Does Pre-Weaning Mixing and/or Object Enrichment Improve Piglet Behaviour, Welfare, and Performance Around Weaning?

by

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ABSTRACT

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While abrupt weaning is a common practice in commercial swine barns, it subjects piglets to numerous changes at once; piglets are not only separated from their sow but also mixed with unfamiliar pigs, transported to a new environment, and provided a new diet. Weaning stress is often associated with negative welfare consequences. Our objective was to study the effects of early-life pre-weaning socialization (starting at 1 to 3 days of age) in multi-litter groups as well as object enrichment (burlap sheet) in the pre- and post-weaning environment. We compared piglet performance, behaviour, and welfare across 6 treatments that combined group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no). We recorded piglet behaviour, piglet body weights, and sow and piglet lesion scores. An ANOVA linear model was run on all normal conforming data, expressed per experimental unit (and behaviour data were averaged over time), while data that did not meet the normality criteria were analyzed using the Kruskal-Wallis test.

When given the opportunity in the sow barn, piglets in multi-litter groups socialized with other litters. Although pre-weaning burlap use and cross-sucking were seldom observed (<5%
and 10%, respectively) it tended to increase with mixed group size \( (P < 0.1) \). Although there was no difference in the proportion of piglets nursing \( (P > 0.10) \), piglets were less active in the single crate groups and most active in the groups of two litters mixed \( (P = 0.03) \) pre-weaning. Post-weaning piglets manipulated the burlap more frequently when not mixed pre-weaning, compared to the groups of 4 litters mixed \( (P = 0.02) \).

Pre-weaning displacements were observed more often in non-enriched groups around the pen \( (P = 0.03) \) but tended to be observed more often in enriched groups at the teat \( (P = 0.07) \). Piglets’ biting of sows did not differ between treatments but, the biting of other piglets \( (P = 0.07) \) and pen object manipulation \( (P = 0.08) \) tended to be observed more frequently in non-enriched groups. Similarly, in the post-weaning environment, fighting throughout the pen tended \( (P = 0.06) \) to be observed less in the enriched groups while biting \( (P < 0.001) \), pen object manipulation \( (P = 0.006) \), and displacements throughout the pen \( (P = 0.003) \) were observed significantly more frequently in non-enriched groups. Post-weaning biting was observed the least in groups of pigs of 4 litters mixed pre-weaning, while piglets that were not mixed pre-weaning were observed biting the most \( (P = 0.03) \). There was a slight interaction effect for fighting at the feeder \( (P = 0.06) \) indicating that mixing groups of 4 litters pre-weaning reduced the number of observed fights at the feeder post-weaning only when the pigs were also provided enrichment before and after weaning. Post-weaning, there were no differences observed in the proportion of piglets resting, eating/drinking, being active, or using the burlap, or for the observed frequency of displacements at the feeder, social behaviours, or belly nosing \( (P > 0.10) \).

Although the final lesion scores of sow’s teat and udder condition did not differ between treatments \( (P > 0.10) \), sow udder lesion scores worsened most in the single litters compared to 2 or 4 litters mixed \( (P = 0.05) \). The average number of lesions per piglet did not differ between
treatments the day before weaning. However, post-weaning lesion counts tended to be lower (fewer lesions per pig) in the enriched groups vs. non-enriched groups initially ($P = 0.07$) and one week after weaning ($P = 0.10$). Furthermore, pigs mixed in groups of 4 litters pre-weaning also tended to have lower lesion scores ($P = 0.07$) 1-week post-weaning compared to the other 5 treatments. Pre-weaning socialization and object enrichment had no effect on pre-weaning mortality rates, birth weights, weaning weights, 1-week post-weaning weights, and the average number of piglets weaned per sow were similar between treatments ($P > 0.10$).

Overall, social and object enrichment allow piglets to socialize with others at a younger age and redirect their attention and aggression toward objects such as burlap, which does not negatively impact piglet performance and can improve piglet behaviour and welfare around weaning.
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CHAPTER 1: LITERATURE REVIEW

Introduction

In commercial swine production operations, piglets are commonly weaned abruptly and will often experience additional changes or stressors at the same time. Specifically, piglets weaned in commercial operations are separated from their sow, mixed with unfamiliar individuals, transported to, and housed in a new environment, and provided with a new (solid feed) diet. Furthermore, pigs raised in commercial swine production systems are housed in barren environments and are often (re)mixed multiple times throughout their lives and these mixing events can induce physiological and social stress (Ji et al 2021). Stress can have detrimental effects on the pigs’ health, welfare, and productivity (Ko et al 2020). Therefore, it is critical to find and implement practical ways to reduce stress at weaning to improve piglet welfare and public trust in the swine industry.

One way to reduce weaning stress would be to socialize piglets with other litters prior to weaning. Due to the nature of commercial swine production operations, piglets do not have many, if any, opportunities to learn how to socialize or interact with other piglets that are not their littermates because sows are typically housed in separate crates within a single farrowing pen with their piglets. The crates are in place to protect the piglets from crushing and to protect barn employees from the potentially aggressive sows. However, when given the option, sows
will find an isolated, safe place to nest prior to farrowing and then stay in that nest with their litter until piglets are approximately 10 days of age (Turpin et al 2017). At that point, the piglets would begin to encounter other litters in nature (Turpin et al 2017). However, in commercial operations, piglets can be kept isolated with their own litter (approximately 10-12 piglets) until approximately 21 days of age, when they are abruptly weaned from their mother and regrouped into nursery pens with approximately 24 piglets. Prior to being regrouped, many operations require piglets to be transported by trailer to the nursery barn, often off-site. On the trailer, piglets are with unfamiliar pigs for the first time in a novel, high-stress environment – a moving trailer. Furthermore, pigs are social animals by nature and will form a social hierarchy when housed in groups, but the stress at weaning is already associated with increased aggression as these new hierarchies are formed (Tong et al 2019). Mixing piglets prior to weaning may allow them the opportunity to develop skills that can be used when socializing with unfamiliar pigs, which may improve piglet behaviour and welfare. When younger pigs are mixed before weaning, they show lower physiological stress responses, have shorter fights, and experience fewer injuries compared to pigs mixed at weaning, likely due to their smaller size and strength (Pitts et al 2000; Morgan et al 2014; Ko et al 2020). Therefore, one management strategy used to minimize aggression, thereby benefiting piglets around weaning, is to mix piglets earlier than just at weaning.

Another management strategy used to minimize aggression between piglets around weaning is to provide environmental enrichment. Enrichment has been shown to be beneficial to many species of production animals, including pigs. Providing enrichment to young pigs may encourage the redirection of negative behaviours as well as encourage the piglets to exhibit more natural behaviours. As one of the Five (5) Freedoms of Animal Welfare, the freedom to exhibit natural
behaviours is imperative to promote animal welfare (Mellor 2016). Piglets are highly motivated to perform their natural behaviours related to exploration, food seeking, oral manipulation, and socialization (da Silva et al 2016). For hygienic purposes and ease of management, barren environments are common in swine facilities. However, barren environments often lead to piglets developing agonistic behaviours either due to boredom or frustration or competition over resources. These behaviours can include aggression, belly-nosing, tail-biting, and ear-biting, and they can have severe consequences as pigs mature and progress through the production system. Most damage from tail-biting is not significant until the pigs reach the finishing stages (5-8 weeks post-weaning), however, there is evidence suggesting that tail-biting develops at a very young age (Hakansson & Bolhuis 2021). For this reason, it is important to address and attempt to prevent the behaviours from developing as early as possible in a piglet’s life. Providing enrichment in an otherwise barren environment, therefore, has the potential to prevent the agonistic behaviours displayed between piglets mentioned above. However, providing enrichment in a large-scale commercial operation may be more difficult than in a small-scale experimental setting. Common concerns expressed by producers for their hesitancy to install enrichment as a common practice in their operations include cost, the risk to manure systems/pumps, and the additional resources required to ensure enrichment objects are properly cleaned/sterilized to avoid biosecurity risks (Peden et al 2021). Commonly recommended forms of enrichment for commercial operations include socialization, object enrichment, and substrate enrichment. However, the suitability of each form of enrichment to different operations will depend on many factors including but not limited to facility design, manure system functionality, labour force availability, and various other management factors. Therefore, methods that are
effective, low-cost, require minimal labour, and can be implemented without adverse effects on manure systems are the most likely to be utilized by producers.

Discussion

Pre-weaning Socialization

Although improving animal welfare often comes at a cost to producers, Peden et al (2021) estimated that the financial consequences of reducing pig aggression by allowing pre-weaning socialization frequently had a “neutral or positive net effect” due to the low initial cost of modifying partitions between farrowing pens (if required) so they may be removed, low labour requirements to remove and replace partitions, and improved piglet growth performance and should be a priority when considering methods to control aggressive behaviours in pigs.

Encouraging socialization as a form of enrichment may be a cost-effective method to improve the welfare, behaviour, and performance of piglets at weaning and beyond (Morgan et al 2014; Ko et al 2020; Peden et al 2021). Furthermore, this method is practical to implement in many commercial operations as it requires minimal labour and typically only requires one additional step to implement. If producers use common plastic farrowing pens with sow crates in the middle of each pen, allowing piglets to socialize prior to weaning would only require removing the plastic pen dividers. Sows would remain in their individual crates and thereby do not pose any greater risk to the piglets.

As opposed to only mixing piglets at weaning when there are multiple other stressors present, they are introduced to new piglets in a familiar environment with their sow present which
reduces the number of stressors present at one time. Furthermore, mixing at a younger age has the benefit of piglets being smaller and not as strong/rough towards one another as they may be once reaching their weaning age (approximately 21 days of age). Once pre-weaning socialization has been achieved in an operation, it is expected that piglets will learn social skills that they will be able to use when meeting new piglets at the time of weaning and that these social skills will enable them to form a stable hierarchy more quickly after weaning (D’Eath 2005). They are also able to take advantage of the increased space away from the sow to play and explore with their new pen mates which are promoted as part of the Five Freedoms of animal welfare (Mellor 2016).

Pre-weaning socialization has been commonly researched as a method to improve animal welfare which has been shown to benefit the pigs before and after weaning. Fewer agonistic behaviours were observed after weaning in groups of piglets that were socialized with other litters prior to weaning in studies done by Hessel et al (2006) and Ledergerber et al (2015). When fewer agonistic behaviours are performed fewer injuries/lesions occur (Salazar et al 2018; Morgan et al 2014; Pitts et al 2000). Furthermore, improved performance was observed in groups of weaned piglets that were socialized prior to weaning (Hessel et al 2006).

Many researchers have documented positive results when mixing smaller groups of 2 to 3 litters in farrowing rooms (Hessel et al 2006, Parratt et al 2006; Salazar et al 2018; Van Kerschaver et al 2021), while no published study to date has evaluated the effect of larger group sizes beyond 3 litters. In a recent unpublished study, although no statistical significance was found, there was numerically less pre-weaning mortality in mixed litter groups when 2 adjacent litters were mixed preweaning. Possibly due to increased space for the piglets away from the sow. However, when extremely large groups of litters were mixed (13 litters mixed), the same study saw the lowest
performance (low growth rates and high mortality) when compared to the control (single litters) and when only groups of 2 litters were mixed. The reason for seeing decreased piglet performance in the extremely large groups is still unknown. A potential explanation for the above results may have been sow fitness (teat condition during trial) or the fact that piglets were exposed to too many other piglets and sows. Having piglets in larger groups of mixed litters could be the first step in transitioning current commercial farrowing systems to loose farrowing systems, as well as it exposes piglets to a similar number of piglets that they would encounter at weaning. To address the difference between groups of 2 litters and groups of 13 litters, mixing an intermediate number of crates (4 crates) would provide insight as to if there is a ceiling effect (i.e. a maximum number of pens that can/should be mixed to maximize benefits) when mixing piglets pre-weaning in commercial operations.

Most socialization studies also mixed piglets at a later age (day 7 to 18 of life). There is no evidence of a significant relationship between age and aggression (Pitts et al 2000), however, pigs mixed at a younger age showed fewer injuries compared to those mixed when they are older (Pitts et al 2000) which suggests improved welfare of piglets mixed at younger ages, before weaning. Additionally, three of the above-mentioned studies either combined or confounded their socialization treatments with intermittent sucking and/or sow presence, meaning that there is no way to differentiate the effects of benefits from mixing piglets vs. keeping them with their sow.

Intermittent mixing has been discussed as another method to improve piglets’ social skills and post-weaning behaviours. However, this method involves removing and replacing the barriers on multiple occasions and would be especially labour-intensive in a commercial operation. Furthermore, in the Ji et al (2021) study, the continuous mixing groups outperformed the
intermittent mixing groups as they found that the longer contact time reinforced social skill
development and hierarchal formations, ultimately reducing aggression among the piglets.

Another gap in the former literature is that numerous studies pseudo-replicated their samples by
considering multiple litters who grouped together as separate experimental units. Therefore,
more robust research is needed to evaluate whether mixing young piglets in groups greater than 3
litters is beneficial. A recent review estimating the financial implications of implementing new
systems on farms to reduce pig aggression found that pre-weaning socialization was the most
feasible compared to other systems because it required little alterations to current crate farrowing
systems and little additional labour, keeping costs low for producers (Peden et al 2021).

Object Enrichment (Burlap)

Pigs are naturally curious animals and rooting, chewing, and exploring are all-natural behaviours
that they exhibit. These behaviours should be encouraged as part of the 5 Freedoms of Animal
Welfare. For example, providing object enrichment in the form of burlap sheets can satisfy
piglets’ innate motivations to root, chew, and explore. Hanging burlap sheets is an ideal form of
object enrichment for commercial production operations because they are cost-effective, pose
little risk to the manure system, and pose no health risks to the piglets as long as a new sheet can
be used for each batch of litters. Furthermore, piglets who might otherwise bite their littermates
and develop destructive agonistic behaviours (such as tail/ear biting or belly nosing) would
instead have an outlet for these behaviours that may encourage the redirection of the behaviour.
This could limit injuries caused to other littermates and improve the welfare of the aggressor and
the victim. Alternative types of enrichment such as substrates (straw) or rubber toys have a
higher risk of damaging manure systems and require additional cleaning or sanitization practices to be implemented, respectively.

Although enrichment has commonly been recognized as a means to improve animal welfare (Fynn et al 2021; Ledergerber et al 2015; Schmitt et al 2020), providing enrichment in a commercial operation can be challenging for producers. Often coming at a cost to producers, posing a risk to their biosecurity, and/or a risk to their manure systems, enrichment, beyond nutritional enrichment, in the form of a creep feeder, and social enrichment, being housed with littermates and their sow in the farrowing barn and group pens once weaned, is not commonly added in swine operations. However, many studies have documented results that support the inclusion of enrichment because it encourages natural behaviours and exploration (Fynn et al 2021).

Ledergerber et al (2015) found that piglets weaned into pens with enrichment showed fewer agonistic behaviours within the first 12 hours post-weaning compared to those weaned into a pen with no enrichment. Certain types of agonistic behaviours can have more negative implications than others. Tail and ear lesions can result from agonistic behaviours between pigs and can have negative impacts on pig health, welfare, and overall productivity through the growing stage as well as on the end value of the carcass (Li et al 2017). In order to prevent these negative outcomes, environmental enrichment should be considered to redirect the oral manipulation behaviours often observed in pigs.

Many studies have evaluated the effects of environmental enrichment (Fynn et al 2021; Ledergerber et al 2015; Schmitt et al 2020; Yang et al 2018) but few studies to date have evaluated the use of enrichment in the pre- and post- weaning environment consecutively,
namely, Oostindjer et al (2011). The familiarity of the enrichment from one environment to the other may reduce the stress experienced by the piglets at weaning when numerous other factors are changing (their feed, their pen, being separated from the sow, and their litter mates).

Furthermore, biting behaviours in pigs have been shown to develop at a very young, even though the negative effects on victims of biting are most prevalent in finishing operations (Hakansson & Bolhuis 2021). Therefore, providing an orally manipulable form of enrichment early in piglets’ life should improve the welfare of both the biter and the victim.

Schmitt et al 2020 found that piglets preferred burlap over other objects (bamboo) as enrichment because it could be shaken and allowed for oral manipulation, which was the behaviour most frequently observed. Burlap is a natural fibre that can be manipulated and chewed, and even ingested in small quantities without harmful effects (Fynn et al 2021) and poses less threat to the manure system because it would only enter the slurry if it was torn into very small pieces. The pigs can manipulate the sheet of burlap without forcing it through the slats and into the slurry system below as opposed to straw. Burlap has been shown to have the potential to improve litter performance and provide measurable production benefits when provided as enrichment as it encourages foraging and chewing behaviours and it facilitates solid feed intake thereby resulting in better growth compared to piglets raised in barren environments (Blavi et al 2021).

Combination of Social and Object Enrichment

A recent study looked at both object enrichment and pre-weaning socialization as a strategy to reduce regrouping stress and aggression, by combining object and social enrichment in one treatment and compared it to a barren control group (Ko et al 2020). When provided with social
and object enrichment from birth, weaned pigs showed two times fewer agonistic behaviours and 3.3 times fewer lesions compared to the barren control group in the Ko et al (2020) study. The results indicated improved welfare because of “object exploration, mitigation of weaning stress, and reduced aggression” (Ko et al 2020). However, there is no way to compare social enrichment to object enrichment or discern the effects of the two treatments. Therefore, it is currently unknown whether social or object enrichment is more beneficial, as well as whether the combined effects of early mixing and environmental enrichment are additive or synergistic.

**Future Directions**

Whether the combined effect of pre-weaning socialization and object (burlap) enrichment is additive or synergistic may be revealed as a result of this current study. Upon completion, the results could lead to low-cost common practice recommendations that could be implemented across the industry to improve piglet welfare, behaviour, and performance, thereby having the potential to improve the production efficiency of commercial swine production operations.

**Objectives and Hypotheses**

The objectives of this study are:

1) to determine if early-life (1-3 days of age) pre-weaning socialization strategies in multi-litter groups (2 or 4 litters) reduces aggression and improves piglet welfare and performance compared to no pre-weaning socialization (each litter separately)
2) To determine whether providing environmental enrichment is beneficial to young pigs by encouraging natural behaviours and thereby redirecting agonistic pig behaviours.

3) To evaluate whether pre-weaning socialization between litters and enrichment interact to improve pig welfare in an intensive commercial operation.

I hypothesize that providing piglets with early-life socialization and environmental enrichment to piglets’ pre- and post-weaning environment, in the form of a burlap sheet, will decrease the occurrences of aggressive behaviour and should result in fewer or less severe lesions among weaned pigs. This will, in turn, increase pig performance and improve the welfare of socialized piglets, such that the combination of both treatments provides a benefit which is additive, or greater than the sum of both treatments.
CHAPTER 2

Effects of Pre-Weaning Mixing and Object Enrichment (Burlap) on Piglet Performance, Behaviour, and Welfare in the Pre-Weaning Environment

Abstract

When piglets are weaned in commercial operations, not only are they separated from their sow, but they are often mixed with unfamiliar pigs in an unfamiliar environment with a new diet. These sudden changes can be stressful for piglets, often having negative welfare consequences. Our objective was to study the effects of early-life (1 to 3 days of age) pre-weaning socialization in multi-litter groups as well as object enrichment (burlap sheet) in the pre- and post-weaning environment. We compared piglet performance, behaviour, and welfare across 6 treatments that combined group size (1 vs. 2 vs. 4 litters) and burlap (yes vs. no). Pre-weaning, we recorded piglet behaviour, piglet body weights, and sow and piglet lesion scores. An ANOVA linear model was run on all normal conforming data, expressed per experimental unit (and behaviour data were averaged overtime). When given the opportunity in the sow barn, piglets in multi-litter groups socialized with other litters. Burlap use and cross-sucking were observed in <5% and 10% of the observations, respectively but tended to increase with mixed group size (0.05 < P < 0.1). While there was no difference in the proportion of piglets nursing (P > 0.10), piglets were less active in the single crate groups and most active in the groups of two litters mixed (P =
0.03). Additionally, observed piglet/sow biting behaviours did not differ between treatments, however, piglet/piglet biting \((P = 0.07)\), and pen object manipulation \((P = 0.08)\) tended to be observed more frequently in non-enriched groups. Similarly, piglet displacements were observed more often in non-enriched groups around the pen \((P = 0.03)\) but tended to be observed more often in enriched groups at the teat \((P = 0.07)\). Pre-weaning socialization and object enrichment had no impact on piglet performance; Pre-weaning mortality rates, weaning weights, and the average number of piglets weaned per sow were similar between treatments \((P > 0.10)\). The average number of lesions per piglet did not differ between treatments the day before weaning. Although the final lesion scores of sow’s teat and udder condition did not differ between treatments \((P > 0.10)\), sow udder lesion scores worsened most in the single litters than in the mixed litters \((P = 0.05)\). Overall, social and object enrichment gives piglets the opportunity to socialize with others at a younger age and to redirect their attention and aggression toward objects such as burlap which does not negatively impact piglet and sow performance or behaviour and ultimately, may improve piglet welfare around weaning.

**Introduction**

In commercial swine operations, piglets are typically housed with their sow and littermates for approximately 21 days from birth until weaning. During their time with their sow, social groups remain relatively stable as piglets do not typically have the opportunity to socialize with unfamiliar pigs until later when they are weaned. Upon weaning, piglets are separated from their sow, transported to a new environment, fed a new diet, and mixed with unknown pigs. The impacts of these stressors can affect pig performance, behaviour, and welfare throughout the
production system (Ko et al 2020). Therefore, reducing piglet stress around weaning has the potential to benefit the entire production system. To effectively reduce the negative impacts of stress at weaning, interventions should be cost-effective and applicable in commercial settings, and they should encourage piglets’ natural behaviours. The two most practical forms of enrichment for piglets are thus: 1) early socialization (social enrichment) through mixing with other litters (Peden et al 2021), and 2) object enrichment (Godyn et al 2019).

Shortly after birth, piglets’ first experience forming a social hierarchy is establishing a teat order whereby they select a teat and, for the remainder of their nursing period, they will defend it as theirs (Chou et al 2021). Their hierarchy will likely remain stable until they are weaned and regrouped in the nursery, where increased aggression (displacements, biting, and fighting) and associated lesions are common (Pitts et al 2000; Ko et al 2020). Providing piglets with the opportunity to socialize with unfamiliar pigs in the pre-weaning environment may allow them to develop social skills that they can use during the weaning transition. Furthermore, this can spread out the stressors they experience because they already have prior experience socializing with unfamiliar pigs. When piglets are socialized preweaning, their subsequent behaviour (after weaning) reflects a more relaxed state (Morgan et al 2014) and they engage in fewer agonistic behaviours (Hessel et al 2006; Ledergerber et al 2015; Salazar et al 2018) compared to pigs mixed for the first time at weaning. Although there is no known relationship between piglet age at mixing before weaning and aggression, another potential benefit of early socialization is that the piglets are younger, smaller, and have less potential to inflict serious harm to other pigs if any agonistic behaviours do occur (Pitts et al 2000; Van Kerschaver et al 2021). It could also promote transferable social skills that set the piglets up for a successful weaning transition, thereby improving piglet performance, behaviour, and welfare around weaning. Several
researchers have evaluated the effects of mixing piglets before weaning, but they did so only once piglets were a minimum of a week old (D’Eath et al 2005; Hessel et al 2006; Camerlink et al 2021; Salazar et al 2018) and also only mixed groups of 2 or 3 litters pre-weaning. Additionally, some studies may have pseudo-replicated samples or confounded results with other treatments (Turpin et al 2017; Wenbo et al 2021). However, a recent review estimated that pre-weaning socialization is a low-cost, feasible system to implement on farms to reduce pig aggression (Peden et al 2021). There is, therefore, a need to more robustly evaluate the effects of pre-weaning mixing of piglets less than 1 week of age in groups larger than 2 or 3 litters.

Given that piglets are naturally curious animals who begin to explore their environment at a young age (Swan et al 2021), providing object enrichment in the form of a burlap sheet encourages piglets to engage in their natural exploratory, chewing, and rooting behaviours (Ledergerber et al 2015; Schmitt et al 2020; Fynn et al 2021). By providing enrichment to the piglets in their pre- and post-weaning environments, there is also an element of familiarity in their environment that is carried over before and after weaning. This may reduce their stress at weaning and provide the pigs with comfort and a positive outlet for directing their stress. Burlap sheets meet five of the “Six Ss” for selecting enrichment put forth by the National Farm Animal Care Council of Canada (NFACC 2021) by being safe, sanitary, soft, simple, and suspended. The burlap sheets were 100% natural, untreated jute plant fibres woven together which is low risk if consumed by piglets. A burlap sheet may be the optimal form of enrichment for piglets because it poses minimal risk to the manure systems and does not require additional biosecurity measures as would straw or reusable rubber toys, respectively. If pigs are provided with a positive outlet for their natural behaviours, they may redirect any destructive behaviours or chewing/biting on
their pen mates to the burlap (Yang et al 2018). Providing enrichment may encourage play, reduce agonistic behaviours between piglets, and improve piglet welfare post-weaning (Fynn et al 2021; Ledergerber et al 2015; Yang et al 2018; Schmitt et al 2020). Although many previously published studies focus on the effects of enrichment provided post-weaning, few studies have evaluated the effects of providing the same type of enrichment in both the pre- and post- weaning environment on behaviour and welfare of piglets.

It is currently unknown if object enrichment and pre-weaning socialization are additive or synergistic in commercial settings as current literature compares groups of piglets that were socialized and provided enrichment to control groups of piglets that were not socialized or provided enrichment (Ko et al 2020) or evaluate the effects of either mixing or enrichment but not both. The objective of this study was, therefore, to evaluate the effectiveness of pre-weaning mixing and object enrichment (in the form of burlap) to reduce weaning stress in piglets in commercial operations. We hypothesized that providing piglets with pre-weaning socialization and/or a burlap sheet, both pre- and post-weaning, would increase the agonistic behaviour among piglets pre-weaning, but improve pig performance and welfare after weaning.

Materials and Methods

This study was conducted during the summer of 2022 (June – August) at two commercial facilities, a conventional sow barn and a conventional nursery barn. Both barns are located in South-East Manitoba, Canada. All experimental procedures were approved by the Animal Care Committees of the Research Ethics Board (Protocol Reference Number: F21-022, AC11708) at
the University of Manitoba, Fort Garry campus. Experiment factors (social and object enrichment) did not interfere with routine pig care and management procedures, which were conducted by barn staff.

Animals, Housing, and Experimental Design

The farrowing barn houses 6000 sows. Of the total of 32 farrowing rooms in this facility, we focused on 4 farrowing rooms on trial per replicate and ran 3 replicates, however, one was interrupted by extreme weather and had to be terminated prematurely. Of the 26 crates in each farrowing room, 24 were on trial while 2 were designated as not on trial (N.O.T.) to accommodate any nurse sows/foster-offs after the start of the trial period as well as aborted pregnancies before the start of the trial. The farrowing pens used in this trial measured 6 ft 9 in × 5 ft 4 in (2.06 m × 1.63 m) with a sow crate in the center measuring 6 ft 6 in × 2 ft (1.98 m × 0.61 m).

In this study, we used a 3 × 2 factorial design and a complete randomized block design (Table 1) to assess the effects of: 1) group size (1 litter, 2 litters mixed, 4 litters mixed) and 2) object enrichment (enriched vs. non-enriched). Litters (n = 288) were randomly assigned to one of 6 treatments where the size of each experimental unit (considered to be the group of piglets to which the treatment was applied) differed according to the treatment (n = 168 total experimental units): 1 litter, not enriched (1N, n = 48 × 1 litter), 1 litter, enriched (1E, n = 48 × 1 litter), 2 litters, not enriched (2N, n = 24 × 2 litters), 2 litters, enriched (2E, n = 24 × 2 litters), 4 litters, not enriched, (4N, n = 12 × 4 litters), and 4 litters, enriched (4E, n = 12 × 4 litters). The estimated minimum sample size of the number of experimental units needed to detect treatment
differences was calculated to range between \( n = 2 – 14 \) per treatment with 80% power and an alpha of 0.05 (https://www.stat.ubc.ca/~rollin/stats/ssize/), using estimates from previous studies for our primary outcome variables, including behaviour, growth performance, and amount of lesions (Camerlink et al 2021; Salazar et al 2018; Van Kerschaver et al 2021).

Given that our objective was to evaluate the effect of pre-weaning mixing and/or object enrichment on piglet behaviour, performance and welfare at weaning, these numbers in the sow barn allowed us to have roughly similar sizes and numbers of groups in each treatment after weaning. The allocation of treatments was randomized within rooms using a random number generator, balanced for sow parity, and each treatment was present in each room (block) as this was a complete randomized block design.

**Table 1.** Treatments (3 \( \times \) 2 factorial design) evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no)

<table>
<thead>
<tr>
<th>Pre-weaning Mixing Factor</th>
<th>Object Enrichment Factor</th>
<th>No pre-wean mixing</th>
<th>Pre-wean mixing (2 crates)</th>
<th>Pre-wean mixing (4 crates)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Burlap</strong></td>
<td></td>
<td>1 crate only + burlap (1E)</td>
<td>2 crates mixed + burlap (2E)</td>
<td>4 crates mixed + burlap (4E)</td>
</tr>
<tr>
<td><strong>No Burlap</strong></td>
<td></td>
<td>1 crate only + no burlap (1N)</td>
<td>2 crates mixed + no burlap (2N)</td>
<td>4 crates mixed + no burlap (4N)</td>
</tr>
</tbody>
</table>

Piglets were on trial for approximately 3 weeks in the farrowing rooms, followed by an additional week in the nursery for a total of 4 weeks. The following procedures will be referred
to as ‘piglet processing’: all piglets were administered an iron supplement 1-day post-farrowing and male piglets were castrated by trained barn staff, as per the current on-farm protocols. Litters were balanced based on the number of piglets relative to their sow’s functional teats and based on the number of piglets per litter per room, as per standard practice at the barn, prior to the start of the trial (day 0 to 2 of life). All piglets on trial were out of Fast F1 sows crossed to a DNA Duroc 600 boar.

The trial began on trial day 0, which occurred 1 to 3 days after the entire room had farrowed and within 24 hours of processing. At this point, we applied our treatments. The plastic panels that divided the farrowing pens between each sow were removed to allow socialization between litters, but before removing the panels, we marked each sow and her piglets with animal-safe paint, by crate, to allow identification of piglets and their respective sows within each experimental unit after mixing occurred. At the same time, two 1ft × 2 ft (0.31 m × 0.61 m) burlap sheets were secured using C-clamps at the back of the farrowing pen for the enriched treatment groups, out of reach of the sow, which was an appropriate length to just reach the ground for ease of access for the piglets.

Prior to weaning, a new system of painting piglets was used, this time marking piglets according to treatment to facilitate the identification and sorting at the nursery. Piglets were weaned at an average age of 22 days ± 4 days at which time all piglets in each room were mixed and moved by livestock trailer to a nursery barn off-site. Post-weaning results will be discussed in a companion manuscript (Chapter 3).
Behavioural Observations

Two types of behaviour observations were made four times on each observation day (twice in the AM, twice in the PM), occurring on trial days 3, 5, 9, 11, and 13 ± 1 day. Scan sampling focused on behavioural states (sucking, active, resting, using burlap), whereas continuous sampling focused on event behaviours (fighting, biting, socializing, displacements, etc.).

Scan behaviour observations were made by counting the number of piglets performing each of the listed behaviours: eating/drinking, resting, active, using burlap, at the start of each of the four observation times on each observation day. Continuous behaviour observations used one-zero sampling, recording two consecutive 30-second observation periods, at each of the four observation times on each observation day.

Piglets did engage with the burlap, however, it was not observed frequently enough (<5% of observations) to be considered part of this analysis but will be discussed in a companion manuscript (Chapter 3). Scan behaviour observations were made by counting the number of piglets performing each of the listed behaviours: sucking, active, resting, and using burlap, at the start of each of the four observation times on each observation day. Since resting was the state behaviour predominantly observed, nursing and active results were analyzed as representative averages scaled to the group size, calculated as the natural log of the difference between the proportion and the proportion resting. Scan observations also collected piglet movement data in mixed groups by counting the number of piglets of each colour in a crate at the time of observation as an indicator of the piglets travelled across the mixed crates (by referencing the sow’s assigned colour).
Continuous behaviour observations used one-zero sampling, recording two consecutive 30-second observation periods, repeated four times per observation day (two in AM, two in PM). Four trained observers with a moderate or higher, interobserver reliability score for each behaviour (Table 2) performed in-person observations. The teams of two-observers alternated rooms and crates between observation periods so that each team observed each room twice and each member of the team observed each pen twice per day also.

**Table 2.** *Behaviour Observation Interobserver Reliability Scores (IOR)*

<table>
<thead>
<tr>
<th>Continuous Behaviour Observations</th>
<th>Kappa</th>
<th>Scan Behaviour Observations</th>
<th>ICC(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fighting</td>
<td>0.70</td>
<td>Nursing</td>
<td>0.73</td>
</tr>
<tr>
<td>Biting</td>
<td>0.66</td>
<td>Active</td>
<td>0.91</td>
</tr>
<tr>
<td>Displacement</td>
<td>0.58</td>
<td>Resting</td>
<td>0.88</td>
</tr>
<tr>
<td>Socializing</td>
<td>0.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pen Objects</td>
<td>0.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) ICC3 (*Model: Two-way; Type: consistency*)

**Piglet Lesion Scoring**

Lesions were scored using the system presented by Turpin et al 2017 which assessed the severity of scratches (red marks and scabs) on the piglets’ ears, tail, and body. Lesions were scored by trained observers in teams of two (ICC between teams = 0.83) on trial days 5, 9, 13 ± 1 day, as well as on the day before weaning. The number of lesions present in a group of pigs was counted and then the number of lesions (expressed per pig to standardize across different group sizes)
was calculated for each experimental unit by taking the total number of (body lesions + tail lesions + ear lesions) / total number of piglets in that unit. Due to the scarcity of piglet lesions in the pre-weaning environment, only data collected from the day before weaning ±1 day were analyzed.

Sow Lesion Scoring

Sow lesions were scored on trial day 1 and on the day before weaning by a single trained observer for all 3 replicates. Each sow was assigned an udder score and a teat score; a score of 0 indicated that no lesions were present or, if lesions were present, a score of 1 to 3 (depending on severity) as described by Van Kerschaver et al (2021). Sow teat descriptions were also noted to indicate if the sow had any inflamed, scabbed, amputated, or split teats. Sow lesion scores assessed sow condition over the course of the lactation period on a per experimental unit basis (averaged across sows within groups of mixed litters).

Litter Performance

Litter weights and the number of piglets weaned per sow were recorded in the sow barn. Initial litter weights were collected on trial day 1 by weighing piglets in a feed cart with a scale (Battery Scale Koenders cart with a Reliable face plate). Pre-weaning litter weights (weaning weight) were collected on the day before weaning by weighing each group of piglets on a walk-on scale that was located down the hall from the farrowing rooms. Weaning weight data were unfortunately not available from replicates 1 and 3.
Pre-weaning mortality data were collected by barn staff, using the farm protocol and recording sheets, on a per-crate basis (the number of piglets weaned per sow, and piglet mortality). These were then combined and expressed on a per experimental unit basis to account for the differences in piglet numbers between single, double, and four litter groups.

**Statistical Analyses**

All data were expressed per experimental unit and behaviour data were averaged over time. An ANOVA linear model was run on all data that met the normality criteria using the Bartlett test and Shapiro-Wilks tests on the residuals of the model. Significant differences were declared at $P < 0.05$ and tendencies were declared at $0.05 < P < 0.10$. If significant differences or tendencies were found, the Fisher’s Least Significant Difference (LSD) post hoc test was used to run pairwise comparisons between treatments. Non-normal conforming data were analyzed using the Kruskal-Wallis test. Treatment factors (number of litters mixed and enrichment) were included to assess any interaction effects. All statistical analyses were run in Rstudio © (Version 2023.03.0+386).

**Results and Discussion**

**Piglet Behaviour**

Piglets in mixed litter groups did travel between pens, showing that they were making use of the additional space and socializing with piglets from other litters. While there was no difference in the proportion of piglets nursing ($P > 0.10$), there was a significant mixing effect in terms of the
proportion of active piglets ($P = 0.03$); piglets from the single crate groups were the least active (26%, i.e., 2 active, 8 resting), while groups of two litters mixed were the most active (37%, i.e., 6 active, 15 resting). Groups of four litters mixed were the intermediate and did not differ from the other groups (33%, i.e., 10 active, 30 resting). Furthermore, a similar proportion of piglets were observed travelling to crates other than their home crate regardless of whether they were in a group of 2 or 4 litters ($P > 0.10$).

Allowing different numbers of litters to socialize before weaning did not impact the observed behaviours among piglets pre-weaning ($P > 0.10$). Cross-sucking was observed seldomly, but it tended to be observed more frequently in the groups of 4 crates compared to the groups of 2 crates ($P = 0.08$). In no previously published studies has there been a comparison of different group sizes on cross-sucking occurrences. However, our results are consistent with other studies that found a low occurrence of cross-sucking overall (D’Eath et al 2005; Morgan et al 2014).

Piglets in our study were mixed 1-3 days after farrowing which is earlier than the above-mentioned studies mixing around day 10 and 12 post-farrowing, respectively. However, the timing of early life socialization between groups of piglets may not influence cross-sucking since the occurrence of cross-sucking was rare in all previous studies, as well as ours, even with the difference in the timing of socialization. Furthermore, the early removal of the pen dividers did not negatively impact the formation of the sow-piglet bond given that we observed minimal cross-sucking and piglets responded well to their sow’s vocalizations and generally scurried back to their own sow for nursing. Because the timing of partition removal has not been shown to influence the incidence of cross-sucking among mixed litters (Van Kerchaver et al 2021), implementing early-life socialization can be tailored to each barn’s preference/schedule without risk of negatively impacting the sow-piglet bond. More sows provide more opportunities for
piglets in the mixed groups to cross-suck (D'Eath et al 2005). However, because nursing bouts are typically synchronized between litters nearby (Widowski et al 2007; Silerova et al 2013), we observed most piglets travel back from another crate to their sow when looking for milk. Cross-sucking occurred during 10% of all our behaviour observations. Even with our results indicating a tendency for larger groups of mixed litters to experience more cross-sucking, the seldom occurrence of this behaviour did not result in reduced litter performance in these treatment groups. Based on a previous study, cross-sucking may not be a result of our applied treatments as much as it is due to sow behaviour; Morgan et al (2014) describes some sows as being complaisant to cross-sucking piglets, frequently allowing “alien” piglets to nurse while other sows will not allow “alien” piglets to cross-suck. Although we did not examine which sows allowed cross-sucking, it is possible that there may have been proportionally more complaisant sows in the larger mixed groups. Future work could investigate which piglets were cross-sucking. It would be interesting to know if it is primarily smaller piglets that are “opportunistic feeders”, seeking out teats that are available to them either due to proximity or due to low competition (smaller litter size vs. functional teat ratio) or if it is primarily larger piglets that are “sow hopping” and bullying other piglets off their sows to get more milk. Depending on who is cross-sucking, this may influence management decisions for mixed litters in commercial operations.

Within the enriched groups, the frequency of observed burlap interaction (investigating and/or manipulating) increased with the number of crates mixed ($P = 0.07$). Burlap use was not observed often in the pre-weaning environment ($<5\%$ of the time). However, the slight increase in burlap use observed in the larger mixed groups could be attributed to social learning and social facilitation among piglets. Giving the sow access to the burlap could also encourage piglets to
engage with it however, more research would need to be done to address risks to manure systems if the stronger, and therefore, more destructive, sow was provided burlap as enrichment alongside her piglets.

Encouraging burlap use may be important in the pre-weaning environment because it might help piglets develop the muscles needed to eat solid feed once weaned. The oral manipulation of the burlap can mimic the chewing action the piglets will need to transition to consuming solid feed in the nursery. Furthermore, if piglets can identify the burlap in the pre-weaning environment as an outlet for their natural chewing/biting behaviours, they may be less likely to develop agonistic behaviours such as tail/ear biting. Although our results showed that biting of the sow did not differ between treatments, we found that biting between piglets tended to be observed more often in the groups without access to burlap ($P = 0.07$). This supports the assumption that biting could be redirected from pen mates to the burlap. Not only can having access to burlap redirect the biting behaviours between piglets, but it can also redirect the manipulation of objects around the pen. Pen object manipulation, such as nosing, licking, or chewing on the flooring or bars of the sow’s crate, tended to be observed more often in the non-enriched groups compared to the enriched groups ($P = 0.08$). Though there were no displacements observed at the burlap and overall displacements did not differ between treatment groups ($P > 0.10$), piglet displacement around the pen was observed more often in the non-enriched groups compared to the enriched groups ($P = 0.03$) whereas displacement at the teat tended to be observed more often in the enriched groups compared to the non-enriched groups ($P = 0.07$). Indicating a difference in the observed frequency of displacements depending on the location (around the pen or at the teat), but not overall. We speculate that non-enriched groups were observed displacing their pen mates more frequently around the pen as a means to express frustration or boredom, whereas the
enriched groups were able to redirect these behaviours towards the burlap, instead of their pen mates, or did not experience the same level of frustration or boredom since they were provided enrichment material. The tendency for enriched groups to exhibit more nursing-related displacements may indicate that the enriched piglets were more teat-motivated or worked up a bigger appetite after interacting with the burlap. It is expected that the two types of displacements have different motivations because displacements around the pen do not have a clear “goal” or purpose motivating the piglet to engage in the action (besides moving around the pen) while, in contrast, displacements at the teat are more likely to be part of maintaining/establishing teat order during nursing bouts.

In previous literature, displacements are commonly categorized as aggressive behaviour and are not distinguished from fighting (Fels et al. 2021). However, for our observation, we differentiated between them and neither treatment factor had any impact on fighting at the teat or in the pen ($P > 0.10$). Additionally, belly nosing between piglets was seen in less than 1% of observations in the pre-weaning environment. In terms of social behaviours, there was no observed difference between treatments for sow/piglet or piglet/piglet socialization ($P > 0.10$).

**Piglet Lesion Scoring**

Across treatments, there was no difference between the number of lesions per pig ($P > 0.10$) on the day before weaning. This is consistent with the findings presented by Yang et al. (2018) and Ko et al. (2020) regarding object enrichment and/or social enrichment who did not observe any lesion differences pre-weaning. Piglets in the pre-weaning environment are smaller and less capable of inflicting injury/lesions on pen mates which is another benefit of mixing piglets
earlier in life than at weaning; once piglets reach weaning age, they are larger in size and therefore stronger. Piglets who are provided with the opportunity to socialize with unfamiliar piglets in their familiar pre-weaning environment acquire social skills while the risk of inflicted injury on another is lower. This may continue to benefit the piglet during other mixing events throughout multi-stage production systems, as indicated by many previously published studies (Kutzer et al 2009; Ko et al 2020; Fels et al 2021; Van Kerschaver et al 2021). Even though it was a concern that socializing piglets early in life (pre-weaning), instead of waiting until weaning, may pose a greater risk for piglets developing face lesions (Chou et al 2022), this was not the case based on our pre-weaned lesion results. Furthermore, 28% of producers who participated in a sow and piglet lesion risk factor survey, that included producers from 17 countries, (Chou et al 2022) identified piglets reared in barren environments to be at a greater risk for developing lesions based on their experiences. Although enrichment resulting in reduced piglet lesions is not reflected in our study or others (Yang et al 2018; Ko et al 2020), 38 of the 75 producers surveyed (51%) had implemented enrichment on their own and 33 of 75 (44%) of them reported it working to reduce piglet face lesions (Chou et al 2022).

**Sow Lesion Scoring**

Final sow lesion scores (scored on the day before weaning) for both udders and teats did not differ between treatments (n = 109; 1N (n = 32 × 1 litter), 1E (n = 29 × 1 litter), 2N (n = 16 × 2 litters), 2E (n = 16 × 2 litters), 4N (n = 8 × 4 litters), 4E (n = 8 × 4 litters)) (P > 0.10). However, sows in the single litter treatment groups tended (P = 0.06) to start off with lower (less severe) initial lesion scores on day 1 of the trial. Across all treatments, both udder and teat scores worsened over the course of the trial (Figure 1). Further, the average change in udder lesion
scores (final lesions score - initial lesion score) differed between treatments due to the mixing factor ($P = 0.05$); the udder lesion scores of single litter sows worsened more over the course of the trial compared to sows from the groups of two litters ($P = 0.03$) and four litters ($P = 0.09$).

The incidence of infectious teats was higher ($P = 0.002$) and the incidence of split teats tended to be higher in sows in the mixed litter groups ($P = 0.06$) whereas the incidence of non-functional teats, amputated teats, and scabs were not different between treatments ($n = 109$; $1N$ ($n = 32 \times 1$ litter), $1E$ ($n = 29 \times 1$ litter), $2N$ ($n = 16 \times 2$ litters), $2E$ ($n = 16 \times 2$ litters), $4N$ ($n = 8 \times 4$ litters), $4E$ ($n = 8 \times 4$ litters)) ($P > 0.10$).

**Figure 1.** Evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no) on average Initial$^1$ and Final$^2$ Sow Udder Lesion Scores$^3$ by Treatment$^4$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Initial Udder Score</th>
<th>Final Udder Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1N</td>
<td>1.07</td>
<td>2.07</td>
</tr>
<tr>
<td>1E</td>
<td>1.22</td>
<td>1.97</td>
</tr>
<tr>
<td>2N</td>
<td>1.47</td>
<td>2.03</td>
</tr>
<tr>
<td>2E</td>
<td>1.62</td>
<td>2.03</td>
</tr>
<tr>
<td>4N</td>
<td>1.44</td>
<td>2.03</td>
</tr>
<tr>
<td>4E</td>
<td>1.59</td>
<td>2.03</td>
</tr>
</tbody>
</table>

$^1$Scored day 1 of trial. $^2$Scored the day before weaning.

$(score \ 0 = \ no \ lesions; \ score \ 1 = \ mild \ lesions; \ score \ 2 = \ moderate \ lesions; \ 3 = \ severe \ lesions)$

$^4$ $1N$ ($n = 32 \times 1$ litter, not enriched), $1E$ ($n = 29 \times 1$ litter, enriched), $2N$ ($n = 16 \times 2$ litters, not enriched), $2E$ ($n = 16 \times 2$ litters, enriched), $4N$ ($n = 8 \times 4$ litters, not enriched), $4E$ ($n = 8 \times 4$ litters, enriched)
Our results support previously published data suggesting there are negative effects of larger group sizes (number of litters) on sow udder condition, indicated by more udder damage in sows with litters that were socialized pre-weaning (Camerlink et al 2021). However, Van Kerschaer et al (2021) found that mixing litters of piglets had no impact on udder lesion scores. When sows suckle larger litters, it is expected that they would be more likely to develop teat lesions due to more teats being used by piglets during each nursing bout or due to the increased fighting between piglets in larger groups (Norring et al 2006). This supports the perception of producers who selected large litter size as the highest risk factor attributed to sow teat lesions (Chou et al 2022). However, since mixing piglets pre-weaning involves removing the dividers between adjacent pens, there are more piglets split across more sows which may explain why the lesion scores of sows in our mixed litter groups did not worsen as much as the single litter sows. It is also possible that not all teat lesions are due to direct piglet effects (fighting for and biting of teats). Teat lesions can be a result of ventral lying which increases in later lactation as “a way for sows to avoid stimulus from her piglets” (Norring et al 2006) so it would be expected that larger groups of piglets disturb the sow more and therefore would result in more ventral lying. Although we did not record sow behaviour or pen hygiene as part of this study, the higher incidences of specific teat conditions (inflamed and split teats) may be due cross-sucking or reasons beyond the scope of this study and may be a concern with mixing groups on farm initially (Camerlink et al 2021). Although mixing litters results in more piglets around the sow at a given time and may influence sow behaviour, it did not negatively impact the sow’s fitness or piglet performance as a result. Contrarily, our results indicate that mixing piglets from adjacent pens pre-weaning can lessen the worsening of udder condition during lactation, providing a positive indication for producers that are considering mixing 2 or 4 litters before weaning in
commercial settings. More research is needed to determine the cause of teat inflammation and split teats to determine how our results may influence management decisions in the future. Additionally, our results based on the presence or absence of enrichment in the pre-weaning environment are consistent with the results that were found in other studies (Lewis et al 2006; Swan et al 2021): there were no significant differences in udder or teat lesion scores between treatments with or without enrichment ($P > 0.10$). Although enrichment may provide an outlet for piglets’ natural chewing and biting behaviours and redirect some behaviours away from the sow (Lewis et al 2006), piglets are still highly motivated to perform teat-seeking behaviours, establish a teat order, and nudge the sow’s udder to stimulate milk let down. Therefore, access to enrichment, such as burlap, may redirect some exploratory behaviours of piglets away from the sow’s udder/teats (Chou et al 2022) but only numerical differences in sow lesion scores were found in the current study as well as by Lewis et al (2006). Literature evaluating the effect of pre-weaning enrichment on piglet behaviour is limited however, our findings are consistent with other published literature and support the inclusion of enrichment in the pre-weaning environment to benefit the piglets as well as the sows (Chou et al 2022).

**Litter Performance**

Litter performance was not impacted by allowing piglets to socialize pre-weaning or by adding burlap to their environment. Neither piglet birth weights nor weaning weights were significantly different between treatments ($P > 0.10$) (Table 3). Furthermore, the average number of piglets weaned per sow was the same across treatments ($P > 0.10$) (Table 3).
Table 3. Average litter performance parameters when evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no) did not differ by treatment. 

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of piglets weaned per sow&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Weaning weight per piglet (kg)&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Birth weight per piglet (kg)&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1N</td>
<td>10.9 ± 1.36</td>
<td>6.6 ± 1.10</td>
<td>2.0 ± 0.41</td>
</tr>
<tr>
<td>1E</td>
<td>10.5 ± 1.71</td>
<td>6.5 ± 1.19</td>
<td>1.9 ± 0.52</td>
</tr>
<tr>
<td>2N</td>
<td>10.3 ± 1.87</td>
<td>6.4 ± 0.72</td>
<td>1.9 ± 0.32</td>
</tr>
<tr>
<td>2E</td>
<td>10.5 ± 1.12</td>
<td>6.4 ± 1.08</td>
<td>1.9 ± 0.31</td>
</tr>
<tr>
<td>4N</td>
<td>10.7 ± 0.89</td>
<td>7.1 ± 1.04</td>
<td>1.8 ± 0.26</td>
</tr>
<tr>
<td>4E</td>
<td>10.3 ± 1.20</td>
<td>6.4 ± 0.92</td>
<td>1.9 ± 0.22</td>
</tr>
</tbody>
</table>

<sup>1</sup>Expressed per experimental unit, 1 litter, not enriched (1N), 1 litter, enriched (1E), 2 litters, not enriched (2N), 2 litters, enriched (2E), 4 litters, not enriched (4N), 4 litters, enriched (4E)

<sup>2</sup>1N (n = 45), 1E (n = 44), 2N (n = 24), 2E (n = 24), 4N (n = 12), 4E (n = 12)

<sup>3</sup>1N (n = 16), 1E (n = 14), 2N (n = 8), 2E (n = 8), 4N (n = 4), 4E (n = 4)

<sup>4</sup>1N (n = 32), 1E (n = 30), 2N (n = 16), 2E (n = 16), 4N (n = 8), 4E (n = 8)

Our results are supported by the findings of numerous studies finding that pre-weaning socializing between piglets does not result in differences in piglet body weights at weaning (Ledregerber et al 2015; Turpin et al 2017; Camerlink et al 2021; Van Kercshaver et al 2021). Others also found no effect of pre-weaning socialization on the number of piglets weaned per sow (D’Eath et al 2005; Kutzer et al 2009). All these results indicate that mixing piglets preweaning does not have a negative impact on piglet performance. Furthermore, consistent with
previously published literature, piglet weight did not differ with or without access to enrichment (Lewis et al 2006; Yang et al 2018; Swan et al 2021).

Additionally, pre-weaning mortality over the course of the trial (day 2 ± 1 to 22 ± 4 of life) averaged 8.9% and was not different between treatments ($P > 0.10$). However, mortality, specifically from being crushed by the sow (laid on), was numerically lower for the mixed groups. Van Kerschaver et al (2021) also found no difference in mortality from 16 days prior to weaning up (when their treatments were applied) until weaning at 21 days of age and did not look further into the causes of mortality. In our results, the proportion of mortality that was due to crushing by the sow decreased as the number of litters mixed increased ($>60\%$ of mortality in single crates, 55-60\% of 2-crate mortality, <50\% of 4-crate mortality) ($P > 0.10$). Furthermore, the proportion of piglets crushed by the sow out of the total piglets per experimental unit was significantly different between treatments ($P = 0.02$). Specifically due to mixing factor ($P = 0.004$), with single litters having almost 10\% of piglets laid on, double litters having 6\% of piglets laid on, and groups of 4 litters having 4\% of piglets laid on. This may be from an increased space allowance per pig and more safe space available away from the sow after we removed the dividers separating the farrowing pens. Furthermore, in the sow barn used in this study, one heat mat was shared between two adjacent crates so if the dividers that spanned across the heat mats were removed, it would increase the available space on the heat mat, providing an alternative heat source to the sow’s body heat for more piglets, thereby reducing the risk of the piglets being crushed by the sow.

These results are encouraging for the implementation of both object and social enrichment within the industry because the piglets’ pre-weaning performance was not negatively impacted, yet, they have the potential to better prepare the piglets for the weaning transition.
Conclusion

Our treatment factors allowed adjacent litters to socialize pre-weaning (as groups of 2 or 4 litters) and/or interact with burlap as object enrichment. Overall, treatment effects were neutral in terms of litter performance, piglet lesions, and many behaviours before weaning. While in the groups of enriched piglets, fewer displacements were observed around the pen and there tended to be fewer biting behaviours exhibited and less pen object manipulation, they also tended to displace piglets at the teat more frequently than non-enriched groups. Furthermore, the groups of piglets that were not mixed were observed to be the least active, use the burlap the least, and the sows were found to have the most worsening udder lesion scores when compared to the mixed litters. However, there was an increase in observed cross-sucking among larger groups of mixed litters. Additionally, we addressed many potential concerns with pre-weaning socialization and object enrichment, most notably, the feasibility, labour requirements, and risk to slurry manure systems. Overall, piglet and sow performance and behaviour are not negatively impacted, and ultimately, piglet welfare may be improved around weaning.
CHAPTER 3

Effects of Pre-Weaning Mixing and Object Enrichment (Burlap) on Piglet Performance, Behaviour, and Welfare in the Post-Weaning Environment

Abstract

The process of weaning piglets in commercial swine operations subjects them to numerous abrupt and stressful changes often resulting in negative welfare consequences. Our objective was to study the effects of early-life pre-weaning socialization (starting at 1 to 3 days of age) in multi-litter groups as well as object enrichment (burlap sheet) in the pre- and post-weaning environment. We compared piglet performance, behaviour, and welfare across 6 treatments that combined group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no). After weaning, we recorded piglet behaviour, lesion scores, and body weights. An ANOVA linear model was run on all normal data, expressed per experimental unit (and behaviour data were averaged over time), while data that did not meet the normality criteria were analyzed using the Kruskal-Wallis test. Non-enriched groups of piglets were observed manipulating pen objects more often than the enriched groups ($P = 0.006$). Biting behaviours among weaned pigs, including the chewing of ears and tails of pen-mates but excluding fighting, was observed the least in groups of pigs of 4 litters mixed pre-weaning, while piglets that were not mixed pre-weaning were observed biting the most ($P = 0.03$). Piglets who were not mixed pre-weaning also
manipulated the burlap more frequently than the piglets from groups of 4 litters mixed pre-weaning ($P = 0.02$). Biting ($P < 0.001$) and displacements ($P = 0.003$) throughout the pen were observed less and fighting throughout the pen tended ($P = 0.06$) to be observed less in the enriched groups. There was a slight interaction effect for fighting at the feeder ($P = 0.06$) indicating that mixing groups of 4 litters pre-weaning reduced the number of observed fights at the feeder post-weaning only when the pigs were also provided enrichment before and after weaning. Post-weaning lesion counts tended to be lower (fewer lesions per pig) in the enriched groups vs. non-enriched groups initially ($P = 0.07$) and one week after weaning ($P = 0.10$). Furthermore, pigs mixed in groups of 4 litters pre-weaning also tended to have lower lesion scores ($P = 0.07$) 1-week post-weaning compared to the other treatments. Body weights did not differ significantly between treatments one week after weaning ($P > 0.10$). There were also no differences observed between treatments in the proportion of piglets resting, eating/drinking, being active, or using the burlap, as well as for the observed frequency of displacements at the feeder, social behaviours, or belly nosing ($P > 0.10$). Overall, social and object enrichment allow piglets to socialize with others at a younger age and redirect their attention and aggression toward objects such as burlap, which does not negatively impact piglet performance or behaviour and may improve piglet welfare around weaning.

**Introduction**

The weaning process in multistage commercial swine operations is often the first major disruption in a piglet’s life; it is also more abrupt and at an earlier age than would be observed naturally (Salazar et al 2018). During the weaning transition, piglets may be separated from their
littermates and must form a new social hierarchy with new pen-mates. The piglets must also adapt to a new environment and new feed, as well as being without their sow. They experience increased stress, changes to their physical and social environments, and the additional stress of handling and potentially transport. Moving piglets to a nursery facility usually requires being transported by livestock trailer in large groups of unfamiliar piglets. If transport off-site is not required, the moment piglets are regrouped in the nursery would be when they first meet unfamiliar piglets. As a result, the weaning transition can have detrimental effects on piglets’ welfare, health, and production parameters around weaning which may influence future performance and welfare (Ko et al 2020). Therefore, producers are continually working towards reducing the impact of stress associated with the weaning transition on their piglets. Effective methods to reduce piglet stress around weaning should focus on encouraging natural behaviours while also considering associated labour and costs, especially to be feasible in large-scale, commercial operations.

The establishment of social hierarchies often results in heightened aggression and agonistic behaviours among groups of unfamiliar pigs (i.e., newly weaned pigs) (Ledregerber et al 2015). Weaning is commonly associated with a growth check for piglets (Schmitt et al 2019). Ideally, piglets would experience a smooth transition from their sow’s milk to solid feed, from the farrowing pen to a nursery pen, and to a new social group with a minimal negative impact on their health, performance, and behaviour. It has been shown that allowing piglets to socialize with other litters pre-weaning improves a piglet’s adaptability once weaned, allowing hierarchies to be established faster when re-grouped (D’Eath et al 2004; Hessel et al 2006). What has not yet been well documented is if varying the number of litters mixed before weaning has an impact on piglet performance or behaviour after weaning. Mixing groups of 2 to 3 litters before weaning
has been previously studied and shown to be advantageous in terms of piglet behaviour (less aggression) and welfare around weaning (Hessel et al 2006; Parratt et al 2006; Salazar et al 2018; Van Kerschaver et al 2021). Further research is needed to evaluate whether mixing young pigs in groups greater than 3 litters is beneficial for the adaptability of piglets to subsequent mixing. In a study evaluating the impact of pig group size post-weaning (20 vs. 80 × 30-kg growing pigs) on aggressive behaviour, pigs that were housed in the larger groups displayed less aggression toward unfamiliar pigs when introduced in pairs to a pair of unknown pigs 6 weeks after being weaned (Turner et al 2001). Therefore, pre-weaning socialization may spread out stressors for young pigs, as well as give them an opportunity to develop transferable social skills that can continue to be used at future mixing events, such as at weaning, thereby improving piglet performance, behaviour, and welfare.

It is also common for pig production facilities to keep the animals’ environment simple (barren) to allow ease of cleaning between groups of pigs, thereby reducing biosecurity risks. Barren environments can predispose pigs to perform more agonistic behaviours such as biting of ears and tails, and belly nosing, especially when stressed. Providing piglets with access to enrichment may provide a positive outlet for stress and reduce the frequency of undesirable behaviours during weaning; burlap, specifically, has been shown to have the potential to benefit pigs raised in commercial operations (Fynn et al 2021). Although it is not until the finishing stage when the negative effects of biting behaviours among pigs become apparent in victims, biting behaviours typically develop at a young age in pigs (Hakansson & Bolhuis 2021). Therefore, providing burlap sheets as enrichment as early as possible in a pig’s life may redirect biting behaviours from their pen-mates to the burlap sheet providing a positive outlet for the development of their natural chewing behaviours, improving the welfare of both the biter and the victim. To facilitate
the transition for weaned pigs, studies have evaluated providing enrichment in the post-weaning environment (Ledregerber et al 2015) while few have evaluated its impact when provided in both pre- and post- weaning environments. Oostindier et al (2013) found that post-weaning enrichment, as compared to pre-weaning enrichment, had the strongest effect on post-weaning behaviour; piglets with enrichment post-weaning performed more exploratory behaviours and fewer agonistic behaviours such as belly nosing and biting/chewing of pen-mates (Oostindier et al 2013).

A recent study looked at both object enrichment and pre-weaning socialization as a strategy to reduce regrouping stress and aggression, but those authors combined object and social enrichment in one treatment and compared it to a completely barren environment (Ko et al 2020). Therefore, it is currently unknown whether social or object enrichment is more beneficial, as well as whether the combined effects of early mixing and environmental enrichment are additive or synergistic. Therefore, the objectives of this study were to determine if providing piglets with a burlap sheet (object enrichment) in both their pre- and post- weaning environment or allowing the mixing of litters early in life was more beneficial to piglets after the weaning transition. As well as to determine if the level of mixing provides different effects and if either burlap provision or mixing is beneficial compared to a control group with neither.

**Materials and Methods**

This chapter describes the post-weaning results of a study that was conducted during the summer of 2022 (June – August) at two commercial facilities, a conventional sow barn and a conventional nursery barn. Both barns are located in South-East Manitoba, Canada. All
experimental procedures were approved by the Animal Care Committees of the Research Ethics Board (Protocol Reference Number: F21-022, AC11708) at the University of Manitoba, Fort Garry campus. Experiment factors (social and object enrichment) did not interfere with routine pig care and management procedures, which were conducted by barn staff.

Animals, Housing, and Experimental Design

The nursery facility consists of 4 barns; each barn has 4 separate rooms, designated as blocks in our study. We focused on one barn at a time, with trial pigs housed in each of the 4 rooms per replicate. At weaning (nursery day 0), pigs were moved by livestock trailer to the off-site nursery barn (approximately 30-minute travel time). Upon arrival to the nursery, pigs were sorted by treatment and sex, into groups with an average of 22.3 ± 3.3 pigs per pen which was the current standard practice at the barn. All pigs were housed in 10 ft × 6 ft (3.05 m × 1.83 m) pens with 2 wall-mounted water nipples, slatted floors, and a 5-space-free-access dry feeder. The animals were on a wheat/ corn/ soybean meal crumble diet. The lights in the nursery rooms were on 8-hour timers.

The estimated minimum sample size of the number of experimental units needed to detect treatment differences was calculated to range between n = 2 – 14 per treatment with 80% power and an alpha of 0.05 (https://www.stat.ubc.ca/~rollin/stats/ssize/), using estimates from previous studies for our primary outcome variables, including behaviour, growth performance, and amount of lesions (Camerlink et al 2021; Salazar et al 2018; Van Kerschaver et al 2021). We ran 3 replicates, however, one was interrupted by extreme weather and had to be terminated prematurely. Therefore, there are only 2 replicates of post-weaning data available. One of the 2
weaned replicates was split into 2 groups due to the weaning dates being different between farrowing rooms.

To assess the effects of group size and object enrichment on piglet behaviour, performance, and welfare after weaning, treatments were randomly assigned and applied in the sow barn and were carried over to the nursery stage when the pigs were weaned at an average age of 22 days ± 4 days. Designed as a $3 \times 2$ factorial experiment (Table 1), litters in the sow barn were assigned to 1 of 6 treatments. Prior to weaning, piglets were painted according to treatment (six different colours) to facilitate the identification and sorting at the nursery. Due to the nature of the weaning process on the farm, it was not possible to separate the piglets by farrowing room when weaned. For a more detailed description of the experimental design and for pre-weaning results, refer to Chapter 2.

In the nursery, piglets were re-grouped into pens (our experimental units) with others from the same treatment ($n = 89$ experimental units total): 1 litter, not enriched ($1N; n = 14$), 1 litter, enriched ($1E; n = 15$), 2 litters, not enriched ($2N; n = 16$), 2 litters, enriched ($2E; n = 15$), 4 litters, not enriched ($4N; n = 15$), 4 litters, enriched ($4E; n = 14$). There were 10 – 12 pens on trial per room. The allocation of treatments was randomized within rooms using a random number generator and each treatment was present in each room (block) as this was a complete randomized block design.

The nursery portion of the trial began on nursery day 0, after the pigs were sorted into the pens where we applied our treatments. Pre-weaning mixing was previously applied in the sow barn where 2 or 4 neighbouring crates were allowed to socialize or kept as a single crate (current standard practice), based on treatment. Additional environmental enrichment was provided in the sow barn and in the nursery to the enriched treatment groups, as a burlap sheet. Two 24” wide
sheets of burlap were secured using C-clamps on the side of the nursery pen for the enriched treatment groups and was an appropriate length to just reach the ground for ease of access for the piglets. We offered two, 2-foot wide sheets of burlap in each enriched pen based on calculations to provide enough space for approximately 6 pigs (~25% of the pigs in each pen) to use it simultaneously. After one week in the nursery, at the conclusion of the study, the burlap was removed to preserve the integrity of the manure system.

**Behavioural Observations**

On nursery days 1, 6, and 8 ± 1 day, we collected two types of behavioural observations, 4 times per day: 1) scan observations aimed to capture the state behaviours of the pigs on trial (eating/drinking, resting, active, using burlap), and 2) continuous observations aimed to capture the event behaviours among weaned pigs throughout the pen, at the feeder/waterers, and at the burlap (fighting, biting, socializing, displacements, etc.) (Appendix 2). Scan behaviour observations were made by counting the number of piglets performing each of the listed behaviours: eating/drinking, resting, active, using burlap, at the start of each of the four observation times on each observation day.

Continuous behaviour observations used one-zero sampling, recording two consecutive 30-second observation periods, repeated four times per observation day (two in AM, two in PM). Four trained observers with a moderate or higher, interobserver reliability score for each behaviour performed in-person observations (Chapter 2).
Lesion Scoring

Piglet lesions were scored twice in the nursery using descriptions provided by Turpin et al (2017) which assessed the severity of scratches (red marks and scabs) on the piglets’ ears, tail, and body. Lesions were scored initially in the nursery within 24 hours post-weaning, after being sorted into their respective pens, and on nursery day 7 ± 1 day post-weaning to get a final score. Lesions were scored by one observer. The number of lesions present in each pen of pigs was counted and then the number of lesions (expressed per pig to standardize across different group sizes) was calculated for each experimental unit by taking the total number of (body lesions + tail lesions + ear lesions) / total number of piglets in that pen. The change in the number of lesions per pig was calculated by taking the difference between the number of lesions present initially and the number of lesions present on the final scoring day.

Performance

Total piglet weights were collected one week post-weaning for each nursery pen. Piglets were weighed on a walk-on portable scale (*Reliable PR350 Hanging Hog Scale*) in small groups (3 to 7 piglets) to obtain the total weight per pen. The average weight per pig was then calculated by dividing the total weight per pen by the number of piglets present in the pen. Average daily gain was not calculated because pen weights were not measured once initially regrouped in the nursery as to not further disturb piglets and potentially cause additional stress to the weaning process. Furthermore, weighing each group of piglets in the nursery after weaning is not conducive to a “typical wean” and may have influenced piglet behaviour. Our objective was to mimic typical commercial settings as much as possible. Feed intake data was not measured.
Mortality data were collected by barn staff on a per-pen basis. Only one piglet died on trial; therefore, mortality data were not included in this analysis. Furthermore, a sick pen was used for any piglets that were unfit to remain housed with other healthy individuals or if they needed medical intervention. During our trial, a total of 6 pigs were relocated to the sick pen: 4 unthrifty pigs, 1 lame pig and 1 herniated pig.

**Statistical Analyses**

All data were expressed per experimental unit and averaged over time. An ANOVA linear model was run on all data that met the normality criteria using the Shapiro-Wilks test on the residuals of the model and the Bartlett test. Significant differences were declared at $P < 0.05$ and tendencies were declared at $0.05 < P < 0.1$. If significant differences or tendencies were found, an LSD-post hoc test was used to run pair-wise comparisons between treatments. Non-normal conforming data were analyzed using the Kruskal-Wallis test. Treatment factors (number of litters mixed and enrichment) were included to assess any interaction effects.

**Results and Discussion**

**Piglet Behaviour**

Because the weaned piglets spent most of their time resting (Table 4), the scan behaviour data were summarized as a proportion of time spent eating or drinking, being active, or interacting with the burlap, relative to their time spent resting for the purposes of the statistical analysis. There were no differences observed between treatments ($P > 0.10$).
Table 4. The average proportion of piglets across treatments\(^1\) performing state behaviours during observations did not differ between treatments evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no).

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Average proportion of piglets engaged in each behaviour (per experimental unit, per observation, per day, expressed per piglet) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BURLAP</td>
<td>3 ± 0.02%</td>
</tr>
<tr>
<td>EATING</td>
<td>8 ± 0.03%</td>
</tr>
<tr>
<td>ACTIVE</td>
<td>17 ± 0.06%</td>
</tr>
<tr>
<td>RESTING</td>
<td>71 ± 0.09%</td>
</tr>
</tbody>
</table>

\(^1\)1N (n = 14 \times 1\) litter, not enriched), 1E (n = 15 \times 1\) litter, enriched), 2N (n = 16 \times 2\) litters, not enriched), 2E (n = 15 \times 2\) litters, enriched), 4N (n = 15 \times 4\) litters, not enriched), 4E (n = 14 \times 4\) litters, enriched)

There was no observed difference between treatments for displacements at the feeder or for social behaviours (\(P > 0.10\)). Our results are consistent with those presented by Salazar et al (2018) that social behaviours, positive interactions among pigs including play behaviours, were not different between socialized and non-socialized piglets within 1-week of weaning; those authors only began to see differences in social behaviours 14 days after weaning. It is possible that we did not observe changes in social behaviours during our trial as our trial ended at 7 days post-weaning.

Similar to the results of Gardner et al (2001), no difference in belly nosing was observed in our study. Although belly nosing is a behaviour that is common in newly weaned pigs, it has been previously reported to be a poor indicator of stress in piglets (Gardner et al 2001) because the causative effects behind the behaviour are still unknown. It has been suggested that belly nosing may provide comfort through social contact for piglets performing the behaviour however, it is
weaning age that has been the strongest predictor of belly nosing, not food quality or quantity or other stressors according to previously published literature (Widowski et al 2008).

We observed an interaction effect between the mixing factor and the enrichment factor on the observed frequency of fighting at the feeder ($P = 0.06$) (Figure 2). We observed fighting least often in groups of 4 litters that were mixed pre-weaning and provided enrichment indicating that there is an interaction effect benefitting piglets after weaning. However, there was also more fighting at the feeder when piglets were mixed with 4 litters pre-weaning and not provided burlap before and after weaning (Figure 2). Overall, observed fighting in pens of piglets from the single litters and groups of 2 litters mixed pre-weaning did not differ with or without enrichment or from any other treatments (Figure 2).

**Figure 2.** The interaction effect between group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no) on the observed frequency of fighting at the feeder averaged overtime and per experimental unit

![Graph showing interaction effect between group size and burlap provision](image)

1 $1N$ ($n = 14 \times 1$ litter, not enriched), $1E$ ($n = 15 \times 1$ litter, enriched), $2N$ ($n = 16 \times 2$ litters, not enriched), $2E$ ($n = 15 \times 2$ litters, enriched), $4N$ ($n = 15 \times 4$ litters, not enriched), $4E$ ($n = 14 \times 4$ litters, enriched)
Effects of Pre-weaning Mixing (Social Enrichment)

Biting behaviours were influenced by pre-weaning mixing in our study ($P = 0.03$) (Table 5); piglets that were mixed in groups of 4 litters pre-weaning were observed biting the least while piglets that were not mixed pre-weaning were observed biting the most and piglets that were mixed in groups of only 2 litters pre-weaning performed an intermediate amount of biting that did not differ from other levels of mixing.

**Table 5.** *Evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) on the average observed biting behaviour in weaned pigs differed between treatments*.1.

<table>
<thead>
<tr>
<th>Biting Frequency</th>
<th>Single litters pre-weaning</th>
<th>2 litters mixed pre-weaning</th>
<th>4 litters mixed pre-weaning</th>
<th>SEM</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>2.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.45&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.13</td>
<td>0.03</td>
</tr>
</tbody>
</table>

<sup>1</sup> 1N ($n = 14 \times 1$ litter, not enriched), 1E ($n = 15 \times 1$ litter, enriched), 2N ($n = 16 \times 2$ litters, not enriched), 2E ($n = 15 \times 2$ litters, enriched), 4N ($n = 15 \times 4$ litters, not enriched), 4E ($n = 14 \times 4$ litters, enriched)

The effect of mixing piglets pre-weaning has been previously shown to reduce observed aggressive behaviours associated with establishing a hierarchy within groups (Hessel et al 2006). In previous studies, mixing piglets before weaning reduced aggressive behaviours after weaning, presumably because piglets were more quickly establishing a new, stable social hierarchy with the social skills previously established (Hessel et al 2006; Ledergerber et al 2015; Fels et al 2021; Van Kerchaver et al 2021). Our results and those of Camerlink et al (2021) indicate that pre-weaning mixing has little effect on agonistic piglet behaviours (other than biting) post-weaning.
Although the observed frequency of burlap investigation was not impacted by the mixing factor ($P > 0.10$), the actual manipulation of burlap differed ($P = 0.02$) by treatment and was observed most frequently in the groups of piglets from single litters, while piglets from groups of 4 litters were observed manipulating the burlap the least (Table 6).

Table 6. Evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) on the average observed burlap use in weaned pigs between treatments$^1$.

<table>
<thead>
<tr>
<th></th>
<th>Single litters pre-weaning</th>
<th>2 litters mixed pre-weaning</th>
<th>4 litters mixed pre-weaning</th>
<th>SEM</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigating Burlap</td>
<td>0.60</td>
<td>0.44</td>
<td>0.70</td>
<td>0.70</td>
<td>0.65</td>
</tr>
<tr>
<td>Manipulating Burlap</td>
<td>3.10$^a$</td>
<td>2.78$^{ab}$</td>
<td>1.73$^b$</td>
<td>1.51</td>
<td>0.02</td>
</tr>
</tbody>
</table>

$^1$1N ($n = 14 \times 1$ litter, not enriched), 1E ($n = 15 \times 1$ litter, enriched), 2N ($n = 16 \times 2$ litters, not enriched), 2E ($n = 15 \times 2$ litters, enriched), 4N ($n = 15 \times 4$ litters, not enriched), 4E ($n = 14 \times 4$ litters, enriched)

We speculate that burlap use indicates the level of stress the piglets experienced as a result of weaning because providing enrichment to piglets around weaning has previously been shown to be an effective strategy to reduce stress (Ledergerber et al 2015). In the current study, burlap use was observed more in the single litter groups compared to those that were mixed in groups of 4 litters pre-weaning; this could indicate that piglets in the single litter groups were using it as an outlet for their stress associated with being mixed with unfamiliar pigs, not having previous opportunities to socialize. Piglets from the larger mixed groups may have developed social skills that they could then apply in the post-weaning environment, or they were familiar with more individuals, resulting in reduced stress due to mixing at weaning and reducing the development
of agonistic behaviours, such as chewing and biting. Others also found that mixing piglets pre-weaning provided piglets an opportunity to develop social skills pre-weaning thereby reducing the incidence of agonistic behaviours and improving welfare (D’Eath et al 2004; Morgan et al 2014; Ko et al 2020; Fels et al 2021).

**Effects of Burlap Provision (Object Enrichment)**

Our results indicate that having access to enrichment reduced the frequency of agonistic behaviours observed between piglets. Biting ($P < 0.001$) and displacements ($P = 0.003$) throughout the pen were significantly lower in the enriched groups compared to the non-enriched groups. Furthermore, piglets in the non-enriched groups tended to be observed fighting throughout the pen more frequently than enriched groups ($P = 0.06$). These results could indicate piglets were redirecting their energy and aggression toward the burlap, which is further supported by previously published studies (D’Eath et al 2004; Ledregerber et al 2015).

Additionally, non-enriched groups of piglets were observed manipulating pen objects more often than the enriched groups ($P = 0.006$). This could indicate that, if piglets are provided with a safe, soft and sanitary enrichment object that encourages their natural oral manipulation behaviours (NFACC, 2021), they will be less likely to manipulate other objects around the pen (feeders, waterers, loose flooring, etc.). Piglets can be very destructive, especially as they grow and become stronger, such that their manipulation of pen objects could wreck the pens and producers could incur repair costs. In addition, the piglets’ welfare could be at risk if they ingest materials around the pen (such as rubber flooring pieces) or if they chew on a sharp corner of the metal feeder. Since piglets will engage in oral manipulation at the cost of their pen integrity and/or
health, encouraging piglets to express their natural behaviours with a positive outlet (such as a burlap sheet) can improve their welfare by decreasing the occurrence of agonistic behaviours and resulting lesions, while satisfying their innate desire to explore their environment with their snout/mouth.

Table 7. The averaged effects of burlap provision (yes vs. no) on observed behaviour differed in weaned pigs across treatments$^1$.

<table>
<thead>
<tr>
<th></th>
<th>Not Enriched with Burlap</th>
<th>Enriched with Burlap</th>
<th>SEM</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biting</td>
<td>3.04$^a$</td>
<td>1.82$^b$</td>
<td>1.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Displacements throughout the pen</td>
<td>1.46$^a$</td>
<td>0.91$^b$</td>
<td>0.85</td>
<td>0.003</td>
</tr>
<tr>
<td>Manipulation of Pen objects</td>
<td>2.40$^a$</td>
<td>1.60$^b$</td>
<td>1.27</td>
<td>0.006</td>
</tr>
</tbody>
</table>

$^1$ $^1N$ (n = 14 × 1 litter, not enriched), $^1E$ (n = 15 × 1 litter, enriched), $^2N$ (n = 16 × 2 litters, not enriched), $^2E$ (n = 15 × 2 litters, enriched), $^4N$ (n = 15 × 4 litters, not enriched), $^4E$ (n = 14 × 4 litters, enriched)

Lesion Scoring

Initial lesion scores were lower than final lesion scores across all treatments. Because social hierarchies within groups of pigs are established approximately one week after weaning, the number of lesions would increase as the hierarchies are established through fighting and biting (Tong et al 2019). The initial number of lesions per pig (within 24-hours of weaning, transport, and sorting) was not significantly different between mixing factors while enriched pigs tended ($P = 0.07$) to have fewer lesions per pig compared to non-enriched groups. Consistent with other
studies, piglet lesions were not affected by mixing until several days after weaning (day 4 post-weaning: Kutzer et al 2009; Fels et al 2021) or two months later (day 61 post-weaning: D’Eath 2004). Our results indicate that it was burlap provision pre-weaning, and not early-life mixing that may have improved their welfare on the trailer when being transported between the sow barn and nursery.

Furthermore, reducing skin lesions in weaned pigs can also reduce the incidence and/or spread of common skin diseases like Exudative Epidermitis (greasy pig disease). Greasy pig disease is an endemic problem worldwide that is spread through contact between pigs; skin lesions increase its transmission by facilitating the entry and transfer of infectious bacteria (Park et al 2013). Although Park et al (2013) list many treatment options that are available through veterinary care, proactive and prevention measures through management practices such as mixing piglets pre-weaning and adding enrichment to their environment should be prioritized on-farm.

In contrast, the final lesion scores were influenced by both the mixing and enrichment factors. After one week in the nursery, piglets from the mixed groups of 4 litters pre-weaning tended ($P = 0.07$) to have fewer lesions than the mixed groups of 2 or single litter groups pre-weaning. Further, enriched groups tended ($P = 0.1$) to have fewer lesions per pig compared to the non-enriched groups. Therefore, both management strategies had a positive effect on the number of piglet lesions one week after weaning although there was no significant difference in the calculated difference between initial and final lesion scores during the week after weaning ($P > 0.10$). In comparison, Yang et al (2018) did not observe enrichment effects on pig lesions; however, lesions were only scored 1 and 2 days after weaning in that study, whereas we scored lesions 1 and 7 days after weaning. Because establishing a hierarchy can take several days after mixing pigs (Tong et al 2019), our lesion scoring schedule should have better captured any
lesions resulting from aggression/ fights establishing a hierarchy. Furthermore, our piglets had access to enrichment before and after weaning while the enrichment was only available until weaning in the previous study (Yang et al 2018). This emphasizes the importance of having enrichment in the nursery to redirect agonistic behaviours from pen-mates to the enrichment device and is further supported by Oostindier et al (2013). It would be worth evaluating which timing of enrichment is most beneficial to piglets around weaning in a future study. In our study, piglets had access to burlap in the sow barn and the nursery to create familiarity between the two environments. Other studies either only provide the enrichment in the pre-weaning environment (Yang et al 2018; Schmitt et al 2020; Ko et al 2020) or the post-weaning environment (Ledregerber et al 2015).

Performance

It is common for piglets to experience a growth check after weaning (Campbell et al 2013). We measured the average piglet weights per pen 1-week post-weaning to evaluate the treatment effects on piglet performance. Our results indicate no significant difference between treatments on piglet weights 1 week after weaning ($P > 0.10$), which is similar to previously published literature evaluating the effects of pre-weaning mixing on post-weaning performance (Morgan et al 2014; Ledregerber et al 2015; Salazar et al 2018; Camerlink et al 2021; Van Kerschaver et al 2021). However, there was a numerical difference ($P = 0.14$) between enrichment factors: enriched pigs weighed numerically more than non-enriched pigs (7.19 kg vs. 6.85 kg per pig) one week after weaning. Ledregerber et al (2015) reported no effects of object enrichment in the nursery on average daily gain and there was no effect of the enrichment factor on pen weights in the current study ($P > 0.10$). If our results had shown that providing burlap increased piglet
weights post-weaning, that would further support that burlap may increase the muscle tone needed to properly digest their solid feed which may ultimately increase feed intake (Blavi et al 2021). Nonetheless, burlap provides piglets with an outlet for their natural chewing behaviours and pre-weaning mixing does not have negative impacts on piglet weights 1-week post-weaning indicating that it may be a beneficial practice to implement at a commercial level.

**Conclusion**

Our treatment factors allowed adjacent litters to socialize pre-weaning (as groups of 2 or 4 litters) and/or interact with burlap as object enrichment pre- and post-weaning. Overall, neither treatment affected piglet weights, initial piglet lesions, or state behaviours (resting, eating/drinking, being active, using burlap) after weaning. However, the lesion scores measured post-weaning indicated that when piglets had access to burlap, they tended to have fewer lesions initially (24 hours after weaning) and 1-week post-weaning. Piglets mixed in larger groups (4-litters mixed) pre-weaning also had fewer lesions one-week post-weaning. Burlap use was observed the most in the pens of piglets that were mixed in groups of 4 litters, while in these same pens, there was less biting observed between piglets. There was less observed biting, displacements throughout the pen, and pen object manipulation in enriched pens of piglets compared to the non-enriched pens of piglets. Furthermore, enriched piglets tended to be observed fighting less than non-enriched piglets. Although our treatments had a neutral effect on piglet performance (i.e., body weights), the frequency of agonistic behaviour (i.e., biting) was improved when piglets were provided with burlap and when they were mixed in groups of 4 litters pre-weaning which may, ultimately, improve piglet welfare around weaning.
CHAPTER 4: GENERAL DISCUSSION & SUMMARY

Major Findings

Use of Burlap as Object Enrichment

Providing piglets with burlap in their pre- and post-weaning environment impacted the frequency of agonistic behaviours observed after weaning, including biting, displacing, and manipulating pen objects, while also reducing fighting and piglet lesion presence. The benefits of providing burlap were more noticeable in the nursery than in the sow barn, which is expected as weaning is a major stressor for pigs. Having access to burlap in their environment before and after weaning may have provided the piglets with a positive coping mechanism for managing the stress they were experiencing from weaning. It is also possible that piglets were still stressed from the weaning event but, when provided with burlap, they had a positive outlet which redirected their negative behaviours (such as biting) to the burlap instead of their pen mates, resulting in fewer lesions and improved welfare for weaned piglets (Chapter 3). Due to high levels of biosecurity, finding suitable enrichment objects for use in commercial farrowing and growing operations can be a challenge. With large numbers of animals cycling through barns, it is imperative that the objects not become a fomite for disease transmission between groups of animals. Additionally, many commercial swine operations use a liquid manure system with slatted crate floors. Therefore, using a substrate as enrichment, such as straw, could damage the manure pumps and
cause the system to fail. Alternative forms of enrichment would pose less of a threat to their manure systems, such as placing or hanging toys in the pen, but those are typically more expensive. In addition to considering producer preference for enrichment type and the suitability of the facility design, the piglets’ preference for different types of enrichments should also be considered. Because burlap also meets the National Farm Animal Care Council of Canada’s (NFACC, 2021) recommendations for enrichment to provide to piglets, burlap is an ideal enrichment type that aligns with producers’ and piglets’ preferences alike. Having access to burlap reduced the observed biting/chewing of pen mates, displacements, and fighting between piglets (Chapter 3), while also reducing the observed occurrence of pen object manipulation displayed by piglets (Chapter 3). When piglets chew on pen objects, it can result in costly damage to the pen that will require repairs or replacements to maintain the integrity of the facilities.

Burlap manipulation was observed most frequently post-weaning in groups of piglets who were not mixed beforehand which may indicate they are responding to stress by manipulating the burlap (instead of what may have been seen as biting other piglets' ears/tails); however, single litter groups were also observed biting their pen mates’ ear/tails most frequently (compared to groups of piglets that were mixed pre-weaning). Additionally, piglets who were not socialized prior to weaning may also have fewer opportunities to engage in rewarding behaviours (such as socialization) because they may not have the skills to socialize positively with unfamiliar pigs. This is consistent with the biting results presented above highlighting that the enriched piglets were observed biting other piglets almost 50% less than the non-enriched groups. This could indicate that while the piglets' drive for oral manipulation remains, it can be redirected from pen
mates and prevent any lesion-causing behaviours to the burlap, especially after weaning, indicating it can be a feasible option for producers to improve piglet welfare around weaning.

**Use of Pre-weaning Mixing as Social Enrichment**

Allowing piglets to socialize with neighbouring litters before weaning impacted their behaviour before and after weaning. Piglets in mixed litter groups exhibited cross-sucking on occasion (during approximately 10% of observations), with the larger group size of 4 litters tending to be observed exhibiting the behaviour more often than the groups of 2 litters (Chapter 2). Consequently, sow lesions were affected pre-weaning and piglet lesions were affected post-weaning. Sows in the single litter groups had a greater change and therefore deterioration in their lesion scores (Chapter 2) compared to sows in the mixed litter groups. This may indicate improved sow welfare when piglets are mixed with other litters in the pre-weaning environment. Although there was a higher incidence of infected teats among mixed litter sows (Chapter 2), how this affects the sow’s performance over time is beyond the scope of this thesis. Piglet lesions were not different between different mixing treatment groups pre-weaning (Chapter 2). However, one week after weaning, piglets from the groups of 4 litters mixed pre-weaning tended to have fewer lesions than the piglets from the groups of 2 and 1 litters (Chapter 3). This could indicate that piglets mixed before weaning did not engage in the typical re-establishment of a social hierarchy commonly established after piglets are mixed after weaning. This may be due to being more focused on teat-seeking behaviour when they were first mixed in the farrowing barn or because it was a single change in their otherwise familiar environment, as opposed to being mixed at weaning which is accompanied by several additional stressors.
Overall Treatment Effects

Based on my results, to see any significant reductions in biting among weaned pigs, it is recommended to mix groups of 4 litters pre-weaning. Although there was a slight reduction in observed biting behaviours after weaning when only 2 litters were mixed pre-weaning, the groups of pigs mixed in larger groups pre-weaning saw significant reductions in piglet biting after being weaned. Mixing in larger groups (4 litters mixed) pre-weaning also tended to improve piglet lesions 1-week post-weaning, but having access to burlap had an even greater impact on reducing the number of lesions per pig after weaning. Displacement behaviours between pigs throughout the pen were reduced pre- and post-weaning and at the teat pre-weaning by providing piglets access to burlap (Chapter 2 and Chapter 3). Therefore, mixing piglets pre-weaning resulted in less biting among pigs, while providing piglets with burlap helped to reduce both displacement behaviours and the development of lesions.

Except for fighting behaviour at the feeder (Chapter 3), the combined effect of pre-weaning socialization and burlap provision was not observed to be additive or synergistic. My results indicate that either enrichment type could be a low-cost option that can be implemented across the industry to improve piglet welfare, behaviour, and performance, thereby improving the production efficiency of commercial swine operations. Depending on the concerns of each operation and the logistical capacity, one may choose to implement one or both enrichment options.
Limitations and Future Research

Enrichment (social and object) has long been a recommended practice in the swine industry to improve animal welfare. However, many previously published pre-weaning mixing studies were conducted at a research facility rather than at the commercial level. For this reason, testing management strategies that are feasible and beneficial in a commercial setting was of utmost importance for my study. Completing my study in a commercial setting provides insight into the options producers could use to implement social and object enrichment on-farm to potentially improve piglet performance, behaviour, and welfare around weaning. However, I had to design my experiment within the constraints of real-world commercial swine operations. This meant that I did not keep the socialized piglets in static groups when transporting them to the nursery after weaning. They were mixed on the trailer with other trial pigs as well as pigs that were not on trial. Once at the nursery, we sorted them by sex and treatment. Consequently, based on observations during sorting, piglets acquired many lesions between being weaned at the sow barn and arriving/being sorted in the nursery. Although we could not identify individual piglets once they left the sow barn, overall final lesion scores in the sow barn were distinctively less severe than the initial scores observed in the nursery across all treatments. It would therefore be beneficial to evaluate the transport conditions for piglets at weaning if they are moved by livestock trailer to another facility. Our results show piglets that had access to enrichment tended to have fewer lesions initially after weaning than those that did not, but because they were all mixed on the trailer during transport, we have no way to confirm that those enriched piglets were not the ones that were causing the lesions of the non-enriched piglets since they would have more developed mastication muscles (from burlap use pre-weaning). When piglets are mixed in the nursery, it would be interesting to know if they seek out familiar piglets because they are
more likely to be in groups with familiar pigs if they were mixed pre-weaning. This would indicate that pre-weaning mixing is beneficial beyond an opportunity to develop social skills because it would also increase the chance piglet would recognize piglets when re-mixed throughout their life (Ko et al. 2020).

Future work could also evaluate the effectiveness of different burlap presentations and the timing of application to the piglets’ pre-weaning environment. We applied both our mixing and object enrichment treatments at the same time, which could have impacted the amount of burlap use. Furthermore, we introduced the burlap when the piglets were only a few days old. At this young age, piglets’ priority behaviours would be teat-seeking/food-oriented and sow bonding-focused; only as they age would their exploratory behaviours begin to develop. For this reason, it may be more beneficial for the piglets if the burlap was introduced later (after adjacent pens were mixed) and this may also create some novelty and interest in the burlap. This may also reduce the issue of soiled burlap. Since our burlap was hung over the rear pen wall panel, it became soiled by the sow’s manure in some cases which could have contributed to the minimal interest in the burlap by the piglets. In a recent study (Schmitt et al. 2020), objects that were suspended away from the wall were more attractive to piglets than those against the wall, which could have also influenced our results. However, due to the facility design at this barn, hanging it from a pen wall panel was the most feasible option. Although hanging the burlap from the front pen panel may have provided the sow access and encouraged piglet use by social facilitation, sows are much stronger than piglets and may have destroyed the burlap resulting in pieces entering the manure system which we avoided by only providing access to piglets. Additionally, performing in-person behaviour observations may have resulted in less burlap manipulation being observed because the burlap was attached to the pen panel that was closest to the walkway where observers had to
stand, and this may have impacted the frequency of observed burlap manipulation. To reduce observer effects, we watched the next pen in the row beside the pen at which we stood, before approaching them up close, to interfere as little as possible with the piglet’s usual behaviours and we waited until the piglets resumed their normal activities, after initially staring at us, before beginning observations. Cameras may have improved the displays of piglet behaviour during the observation period, however, we faced challenges that limited the feasibility of video recordings for our study; namely, there was no wireless internet in the barn to connect the cameras, to eliminate blind spots multiple cameras per pen would have been needed, and each replicate was housed in different rooms with little down time between for switching the cameras over without interfering with farrowing sows.

**Recommendations for Commercial Swine Operations**

Both of our treatment factors had a positive effect on piglet behaviour and welfare around weaning. Mixing pigs in larger groups pre-weaning (groups of 4 litters) can reduce biting among pigs after weaning and may improve piglet lesions 1-week post-weaning (Chapter 3). However, having access to burlap reduced the number of lesions per pig after weaning more than mixing piglets. Displacement behaviours between pigs pre- and post-weaning were also reduced by providing piglets access to burlap (Chapter 2 and Chapter 3). To address specific concerns on individual farms, our summary table (Appendix 3) may be used to make informed decisions about which form of enrichment would be most beneficial in addressing potential behavioural problems among piglets on farm.


APPENDIX

Appendix

1. Ethogram of pre-weaned piglet behaviour for use in the sow barn ........................................ 66
2. Ethogram of piglet behaviour after weaning for use in the nursery ........................................ 68
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   (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no)
   on response variable .................................................................................................................. 70
### Appendix 1. Ethogram of pre-weaned piglet behaviour for use in the sow barn

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Description</th>
<th>Sampling Type</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggressive/Agonistic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fighting</td>
<td>Physical encounter between at least two pigs including head-to-head fights, biting another pig, as well as pushing or knocking another pig with the head causing one pig to retreat/withdraw or both pigs engaging in aggression. May or may not include vocalizations.</td>
<td>Event: Continuous sampling</td>
<td>Ledergerber et al (2015)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ji et al (2021)</td>
</tr>
<tr>
<td>Tail/Ear Biting</td>
<td>Pigs engaged in oral manipulation of pen mate’s tail or ear, may or may not result in wounds.</td>
<td>Event: Continuous sampling</td>
<td>Hakansson &amp; Bolhuis (2021)</td>
</tr>
<tr>
<td>Belly-nosing</td>
<td>Piglet engaged in rhythmic nudging of another piglet’s abdomen (belly) with their nose; at least 3 nudges in a row.</td>
<td>Event: Continuous sampling</td>
<td>Widowski et al (2007)</td>
</tr>
<tr>
<td>Displacement</td>
<td>Physical contact between pigs resulting in one pig losing control over teat/object or needing to move or being pushed out of the way.</td>
<td>Event: Continuous sampling</td>
<td></td>
</tr>
<tr>
<td><strong>Investigative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socializing</td>
<td>Pigs engaged in actions that did not cause the recipient to react negatively. Ex: nudging/sniffing: snout of piglet is used to gently touch another piglet’s or sow’s body, not including any behaviour directed at the sow’s udder or piglet’s abdomen.</td>
<td>Event: Continuous sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Pen objects</td>
<td>Nosing, licking, or chewing any object which is part of the pen (e.g. feeder or bar of sow crate), but excluding the enrichment object. Excluding any behaviour toward creep feed.</td>
<td>Event: Continuous sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Burlap</td>
<td>Manipulating (M) or investigating (I) the enrichment objects (burlap that was deliberately put into the pen by the researcher) with mouth or snout, resulting in visible movement of the target (M) or sniffing or staring at enrichment within 1 foot of burlap (I).</td>
<td>Event: Continuous sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Cross-sucking</td>
<td>Piglet from another litter massages or sucks at another sow’s udder</td>
<td>State: Scan sampling</td>
<td></td>
</tr>
<tr>
<td><strong>Suckling</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piglets or sucks at the [sow’s] udder</td>
<td></td>
<td>State: Scan sampling</td>
<td>Ledergerber et al (2015)</td>
</tr>
<tr>
<td><strong>Eating (Creep feed)</strong></td>
<td>Piglets were deemed as eating creep feed if they were interacting with feed.</td>
<td>State: Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td><strong>Active</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td>Climbing</td>
<td>Piglet uses its feet to elevate itself onto the body of the sow or another piglet. A minimum of two feet must be off the floor and on the sow/ piglet.</td>
<td>State: Scan sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>State</td>
<td>Description</td>
<td>State:</td>
<td>Reference</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Standing</td>
<td>All four legs supporting the body with no ambulation or touching anything with their nose or mouth</td>
<td>Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td>Lying</td>
<td>Whole length of body on the floor or on other pigs, i.e. not supported by their legs. Piglet’s body has contact with the ground</td>
<td>Scan sampling</td>
<td>Morgan et al (2014) Ledergerber et al (2015)</td>
</tr>
<tr>
<td>Sitting</td>
<td>Hind quarters on the floor, front legs supporting body</td>
<td>Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td>Other</td>
<td>Piglet performing behaviour out of the ethogram.</td>
<td></td>
<td>Yang et al (2018)</td>
</tr>
</tbody>
</table>
### Appendix 2. Ethogram of piglet behaviour after weaning for use in the nursery

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Description</th>
<th>Sampling Type</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggressive/Agonistic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fighting</td>
<td>Physical encounter between at least two pigs including head-to-head fights, biting another pig, as well as pushing or knocking another pig with the head causing one pig to retreat/withdraw or both pigs engaging in aggression. May or may not include vocalizations.</td>
<td>Event: Continuous sampling</td>
<td>Ledergerber (2015) Ji (2021)</td>
</tr>
<tr>
<td>Tail/ear biting</td>
<td>Pigs engaged in oral manipulation of pen mate’s tail or ear, may or may not result in wounds.</td>
<td>Event: Continuous sampling</td>
<td>Hakansson &amp; Bolhuis (2021)</td>
</tr>
<tr>
<td>Belly-nosing</td>
<td>Piglet engaged in rhythmic nudging of another piglet’s abdomen (belly) with their nose; at least 3 nudges in a row.</td>
<td>Event: Continuous sampling</td>
<td>Widowski et al (2007)</td>
</tr>
<tr>
<td>Displacement</td>
<td>Physical contact between pigs resulting in one pig losing control over teat/object or needing to move or being pushed out of the way.</td>
<td>Event: Continuous sampling</td>
<td></td>
</tr>
<tr>
<td><strong>Investigative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socializing</td>
<td>Pigs engaged in actions that did not cause the recipient to react negatively. Ex: nudging: snout of piglet is used to gently touch another piglet’s or sow’s body, not belly-nosing.</td>
<td>Event: Continuous sampling</td>
<td>Morgan et al (2014) Yang et al (2018)</td>
</tr>
<tr>
<td>Pen facilities</td>
<td>Nosing, licking, or chewing any object which is part of the pen (e.g. feeder or bar of sow crate), but excluding the enrichment object. Excluding any behaviour toward feeder or waterer.</td>
<td>Event: Continuous sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Manipulating burlap</td>
<td>Manipulating (M) or investigating (I) the enrichment objects (burlap that was deliberately put into the pen by the researcher) with mouth or snout, resulting in visible movement of the target (M) or sniffing or staring at enrichment within 1 foot of burlap (I).</td>
<td>Event: Continuous sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Eating/drinking</td>
<td>Interacting with feed or waterers; Piglet is standing at the trough with head down; the head can either be in the trough or in front of the trough when pigs eat feed.</td>
<td>State: Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td><strong>Active</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climbing</td>
<td>Piglet uses its feet to elevate itself onto the body of another piglet or the feeder or pen divider. A minimum of two feet must be off the floor and on the piglet/other surface.</td>
<td>State: Scan sampling</td>
<td>Yang et al (2018)</td>
</tr>
<tr>
<td>Standing</td>
<td>All four legs supporting the body with no ambulation or touching anything with their nose or mouth</td>
<td>State: Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td><strong>Resting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lying</td>
<td>Whole length of body on the floor or on other pigs, i.e. not supported by their legs.</td>
<td>State: Scan sampling</td>
<td>Morgan et al (2014)</td>
</tr>
<tr>
<td>State</td>
<td>Description</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>Hind quarters on the floor, front legs supporting body</td>
<td>Ledergerber et al (2015)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Piglet performing behaviour out of the ethogram.</td>
<td>Morgan et al (2014)</td>
<td></td>
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<tr>
<td>Other</td>
<td>Piglet body has contact with the ground</td>
<td>Yang et al (2018)</td>
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Appendix 3. Effect of treatments (3 × 2 factorial design) evaluating the effects of group size (1 vs. 2 vs. 4 litters mixed pre-weaning) and burlap provision (yes vs. no) on response variable

<table>
<thead>
<tr>
<th></th>
<th>Burlap added</th>
<th>Mixing 2 litters</th>
<th>Mixing 4 litters</th>
<th>Significance</th>
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<tr>
<td></td>
<td>Pre-wean</td>
<td>Post-wean</td>
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<td>Post-wean</td>
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<tr>
<td>Cross Sucking</td>
<td>-</td>
<td>-</td>
<td>↑</td>
<td>N/A</td>
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<tr>
<td>Burlap Use</td>
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<td>N/A</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Biting among piglets</td>
<td>↓</td>
<td>↓</td>
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<tr>
<td>Displacements</td>
<td>↓</td>
<td>↓</td>
<td>-</td>
<td>-</td>
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<tr>
<td>throughout the pen</td>
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<td></td>
<td></td>
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<tr>
<td>Displacements at the</td>
<td>↑</td>
<td>N/A</td>
<td>-</td>
<td>N/A</td>
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<td>teat</td>
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<tr>
<td>Fighting throughout</td>
<td>-</td>
<td>↓</td>
<td>-</td>
<td>-</td>
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<td>the pen</td>
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<tr>
<td>Fighting at the feeder</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Manipulation of pen</td>
<td>↓</td>
<td>↓</td>
<td>-</td>
<td>-</td>
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<tr>
<td>objects</td>
<td></td>
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</tr>
<tr>
<td>Lesions per pig</td>
<td>-</td>
<td>↓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sow lesions</td>
<td>-</td>
<td>N/A</td>
<td>↓</td>
<td>N/A</td>
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<td>Piglet weights</td>
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<td>-</td>
<td>-</td>
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<td>(weaning &amp; 1-week post)</td>
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<td>weaned per sow</td>
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<td>Pre-wean mortality</td>
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</table>

1↑ Increased; ↓ Decreased; - No change; X Interaction; Significance: * 1.0 > P > 0.05; *** P < 0.05