. Lifetime ADG (ADGlife) was influenced by both weaning age and fostering, with consistent patterns observed before and after depopulation (Figure 2). Pigs weaned at older ages (>28 days) exhibited higher ADG compared with those weaned earlier, indicating a positive association between extended lactation and subsequent growth performance. This trend was evident both before and after depopulation, although overall ADG values were higher in the post-depopulation period. Similarly, fostering treatment affected growth, with non-fostered pigs showing greater ADG than pigs subjected to fostering, particularly those fostered after day 1. Pigs fostered on day 0–1 showed intermediate performance, suggesting that earlier fostering may partially mitigate negative impacts on growth. Collectively, these results highlight the importance of management strategies such as delaying weaning age and minimising or optimising fostering practices to improve lifetime growth performance in pigs.

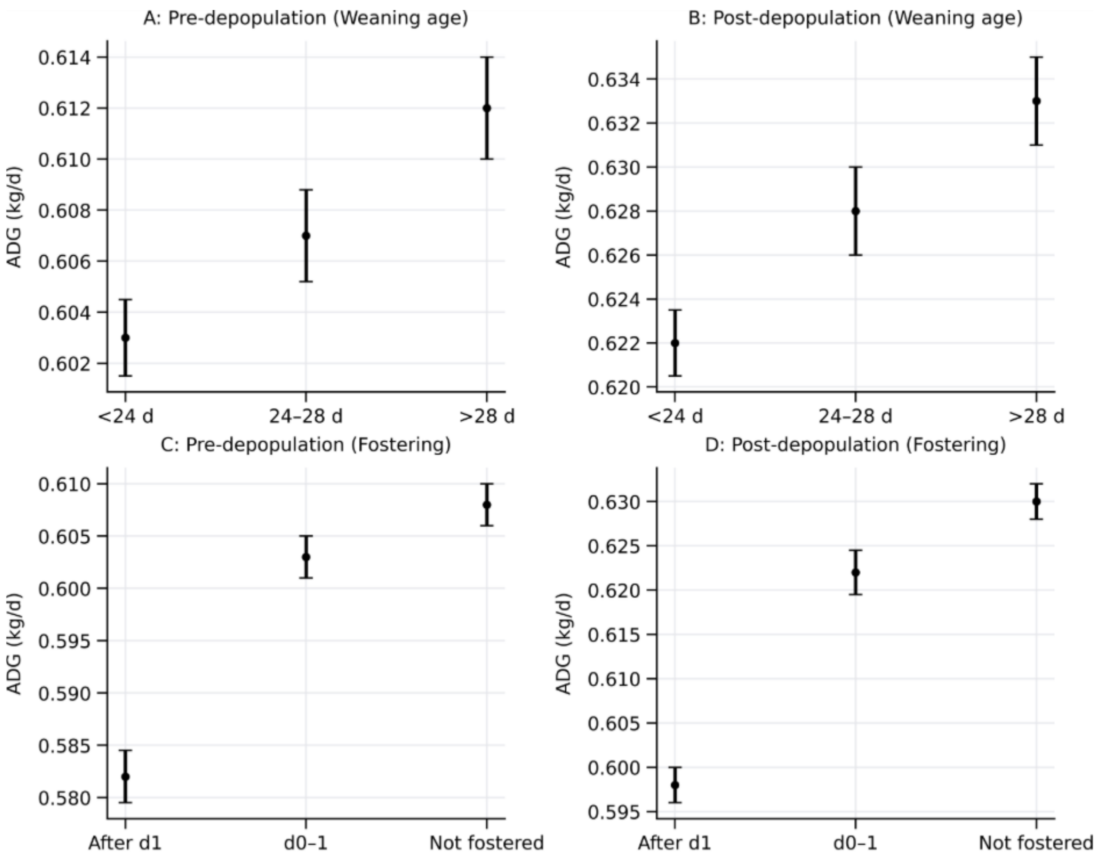

Figure 2. *Least square means (± SE) for lifetime average daily gain (ADG, kg/d) illustrating the effects of weaning age group (<24 d, 24–28 d, >28 d) and fostering treatment (not fostered, fostered d0–1, fostered after d1) before depopulation (A, C) and after depopulation (B, D).*

Backfat thickness (P2) was significantly influenced by both weaning age and fostering before depopulation; but not after depopulation (Figure 3). Prior to depopulation, pigs weaned at younger ages (<24 days) and tended to exhibit greater P2 values compared with those weaned later. This pattern was less pronounced following depopulation, where P2 values were more uniform across weaning age groups. Fostering treatment also affected backfat, with pigs fostered after day 1 generally showing greater P2 compared with pigs fostered earlier or not fostered. In contrast, pigs that were not fostered or were fostered within the first 24 hours tended to have lower P2 values, suggesting leaner carcass composition.

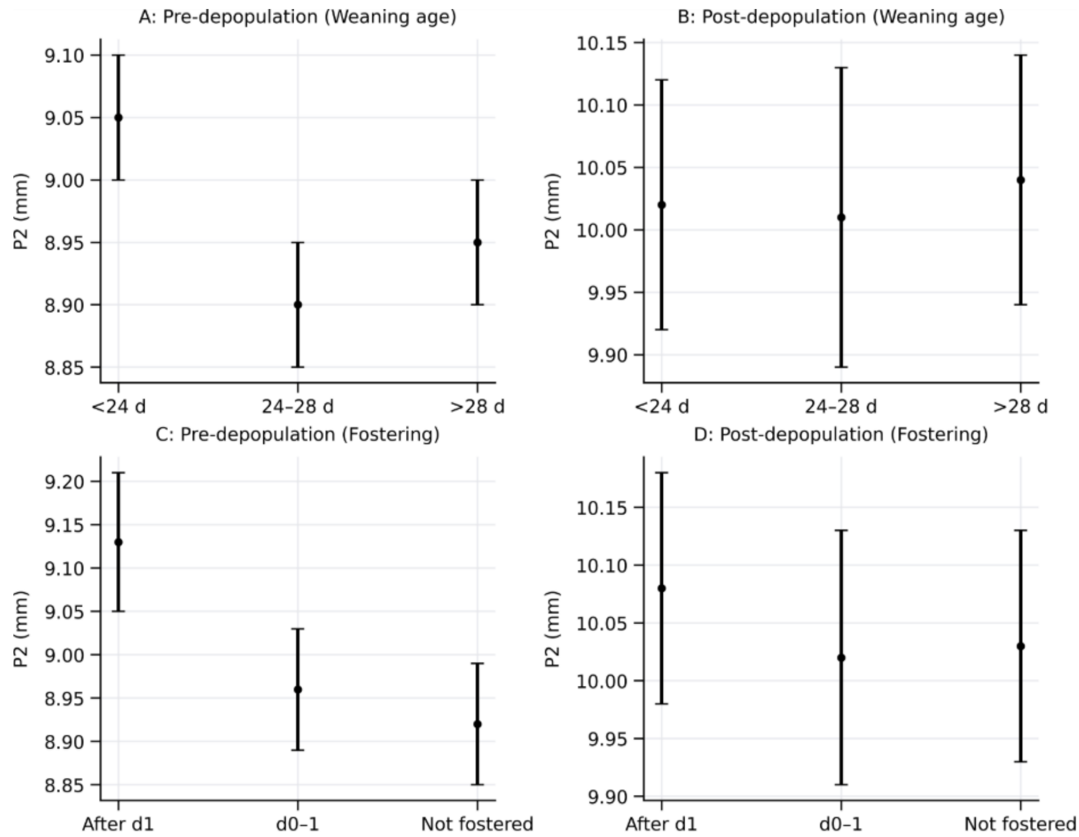

Figure 3. *Least square means (± SE) for backfat thickness (P2, mm) illustrating the effects of weaning age group (<24 d, 24–28 d, >28 d) and fostering treatment (not fostered, fostered d0–1, fostered after d1) before depopulation (A, C) and after depopulation (B, D).*

Post-weaning survival to 70 days of age was influenced by both weaning age and fostering treatment, with consistent trends observed before and after depopulation (Figure 4). Pigs weaned at older ages (>28 days) exhibited higher predicted survival probabilities compared with pigs weaned earlier (<24 days). Intermediate weaning age groups (24–28 days) displayed moderate survival probabilities. Fostering treatment also affected survival outcomes, with pigs that were not fostered or fostered within the first day demonstrating higher survival probabilities compared with pigs fostered after day 1.

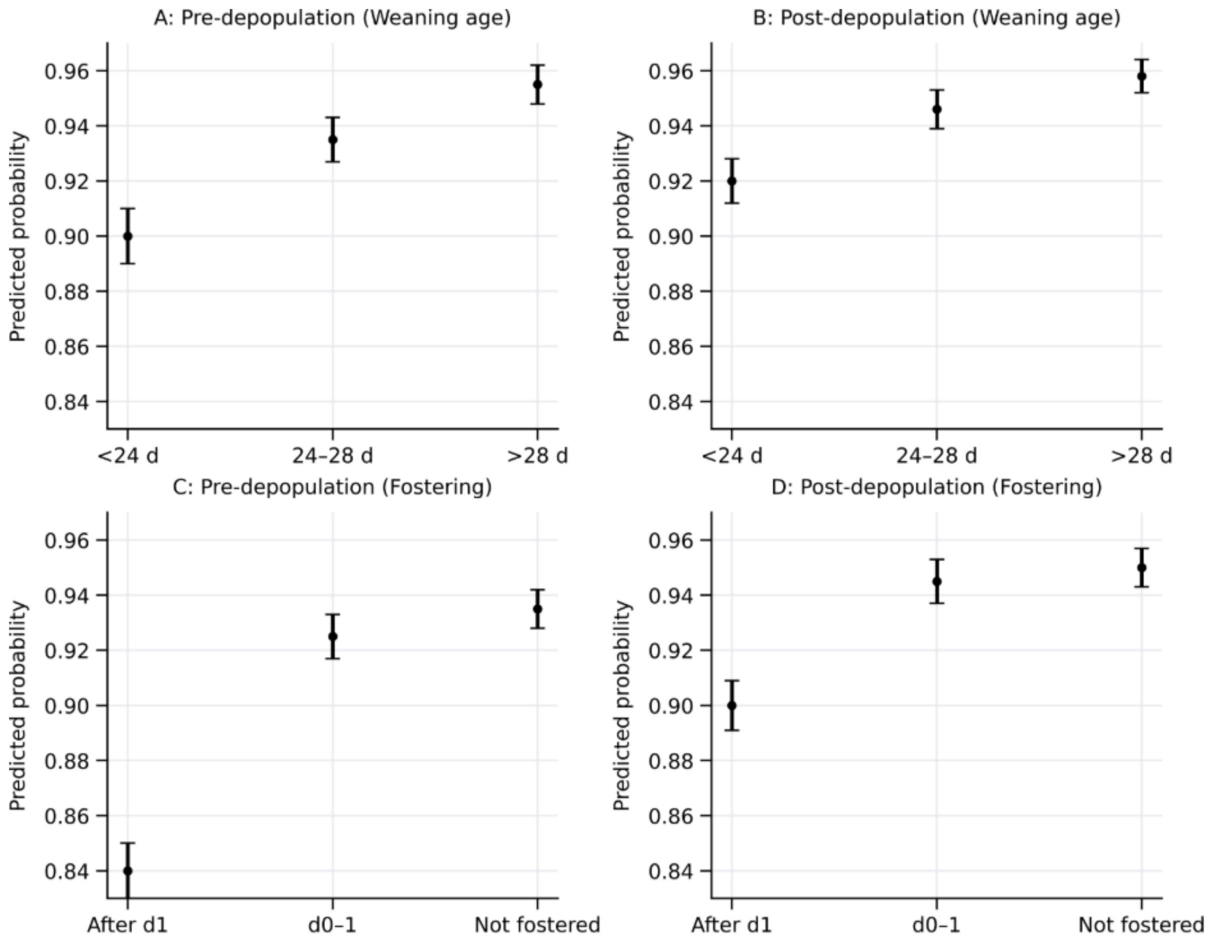

Figure 4. *Predicted probability (± SE) of post-weaning survival to 70 days of age illustrating the effects of weaning age group (<24 d, 24–28 d, >28 d) and fostering treatment (not fostered, fostered d0–1, fostered after d1) before depopulation (A, C) and after depopulation (B, D).*

5.1.3 Management factors influencing lifetime performance – weaning age spread

Weaning age spread influenced growth performance and efficiency during the finisher test period (Figure 5). Pigs originating from groups with a narrow weaning age spread (<8 days) exhibited greater ADG compared with pigs from more variable weaning groups, indicating more uniform growth under consistent early-life management. Average daily feed intake (ADFI) showed a similar numerical trend, with reduced intake observed in the intermediate spread group (8–14 days), although differences were not statistically significant. Feed conversion ratio (FCR) increased as weaning age spread widened, with pigs from the largest spread group (>14 days) demonstrating poorer feed efficiency.

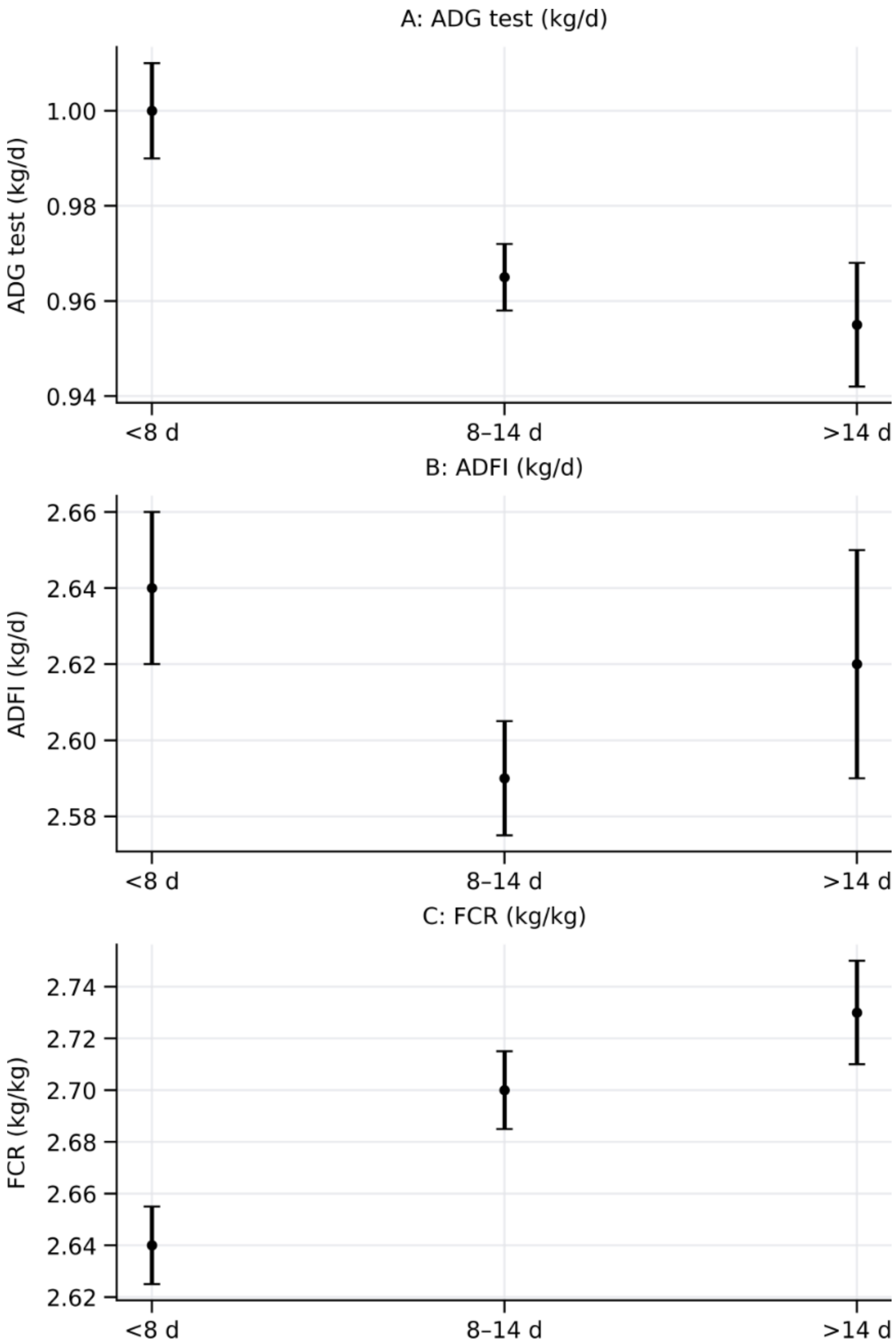

Figure 5. *Least square means (± SE) for performance traits illustrating the impact of weaning age spread grouping (<8 d, 8–14 d, >14 d) on average daily gain during the finisher test (ADGtest; A), average daily feed intake (ADFI; B), and feed conversion ratio (FCR; C). Weaning age spread significantly affected ADGtest and FCR (P < 0.05), but not ADFI (P > 0.05).*

5.2 Objective 2: Weaning age spread impacts

5.2.1 Experiment 1: Commercial evaluation

Summary statistics from the weaner phase are shown in Table 3.

Table 3. *Summary statistics for growth performance in the weaner phase in Experiment 1 showing results for each weaning age spread treatment (A = 3 day weaning age spread and B = 7 day weaning age spread) and sex.*

Weaner Phase Summary, day 0–35

		Pens (n)	Weight In (kg)		ADG (g/d)		ADFI (g/d)		FCR (kg:kg)		
Treatment	Sex	n	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Removals
A	F	13	7.81	0.350	418	26.47	657	58.7	1.58	0.148	6
A	M	14	7.96	0.403	392	20.15	577	31.0	1.47	0.052	13
B	F	14	7.62	0.227	395	19.31	611	37.6	1.55	0.046	6
B	M	14	7.73	0.343	390	33.54	572	39.0	1.47	0.095	16

Ave = mean; SD = standard deviation

The sex x weaning age spread treatment interaction was not significant for weaning weight (*P* = 0.96) and was therefore left out of the model. Average weight at the start of the weaner period (day 0) was significantly different between weaning age spread treatments before the beginning of the experimental phase (*P* = 0.012; Figure 6).

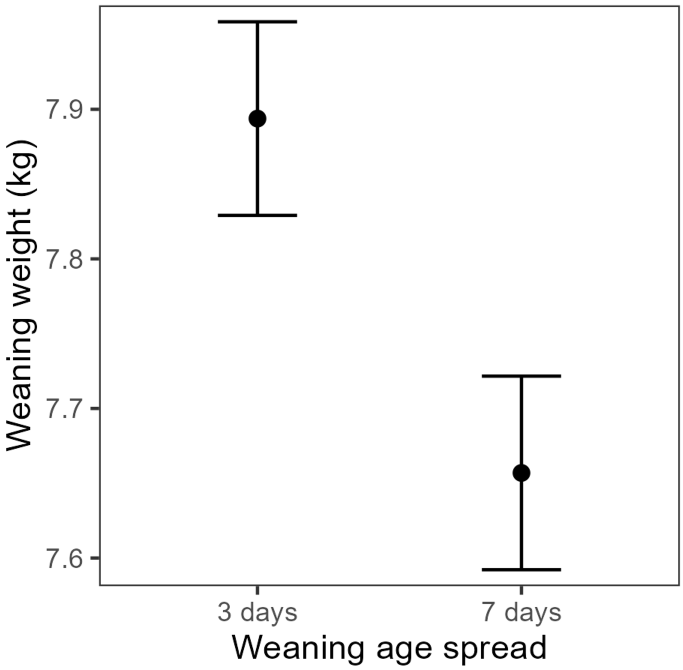

Figure 6. *Difference in weight at start of weaner period between weaning age spread treatments (3 vs. 7 days; P = 0.025). Estimates shown are least squared means ± SD.*

Weight at the end of the weaner period was not influenced by weaning age spread treatment (*P* = 0.29; both 21 ± 0.2 kg) and the interaction with sex was not significant (*P* = 0.24; data not shown).

Similarly, there was no significant effect of the weaning age spread x sex interaction on ADG in the weaner period (*P* = 0.14) and hence this was left out of the model. There was no significant influence of weaning age spread treatment on ADG in the weaner period (403 ± 4.8 vs. 394 ± 4.8 g/day for 3 and 7 days, respectively; *P* = 0.19).

There was a significant influence of the weaning age spread x sex interaction on ADFI in the weaner period (*P* = 0.044; Figure 7). Female pigs with a weaning age spread of 3 days ate more than those with a weaning age spread of 7 days, with no difference in the male groups. There was no significant interactive effect on FCR in the weaner period (*P* = 0.24) and no impact of weaning age spread treatment (*P* = 0.39; data not shown).

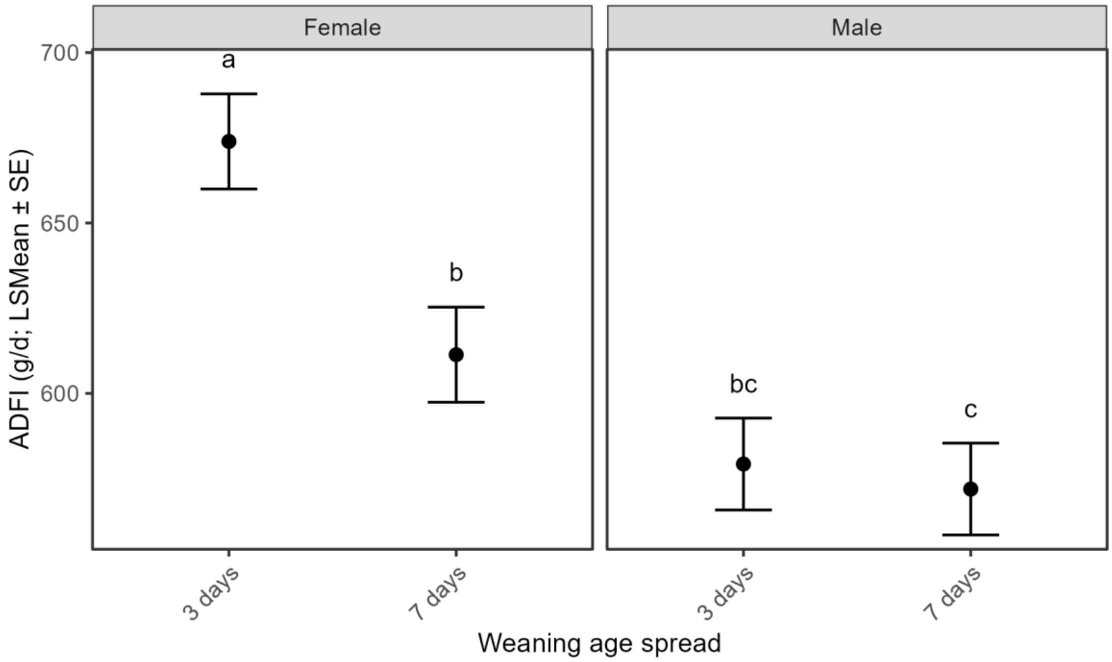

Figure 7. *Difference in average daily feed intake in the weaner period between weaning age spread (3 vs. 7 days) and sex treatments. Estimates shown are least squared means ± SD.*

Summary statistics from the grower-finisher phase are shown in Table 4. The weaning age spread x sex interaction was not significant for any growth performance parameters in the grower-finisher period and was hence left out of the model (*P* ≥ 0.10). There was no significant impact of weaning age spread on average pig weight at 9 weeks of age (*P* = 0.34), 15 weeks of age (*P* = 0.48) or at sale (*P* = 0.67). Similarly, there was no significant impact on ADG in the grower period (9 to 15 weeks; *P* = 0.56) or the finisher period (15 weeks to sale; *P* = 0.56).

Table 4. *Summary statistics for growth performance in the grower-finisher phase in Experiment 1 showing results for each weaning age spread treatment (A = 3 day weaning age spread and B = 7 day weaning age spread) and sex.*

Grower–Finisher Phase Summary (Week 9 to Sale)

		Pens (n)	ADG (kg/d)		ADFI (kg/d)		FCR (kg:kg)		Sale Weight (kg)		
Treatment	Sex	n	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Removals
A	F	7	0.84	0.029	1.94	0.112	2.30	0.106	92.51	2.736	16
A	M	7	0.88	0.023	1.91	0.056	2.16	0.067	95.34	1.503	20
B	F	5	0.85	0.058	1.94	0.098	2.30	0.100	92.08	4.716	19
B	M	7	0.88	0.032	1.92	0.315	2.18	0.416	94.50	2.829	27

Ave = mean; SD = standard deviation

There was no impact of weaning age spread treatment on ADFI in the grower (P = 0.40) or finisher period (P = 0.53), nor on the overall ADFI of the grower-finisher period (P = 0.79; data not shown). Similarly, there was no impact on FCR over any period studied ($P \geq 0.10$; data not shown).

Carcass weight (HSCW) tended to be heavier for pigs in the 3 day weaning age spread group, compared to the 7 day weaning age spread group (P = 0.067; Figure 8). There was no significant interaction with sex (P = 0.90; data not shown).

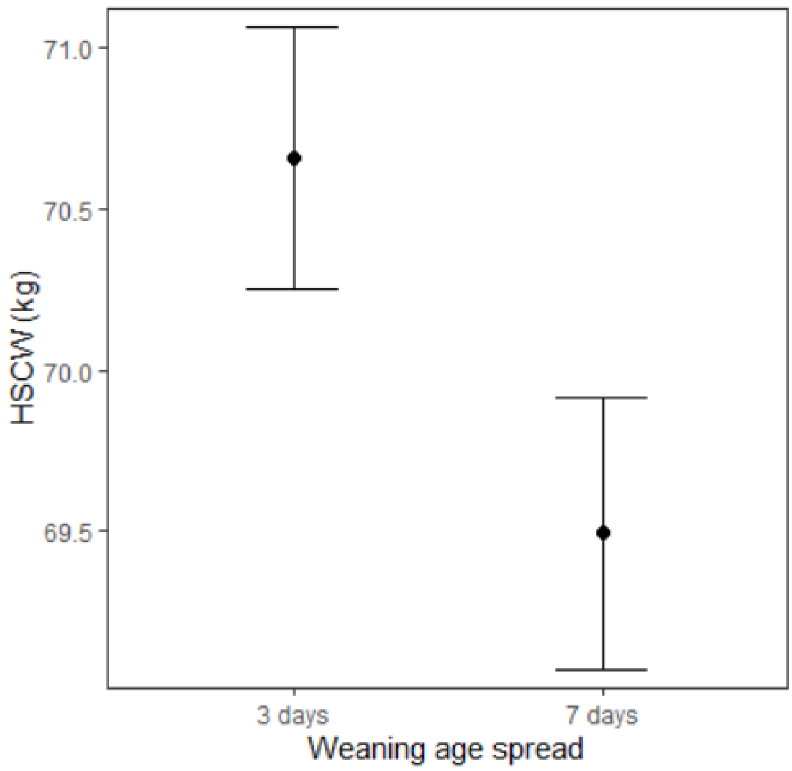

Figure 8. *Difference in hot standard carcass weight (HSCW) between weaning age spread treatments (3 vs. 7 days; P = 0.067). Estimates shown are least squared means ± SD.*

There was no significant impact of weaning age spread group on carcass P2 (P = 0.75), even when correcting for HSCW as a covariate (9.2 ± 0.09 vs. 9.3 ± 0.10 mm, respectively; P = 0.50). However, there was a significant impact of weaning age spread group on carcass LD (P = 0.02) with 3 day weaning age spread pigs having a higher LD (52.9 ± 0.39 mm) than the 7 day weaning age spread pigs (51.4 ± 0.41 mm). This difference tended toward significance when corrected for HSCW as a covariate (52.8 ± 0.41 vs. 51.6 ± 0.42 mm, respectively; *P* = 0.067). There was no significant impact of weaning age spread on lean percentage of the carcass (*P* = 0.22) or dressing percentage (*P* = 0.47; data not shown).

5.2.2 *Experiment 2a: Intensive evaluation – weaner phase*

<u>*Animal Performance*</u>

Average piglet weights (weighed weekly) from weaning (day 0) to the end of the weaner phase (day 35) are shown in Figure 9. Average weight at the start of the weaner period (day 0) was significantly different between weaning age spread x progeny group treatments before the beginning of the experimental phase (*P* < 0.001; Figure 10) and therefore weaning weight was included as a covariate for subsequent performance variables.

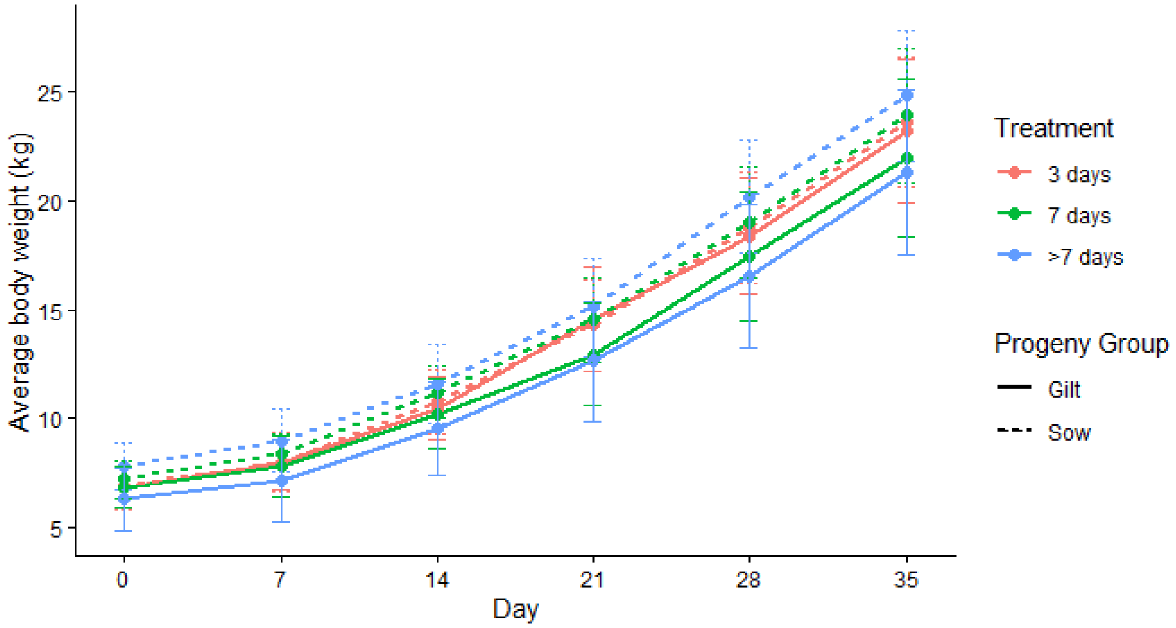

Figure 9. *Average (± SD) piglet weight weekly after weaning from the raw data.*

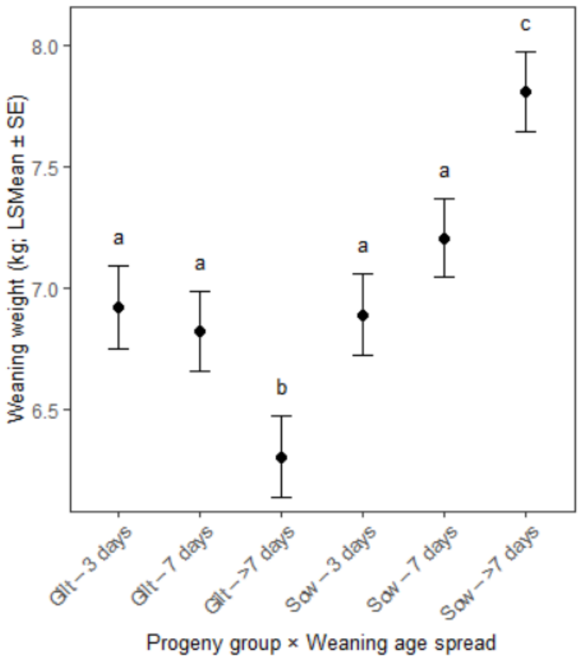

Figure 10. *Least square means (± SE) for weaning weight between progeny group x weaning age spread treatments.* [a,b,c]*Different superscripts denote a significant difference (P < 0.05) between means.*

The interactive effect of weaning age spread treatment x progeny was not significant for piglet weight after day 0 and was therefore left out of the model. There was no significant difference between weaning age spread treatment (*P* > 0.10) or progeny groups (*P* = 0.19) in terms of weight at day 7 and ADG in the first 7 days after weaning when adjusted for weaning weight (data not shown). However, by day 35 there was a significant impact of progeny group on piglet weight and growth performance to the end of the weaner period, with sow progeny (23.6 ± 0.27 kg) significantly heavier than gilt progeny (22.6 ± 0.27 kg; *P* = 0.011) and they also grew quicker over this period (474 ± 7.6 vs. 446 ± 7.7 g/day; *P* = 0.011). There was no significant impact of weaning age spread on weight at day 35 when adjusted for weaning weight (*P* = 0.34; data not shown).

There were no differences in ADFI in the first 7 days between weaning age spread groups (*P* = 0.83); however, sow progeny ate more than gilt progeny (153 ± 7.1 vs. 129 ± 7.1 g/day, respectively; *P* = 0.030). Over the whole weaner period (days 0 to 35) there tended to be an impact of weaning age spread treatment on ADFI (Figure 11; *P* = 0.075) and sow progeny again ate more than gilt progeny (556 ± 10.1 vs. 521 ± 10.1 g/day, respectively; *P* = 0.022). This was in contrast to Experiment 1 where the difference in ADFI after weaning was only seen in females, whereas Experiment 2 was only conducted in males and there was still an impact of weaning age spread seen on these animals.

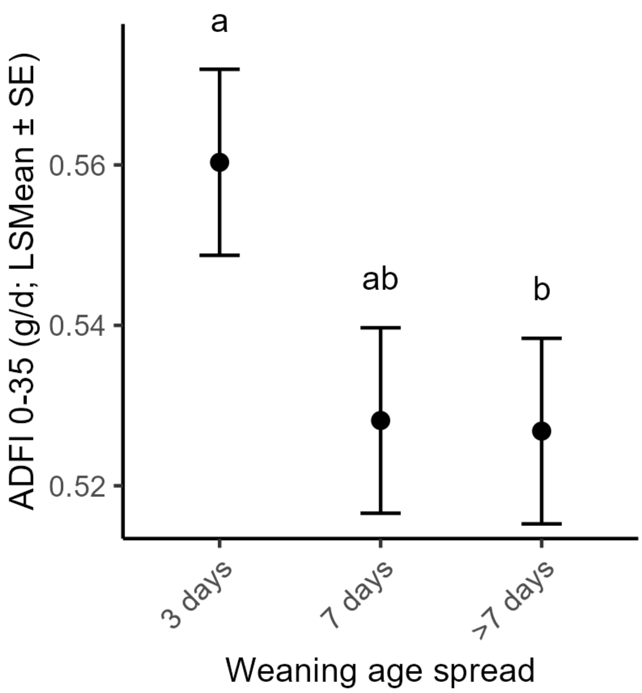

Figure 11. *Average daily feed intake (LSM ± SE) for each weaning age spread treatment over the whole weaner period (days 0 to 35; P = 0.075). [a,b]Different superscripts denote a significant difference (P < 0.05) between means.*

Despite these feed intake differences, there was no significant difference in FCR between weaning age spread treatments over the first 7 days after weaning (*P* = 0.72; data not shown) or throughout the whole weaner period (3 days: 1.22 ± 0.02, 7 days: 1.18 ± 0.02, and >7 days 1.17 ± 0.02 kg:kg; *P* = 0.12). There was no difference in FCR between gilt and sow progeny in either period (*P* ≥ 0.10; data not shown). From these results it seems that a 3 day weaning age spread improves ADFI after weaning; however, the animals are no more efficient in terms of FCR. However, there may be differences in piglet survival and health outcomes that were not able to be picked up in our study due to the limited number of animals used.

Microbiome

Observed-features rarefaction curves plateaued between approximately 2,500 and 5,000 sequences, indicating that sequencing depth was sufficient to capture most within-sample richness (Figure 12). The 3 day weaning age spread group exhibited consistently higher observed feature counts than 7- or >7 day weaning age spread groups across the explored depths, suggesting greater richness for pigs with a 3 day age spread vs. extended age spreads.

Similarly, the Shannon index rarefaction curves plateaued between approximately 2,500 and 5,000 sequences, indicating adequate sampling depth. The 3- and 7 day weaning age spread groups displayed overlapping Shannon diversity values that were consistently higher than those of the >7 day weaning age spread group, suggesting that communities in 3- and 7 day weaning age spreads were more similarly diverse and more compositionally even and/or taxon-rich than those in the >7 day weaning age spread group. There was, however, very considerable variability of genus population and density between animals.

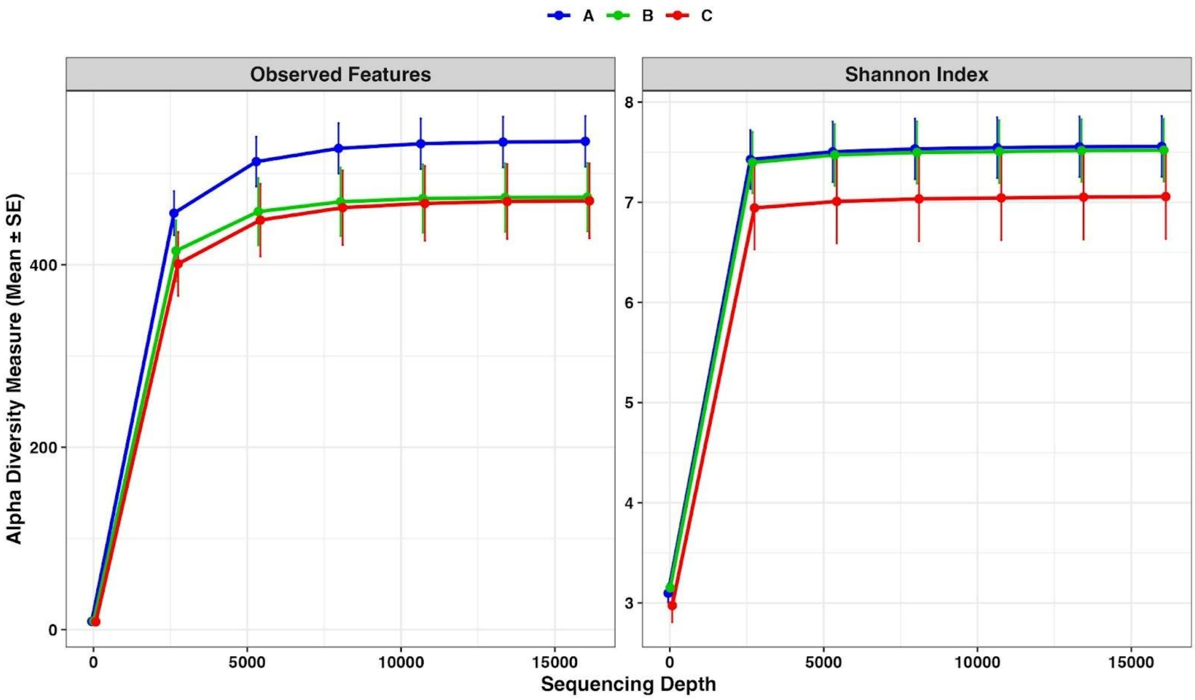

Figure 12. *Alpha Diversity Plot for treatments A (3 day weaning age spread), B (7 day weaning age spread) and C (>7 day weaning age spread).*

Which genus groups were undesirable (e.g., *Escherichia* and *Salmonella*) and which were beneficial (e.g., *Lactobacillus*) could be inferred from the data. *Lactobacillus* was significantly lower in 3 day age spread gilt progeny (Figure 13). *Clostridium* showed variable abundance between gilt and sow progeny across treatments. No *Salmonella* was detected in any of the samples.

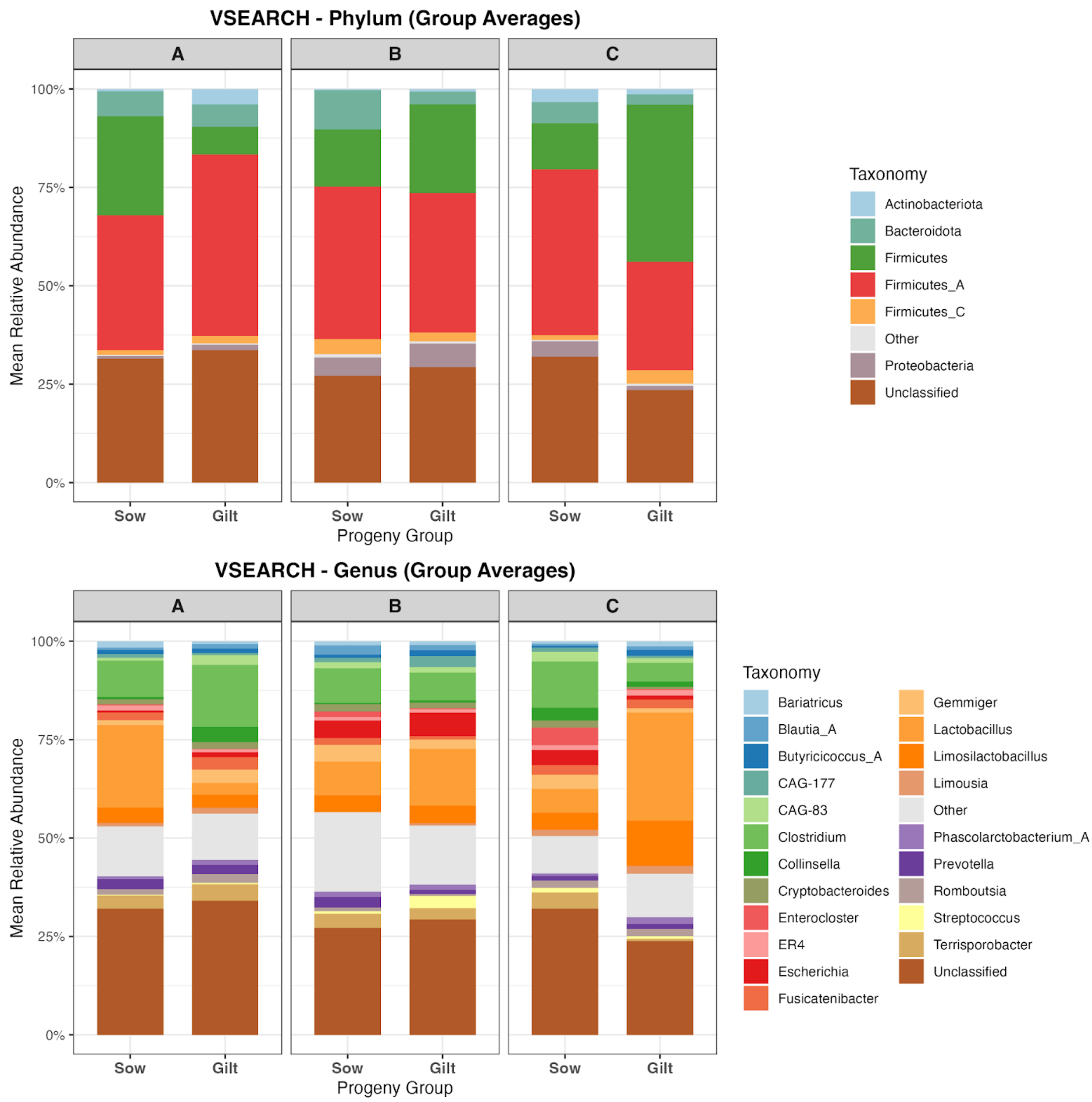

Figure 13. *Average abundance profiles for Treatment A (3 day wean age spread), B (7 day wean age spread) and C (> 7 day wean age spread) and gilt vs. sow progeny.*

When the sample results were further broken down by collection date, this enhanced interpretability and aligned better with biological expectations (Figure 14). At day 0, the gut microbiota was dominated by a more prevalent and diverse *E. coli* population, while *Lactobacillus* and *Streptococcus* were present at relatively higher levels. By day 14, *Lactobacillus* had noticeably decreased, and *Streptococcus* levels had also declined when compared with samples collected at day 0. In contrast, *Clostridium* increased its population diversity by day 14. In addition, *Blautia_A* and *Butyricicoccus_A*, which were only present in small densities at day 0, but were detected in all samples by day 14, indicating a marked shift in the microbiota composition over time.

Figure 14. *Relative abundance plot for Treatments A (3 day wean age spread), B (7 day wean age spread) and C (>7 day wean age spread) separated by progeny type and collection date (where day 0 was 30/6/25 and day 14 was 14/7/25).*

5.2.3 Experiment 2b: Intensive evaluation – lifetime performance

The interaction between weaning age spread treatment and progeny treatment was not significant for pig weight at any timepoint measured in this period (*P* ≥ 0.10). Weaning age spread treatment was not significant for 15 week weight (*P* = 0.20). Sow progeny were significantly heavier than gilt progeny at 15 weeks (65.7 ± 0.55 vs. 64.4 ± 0.56 kg; *P* = 0.007). Sale weight was not different between weaning age spread groups (all 107 ± 1.0 kg; *P* = 0.99) or gilt and sow progeny (*P* = 0.99) when adjusted for sale age and weaning weight. The group suffered from an outbreak of APP and this may have contributed to a high amount of variation in sale weights between animals, hence the power to detect any differences at this time was diminished.

There was a significant interaction between weaning age spread and progeny treatment for ADG in the grower period (9 to 15 weeks; *P* = 0.003; Figure 15). This impact continued into the finisher period (15 weeks until sale; *P* = 0.030) where ADG was higher for the 3 day age spread group within gilt progeny compared to the other age spreads, whereas the 3 day age spread group had the lowest ADG for the sow progeny (Figure 16). This was not in agreement with our commercial study and it is important to note that pigs from different treatment groups shared the same airspace in this experiment, whereas we tried to control this in the commercial experiment by blocking by room. Furthermore, the mortality resulting from an APP outbreak in this study may have impacted our results as well. The divergent gilt vs. sow progeny responses should be interpreted with caution, as this APP outbreak likely increased variation and may have altered pen feed intake dynamics.

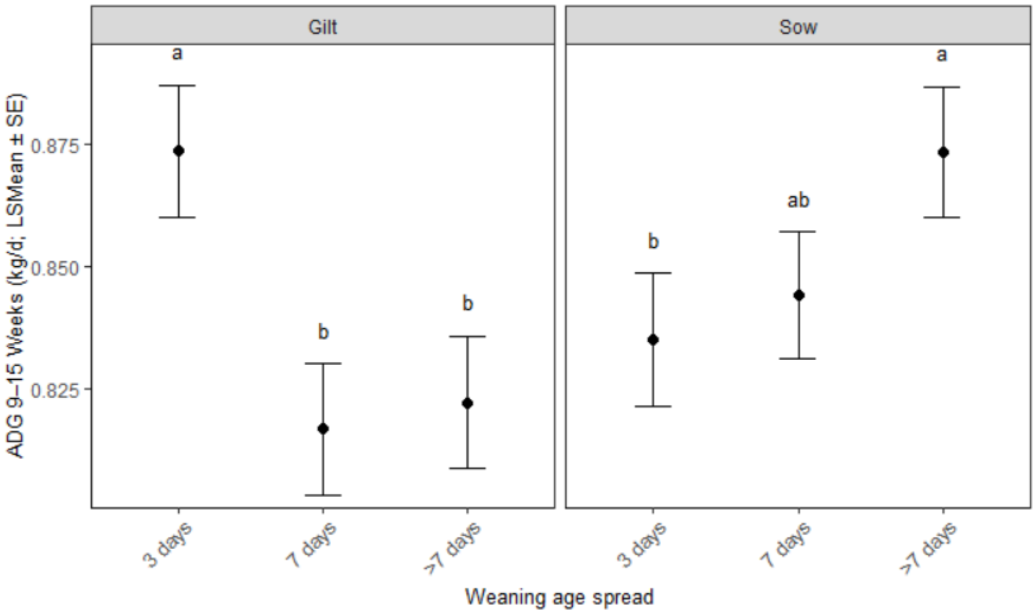

Figure 15. *Impact of the interaction between weaning age spread and progeny group (gilt vs. sow progeny) on average daily gain (ADG) in the grower period (9 to 15 weeks of age; P = 0.003). [a,c]Different superscripts denote a significant difference (P < 0.05) between means.*

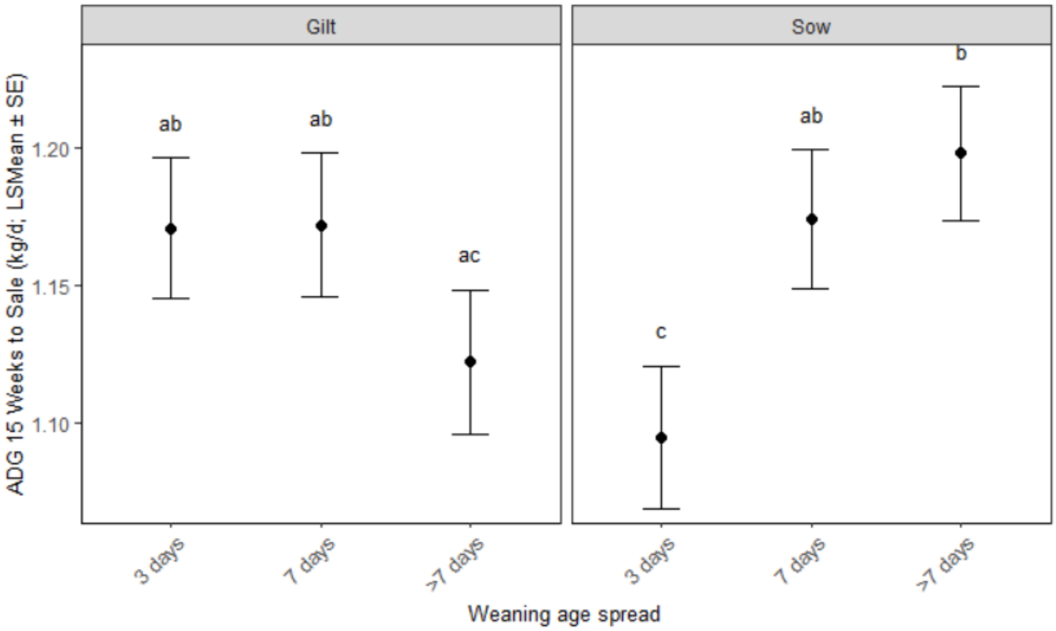

Figure 16. *Impact of the interaction between weaning age spread and progeny group (gilt vs. sow progeny) on average daily gain (ADG) in the finisher period (15 to 22 weeks of age; P = 0.030). [a,b,c]Different superscripts denote a significant difference (P < 0.05) between means.*

There tended to be an interaction between weaning age spread treatment and progeny group on ADFI in the grower period (*P* = 0.087). While there were no significant pairwise differences between interaction means (*P* ≥ 0.10) the interaction seemed to indicate that ADFI in the grower period increases as weaning age spread increases for sow progeny, whereas the opposite was true for gilt progeny (data not shown). Similarly, there was a significant interaction between weaning age spread and progeny group on ADFI in the finisher period (*P* = 0.018) and over the whole grower-finisher period (*P* = 0.017). These variables followed the same trend where ADFI seemed to increase with a lower weaning age spread for gilt progeny and decrease with a lower weaning age spread for sow progeny (data not shown).

Feed conversion ratio (FCR) in the grower period was not different between progeny groups (*P* = 0.52; data not shown). However, there tended to be a difference between weaning age spread groups (*P* = 0.087) in this period, >7 day weaning age spread pigs having the lowest FCR (1.99 ± 0.069) followed by the 7 and 3 day weaning age spread pigs (2.17 ± 0.069 and 2.19 ± 0.069, respectively). There was no difference in FCR in the finisher stage between weaning age spread or progeny groups (*P* ≥ 0.10; data not shown). Over the whole grower-finisher measurement period, FCR tended to be higher in the 3 day weaning age spread group than the other two groups (*P* = 0.064; Figure 17).

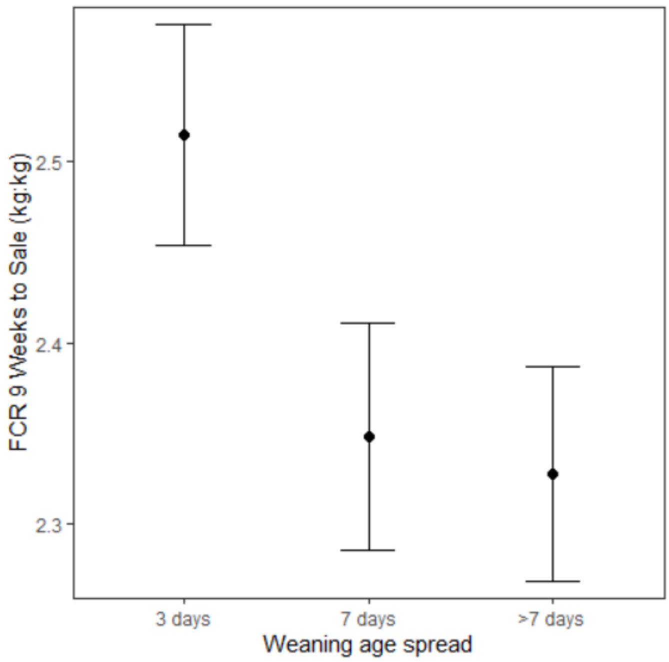

Figure 17. *Impact of weaning age spread on feed conversion ratio (FCR) in the grower-finisher period (9 to 22 weeks of age; P = 0.064).*

Post-weaning lifetime ADG was significantly impacted by the weaning age spread x progeny group interaction (*P* = 0.001) with ADG being higher in lower weaning age spread groups within gilt progeny and the opposite being true for sow progeny (Figure 18).

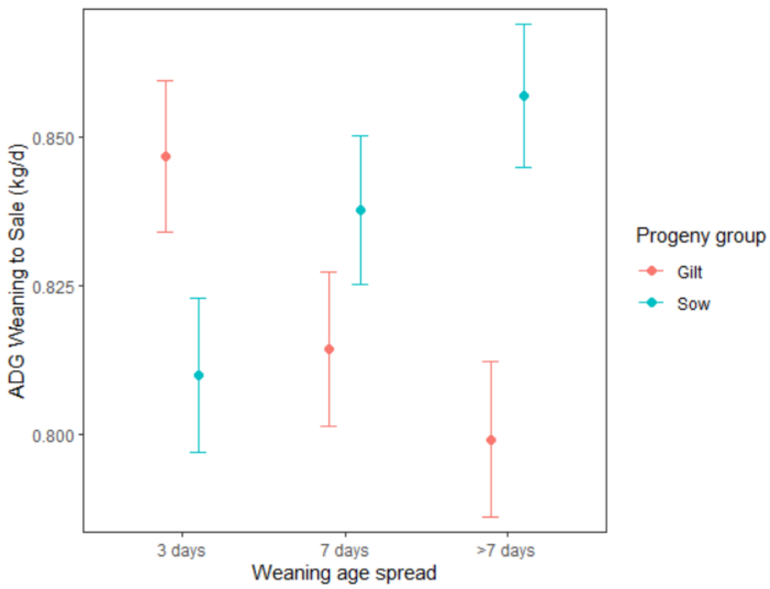

Figure 18. *Impact of the interaction between weaning age spread and progeny group (gilt vs. sow progeny) on lifetime average daily gain (ADG) between weaning and sale (approx. 4 to 22 weeks of age; P = 0.001).*

There was no influence of weaning age spread on HSCW (*P* = 0.88) with 3 day, 7 day and >7 day weaning age spread groups having HSCW of 80.7 ± 1.05 kg, 80.0 ± 1.01 kg and 80.5 ± 1.12 kg, respectively. There was no significant difference between gilt progeny and sow progeny in terms of carcass weight (both 80 ± 1.1 kg; *P* = 0.27). This is not agreement with previous literature (Craig et al., 2017a; Craig et al., 2017b) and again we suspect that the large amount of variation seen, likely introduced by health issues during the experimental period, is why we were unable to detect these differences in this data set. There was no difference in P2 backfat at sale between weaning age spread treatments ($P = 0.82$) or gilt and sow progeny (both 11 ± 0.2 mm; $P = 0.50$) and no difference when P2 was corrected for HSCW as a covariate ($P \geq 0.10$; data not shown). Similarly, there was no significant difference between weaning age spread or progeny group treatments in terms of LD, dressing percentage or percentage lean (all $P \geq 0.10$; data not shown).

5.3 Objective 3: Recommendations

Data obtained from the above experiments strongly suggests that weaning within a 3 day age spread improves pig growth performance. Based on the findings of this project, tightening weaning age spread appears to offer a practical opportunity to improve post-weaning performance, particularly where pigs can be grouped within 3 days of age. Across the retrospective and experimental data, narrower weaning age spread was associated with improved uniformity, better post-weaning feed intake, improved feed efficiency in the larger retrospective dataset, and may have favourable downstream outcomes such as heavier carcass weight and greater loin muscle depth. These biological benefits suggest that increasing weaning frequency from once to twice per week may be economically justified in some production systems if it results in a meaningful reduction in age spread in the weaner facility. The cost-benefit of an additional weaning needs to be weighed up for each production system. This would also depend on the numbers of pigs coming through the system, and the space to house them after weaning.

In addition to reducing weaning age spread, the findings from this project indicate that minimising fostering and increasing weaning age are both likely to improve post-weaning performance. Across the retrospective analyses, pigs that were not fostered generally performed better than pigs that were fostered, with the poorest outcomes observed in pigs fostered after day 1. Early fostering within the first 24 hours appeared less detrimental, suggesting that where fostering is necessary it should be undertaken as early as possible and only when required. Likewise, pigs weaned at older ages consistently showed improved post-weaning survival and lifetime growth compared with pigs weaned younger, indicating that increased physiological maturity at weaning supports better adaptation to the nutritional, social and environmental challenges of the post-weaning period, consistent with previous studies. Together, these results suggest that management strategies aimed at minimising unnecessary fostering, avoiding late fostering, and increasing average weaning age where practical are likely to improve pig robustness, growth performance and overall production efficiency.

Feed intake of piglets was improved post-weaning when weaning age spread was reduced to 3 days (weaning two days per week); however, from the results obtained from our studies, it doesn't look like this translates to pigs being more efficient, which could increase COP. Conversely, it does indicate that this may result in improvements in carcass weight and lean tissue deposition, with the higher HSCW and LD in 3 day age spread group seen in Experiment 1. Furthermore, our studies did not have significant power to detect differences in mortality rates, and it should be further explored whether weaning age spread improves the health and wellbeing of pigs shortly after weaning.

The cost-benefit of a second weekly wean will depend on the specific production system, including herd size, labour availability, shed design, room-filling efficiency, and the ability to maintain all-in all-out flow. The main additional costs are likely to be labour, set-up and pig movement time, transport or handling logistics, and any loss of operational efficiency from more frequent batching. Furthermore, the downstream impact on timing of other labour-heavy tasks, such as mating sows, would need to be taken into consideration (e.g., if this falls on a weekend, for example).

The main benefits of implementing two weans per week over one are expected to arise from improved pig flow and uniformity, lower feed cost per kilogram of gain, and potential improvements in sale value or pigs sold. Therefore, adoption of a second weekly wean is most likely to be justified in larger systems where the production gains from tighter age spread can outweigh the extra labour and operational costs, whereas in smaller or more space-constrained systems, gains may be better achieved through improved planning of farrow dates (e.g., utilising synthetic farrowing induction methods) and wean timings to minimise age spread without increasing weaning frequency.

5.3.1 Cost benefit considerations – adjusting weaning frequency

Assuming 100 sows and litters are currently weaned in one event per week, and this takes 8 staff × 90 minutes, assuming the direct labour cost is $35/hour, then this equates to:

$$8 \times 1.5 \times \$35 = \$420 \text{ per wean}$$

If this can be split into two weans per week of 50 sows per wean (i.e., the same total pig numbers are handled across two smaller events), the direct labour requirement may rise because set-up, pig movement and organisation are repeated twice. If each event now takes 8 staff × 60 minutes (with additional set up time), the weekly labour cost becomes:

$$2 \times (8 \times 1 \times \$35) = \$560 \text{ per week}$$

This is an extra labour cost of about $140 per week, before allowing for additional transport, administration or inefficiencies in room filling. This would also depend on weekend penalty rates for staff, depending on when the weaning or subsequent events (e.g., mating) occur.

The benefit side would come from the improvements associated with a tighter weaning age spread seen in this report, including better early feed intake in some groups, improved feed efficiency in the larger retrospective dataset, and favourable carcass outcomes such as heavier carcass weight and greater LD. For example, if tighter age spread improved value by $0.30 per pig due to a higher value carcass across 1,100 pigs per week, the benefit would be:

$$1{,}100 \times \$0.30 = \$750 \text{ per week}$$

Under that scenario, the production benefit would clearly outweigh the extra labour cost. Even at a much smaller response of $0.05 per pig, the benefit would still be $125 per week, which may still cover the direct labour cost of the second wean in a large system. This illustrates that adoption is most likely to be justified where pig throughput is high and the reduction in age spread can be achieved without compromising pig space utilisation or all-in all-out pig flows and hence health outcomes.

Furthermore, the retrospective data analysis carried out in the high-health status herd as part of Objective 1 showed that the benefit on lifetime performance may be much larger when moving from a wean every 2 weeks to a weekly wean, with the benefits in lifetime ADG and FCR equating to approximately $3.60 profit per pig (Hermesch et al., 2012, 2013). Hence, this can be a consideration in smaller systems as the benefit is larger and has potential to outweigh the additional labour costs of a more frequent wean.

The cost benefit of increasing weaning age is farm dependent and would depend on whether it creates pressure in the farrowing accommodation, reduces sow throughput, or affects batch flow. For example, in a small system, the second wean may not pay because fixed disruption to pig flows is high; however, on a large farming system, even small gains in FCR or survival can outweigh labour very quickly. Therefore, while increasing weaning age may offer substantial biological benefit, the net economic value will depend on whether the farrowing system has enough flexibility to carry pigs for longer without reducing overall productivity.

6. Discussion

Although several sow- and piglet-related factors influenced post-weaning performance in this project, not all of these are able to be manipulated at a commercial level. Factors such as genetic line, parity and inherent sow effects were important sources of variation, but they are more difficult for producers to directly manipulate. Sow progeny were consistently heavier than gilt progeny pens across the entire experimental period, consumed more feed and achieved higher ADG. This aligned with literature on gilt progeny performance, which typically have lower birth weights (Tummaruk et al., 2001; Muns et al., 2015; Craig et al., 2017b) and pre-weaning weight gain (Santiago et al., 2019; Buthelezi et al., 2024), subsequently affecting their early post-weaning performance (Wolter and Ellis, 2001; Zotti et al., 2017). Gilt progeny would, therefore, especially benefit from altering farm management strategies around weaning. Constantly weaning would not be practical or cost effective, but efforts to reduce the wean age spread by focussing on planning the wean around farrow dates and consequently litter ages would contribute to tightening the wean age spread of the resulting herd which would ultimately see performance benefits long term for all progeny, especially gilt progeny.

In contrast, management-related factors such as weaning age, fostering strategy and weaning age spread are more immediately controllable and therefore more useful as practical targets for intervention. The positive effect of increasing weaning age observed in this project is consistent with a broad body of literature showing that older pigs are better equipped to cope with the nutritional, environmental and social stressors associated with weaning and reflecting improved physiological development and post-weaning adaptation in older-weaned pigs (Do, 2012; Ming et al., 2021; Richert et al., 2023; Metallo et al., 2025). In the present study, pigs weaned at older ages consistently showed higher post-weaning survival and improved lifetime growth performance, supporting the view that increased physiological maturity at weaning improves resilience and survivability during the weaning transition period (Pluske et al., 2003; Lyderik et al., 2023) and can also have positive impacts on lifetime performance. In addition to growth responses, weaning age also influences carcass composition. Earlier-weaned pigs tend to exhibit increased fat deposition, whereas pigs weaned at older ages produce leaner carcasses with reduced backfat thickness (Do, 2012). This relationship supports the present findings, where pigs weaned at younger ages showed greater P2 values compared with those weaned later, although this effect appeared reduced under post-depopulation conditions. Collectively, these results suggest that delayed weaning enhances both growth performance and carcass quality, likely due to improved gastrointestinal development, nutrient utilisation, and reduced weaning stress. This reinforces that weaning age remains one of the most important and well-established management controls available to producers. It has been previously suggested that increasing the weaning age could be an effective strategy to improve pig performance (Faccin et al., 2020; Ming et al., 2021; Metallo et al., 2025). However, the practical ability to increase average weaning age will depend on farrowing house capacity, batch size, progeny space and sow throughput.

Fostering was also identified as an important management factor influencing post-weaning outcomes, although this is more difficult to investigate cleanly under controlled conditions because fostering decisions in commercial practice are often driven by underlying sow or litter problems. Furthermore, it would be difficult in a controlled situation to mimic commercial fostering patterns while having statistical power to detect differences in performance due to fostering and minimising the influence of external factors (e.g., environment and management changes). In the retrospective data, pigs fostered after day 1 generally performed worse and had increased fat deposition in later life than pigs that were not fostered or were fostered within the first 24 hours, in agreement with previous work (Harper, 2023) suggesting that late fostering may add further disruption to pigs that are already compromised. In practice, this may reflect issues such as poor sow milk production, disease, mismothering or reduced litter viability rather than fostering itself acting in isolation. Even so, the findings support the practical recommendation that fostering should be kept to a minimum where possible, and where it is required, it should occur as early as possible to reduce disruption to pig performance. Together with the weaning age results, this suggests that early-life management practices such as timing of weaning and fostering can influence later carcass composition, although the magnitude of these effects may depend on herd health status. Our findings suggest that older weaning and early or minimal intervention in litter composition may reduce early-life stress and support post-weaning survival, particularly under more challenging production conditions.

Given the stronger practical relevance of management factors and the difficulty of experimentally isolating fostering effects, the later stages of this project focused on weaning age spread as a novel and commercially relevant factor affecting post-weaning performance. Compared with weaning age alone, weaning age spread better reflects the reality of how pigs are grouped in commercial systems, where pigs of different developmental stages are often mixed within the same weaner space. To date, studies specifically investigating the effects of weaning age spread on pig growth performance and survival are limited. While considerable research has examined the impact of weaning age and fostering independently, the variation in weaning age within groups has received comparatively little attention, with most available literature instead focusing on related concepts such as weaning weight variability and group uniformity. As a result, the direct effects of weaning age spread on outcome such as ADG, feed efficiency and lifetime performance are not well defined. This project therefore addressed an important gap in the literature by examining whether the degree of age variation within weaned groups affects pig performance beyond the effect of mean weaning age alone.

Results from the current study indicated that reducing wean age spread from >7 day spread down to <7 day spread (ideally <3 days) would see improvements in the quality of stock produced during the weaner phase. Labour and time restraints could be a limitation for this recommendation and may not be possible for some farming operations, especially smaller scale farms which have less available labour, which has been shown in the cost-benefit analysis from Objective 3 of this study. The effects of weaning age spread were most apparent in the retrospective analyses, where wider age spread was associated with poorer feed efficiency and, in some cases, reduced growth performance. In the more controlled Experiments 1 and 2, the differences between treatments were more subtle, but still suggested biological and commercial advantages of tighter weaning age spread, particularly in relation to early feed intake, carcass weight and LD. This difference between datasets is not unexpected. The retrospective data captured the full variation and noise present under commercial conditions, and included more extreme age spread ranges, whereas the controlled experiments deliberately reduced confounding factors and compared narrower treatment contrasts (3 vs. 7 vs. >7 days). Unfortunately, the pigs in the controlled study in Experiment 2b were highly influenced by an APP outbreak in the grower-finisher. These results suggest that the impact of weaning age spread may be dependent on progeny type and health challenges and deserve to be further investigated. The lifetime GDC data further suggest that responses to weaning age spread may differ between gilt and sow progeny, with gilt progeny appearing to benefit more from tighter age spread than sow progeny.

A practical implication of this work is whether tighter weaning age spread should be achieved by increasing weaning frequency, for example from one wean per week to two. The biological rationale for doing so is supported by this project, as tighter age spread was associated with better pig uniformity, improved feed intake in some groups, better feed efficiency in the larger dataset, and favourable downstream carcass traits. However, the value of a second weekly wean must be considered in the context of labour availability, facility size, pigs flows, and all-in all-out management. In larger systems, relatively small improvements in performance applied across a high number of pigs may outweigh the additional labour and operational costs of more frequent weaning. In smaller or space-constrained systems, similar gains may be more effectively achieved through better planning of farrow and wean timings rather than by increasing weaning frequency.

An important consideration for smaller farms to tighten weaning age spread may be to use farrowing induction methods to tighten weaning ages. Oxytocin is often used to induce sows in practice when sows or gilts are past their due date, typically beyond 114 days of gestation (Mills et al., 2021). Oxytocin has been noted to both increase uterine contractions, reduce the time of overall labour and increase intra-partum mortality of piglets (Mota-Rojas et al., 2005; 2006; 2007) and therefore has to be used carefully around farrowing. Intramuscular administration of oxytocin has been found to increase (uterine) contraction intensity, resulting in more neonatal deaths (Nam and Sukon, 2020; Hill et al., 2022) and complications such as foetal heart rate dips (Rault et al., 2013), severe hypoxia, ruptured or broken umbilical cords and postnatal bradycardia (Mota-Rojas et al., 2005; 2006). Therefore, while farrowing induction may help some systems reduce age spread, it should only be considered where welfare risks, staffing requirements and veterinary guidance can be appropriately managed. From a sow welfare perspective, inducing a more rapid and intense farrowing process may also increase stress and warrants careful consideration.

An important strength of this project was the combination of large-scale retrospective analysis with targeted experimental studies, but these approaches also differed in what they were able to detect. The retrospective datasets captured broad commercial variation and provided statistical power to identify management-related risk factors across large pig populations. In contrast, the controlled experiments allowed tighter evaluation of weaning age spread under more standardised conditions, but necessarily reduced some of the background variability present in the commercial environment. This highlights that responses may vary between farming systems, genetic lines and environments.

Although post-weaning survival was clearly influenced by weaning age and fostering in the retrospective analyses, the experimental work in this project was not sufficiently powered to detect meaningful differences in mortality or removals between weaning age spread treatments. In the controlled studies, mortality and removal rates were low overall. As a result, the main measurable benefit of tighter weaning age spread in this project appears to lie in improved performance and efficiency rather than a clearly demonstrable reduction in mortality under the conditions studied. Nevertheless, it remains possible that effects on survival may become more apparent in larger commercial populations or in systems facing greater health or environmental challenge, and this deserves to be further studied.

The microbiome plays a key role in the health and production of weaner pigs (Nowland et al., 2019; Holman et al., 2021). The relative abundance and overall microbial diversity of the weaner pig's gastrointestinal tract (GIT) shifted significantly from the day of initial weaning to day 14. This could be attributed to the sudden and drastic change in diet and the impact it had on the composition and population dynamics of the associated microorganisms in the GIT (Jiang et al., 2020; Holman et al., 2021; Rivera et al., 2025). More detail on this aspect can be found in APL Project 2026-0036 Final

Report (Johnson et al., 2026) and this aspect deserves to be further studied to ascertain the impact on weaner transition and how we might manipulate it to our advantage in commercial production.

Experiment 2 demonstrated that sow progeny consistently outperformed gilt progeny across all performance metrics recorded in this study, which is consistent with previous studies (Craig et al., 2017a; Craig et al., 2017b; Craig, 2019). Mixing pigs of different ages at weaning would likely impact individual pig behaviour, with an increase in stress-related behaviours of the younger pigs (Yuan et al., 2004; Jarvis et al., 2008; Metallo et al., 2025) resulting in decreased feed intake and subsequent performance.

In conclusion, this project demonstrated that management of the weaning transition has measurable effects on pig performance that extend beyond the weaner phase and into lifetime production outcomes. Tighter weaning age spread, older weaning age and minimising late fostering were generally associated with improved robustness, growth and/or feed efficiency, although the lifetime response to weaning age spread varied by progeny group and appeared to be influenced by health challenge. Importantly, many of these factors are practical and management-driven, meaning they can be manipulated to some extent within commercial systems. While the economic value of increasing weaning frequency will vary depending on labour availability, herd size and facility space, the findings of this project support tighter management of weaning age spread (~3 days) as a realistic strategy to improve lifetime productivity and overall efficiency in Australian pig production.

7. Implications & Recommendations

As a result of this study, we recommend keeping weaning age spread as tight as possible (ideally within 3 days) to improve piglet performance after weaning and lifetime impacts on the profitability of the farm. However, it must be noted that the response may be greater in vulnerable groups of animals, such as gilt progeny, and may be harder to detect under a disease challenge (e.g., an APP outbreak). This project also further demonstrated that gilt progeny consistently perform more poorly in comparison to sow progeny in the period immediately following weaning. Mixing pigs of different ages at weaning would likely impact individual pig behaviour, with an increase in stress-related behaviours of the younger pigs resulting in decreased feed intake and subsequent performance. Particular attention should be given to gilt progeny, as they may gain the greatest benefit from tighter weaning age spread; however, responses are likely to be influenced by herd health status and disease events.

The cost-benefit analysis performed as part of this project should help producers determine whether tightening the weaning age spread would be worth the benefit in their own system, and would depend on herd size, pig accommodation after weaning and availability of labour.

Focusing on management factors such as weaning age spread, average weaning age and minimising fostering should all help to improve lifetime performance of pigs in Australian production systems. The impact of weaning age spread on transition to weaning and post-weaning survival and health deserves to be further studied.

8. Intellectual Property

None.

9. Technical Summary

From the current project, the below list of recommendations are given for producers to maximise their post-weaning performance (with consideration to the conditions of this study):

- Keep weaning age spread as tight as possible, ideally within 3 days, and no more than 7 days where the production system allows.
- Increase average weaning age where practical, as older weaning age was associated with improved post-weaning survival and better lifetime growth performance.
- Minimise fostering wherever possible, particularly when it is not essential.
- Avoid late fostering, as pigs fostered after day 1 generally performed worse than pigs that were not fostered or were fostered within the first 24 hours.
- If fostering is required, complete it within the first 24 hours to reduce disruption to pig establishment and early development.
- Plan farrow dates and wean allocation carefully to reduce the mixing of pigs of very different ages and developmental stages at weaning.
- Consider whether increasing weaning frequency (for example, from once to twice per week) could reduce age spread enough to justify the extra labour and operational cost in your system.
- Recognise that gilt progeny may require greater attention around weaning, as they were consistently more vulnerable and performed less favourably than sow progeny in the early post-weaning period.
- Prioritise practical management changes that improve pig uniformity and robustness at weaning, as these are likely to deliver benefits in feed efficiency, lifetime performance and carcass value.

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11. Publications Arising

Johnson, K. 2026. *The effects of weaning age spread and parity on the post-weaning performance of pigs.* Honours Thesis. Charles Sturt University.