EASING THE WEANING TRANSITION: PELLET FORM AND SIZE TO REDUCE THE POST-WEANING GROWTH CHECK

7C-006

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By

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Executive Summary

A period of anorexia is often associated with the weaning process when piglets transition to solid feed. This period of low, or no, feed intake impacts the structure, function and health of the gastrointestinal tract resulting in a potential setback in piglet growth, leading to more variation in lifetime performance. Creep feeding is a strategy that is sometimes applied, and occasionally properly, to help ease this transition. However, the impacts of creep feeding on performance after weaning are equivocal.

The provision of creep feed is often seen as a way of providing nutrients when growth of piglets may be compromised by a reduced access to milk and thus a lower energy intake. However, the consumption of creep feed is not purely related to nutrient availability, with the intrinsic exploratory behaviour of the young piglet also driving consumption.

Large pellets are more easily manipulated by the pig, mimicking some of the feedstuffs that wild piglets have been seen to explore in their early stages of development. They also allow the piglet to express 'object play', an important early developmental stage that most young mammals, including humans, go through in the transition to solid feed. Numerous studies have shown the benefits of offering large pellets in the weaning transition to improve post-weaning feed intake.

This study looked at combining this technology with previously developed semi-moist feeds that have been previously shown to promote post-weaning feed intake, with the hypothesis that a large semi-moist pellet will promote heavier body weight at day 28 following weaning.

A previous study (APRIL 6A-103, Easing the transition: large piglets from large pellets.) with the same design showed that piglets expressed greater levels of 'object play' when they were given access to large pellets, but the weaning age was too short (~20 days) to allow the full impacts of creep feeding to be seen. This study looked at piglets with an extended, yet still commercially viable, lactation length - ~26 days.

Piglets were offered four treatments from day 8 of age, using a 2x2 factorial design, investigating small (< 5 mm) or large (12 mm) diameter pellets, and a standard (~10% moisture) or semi-moist (~20% moisture) formulation. Growth and feed intake were monitored and interactions with feed were recorded to observe behaviour during and immediately after weaning.

Unlike the previous study where the shorter lactation length restricted the ability of creep feeding to influence post-weaning performance, this project was able to show that using a large pellet in a managed creep feeding program was able to positively influence post-weaning growth rate. Within this study a significantly greater percentage of litters were observed playing with large pellets compared to small pellets, which supports the increased 'object play' that was observed in a previous study.

This project supports previous findings that large pellets are a readily adoptable technology that can help ease the weaning transition and enrich the lives of pigs coping with the various stressors associated with weaning.

APSA 2023. The impact of pellet size and moisture level of creep feed on post-weaning performance of pigs

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Introduction The transition from milk to solid feed at weaning is often coupled with a drop in feed intake and a decrease in productive performance in pigs. Provision of creep feed during the late lactation period can promote post-weaning feed intake and growth (Bruininx *et al.*, 2002), and high moisture feeds can increase feed intake and support gut development (Chen *et al.*, 2021). However, the intake of creep feed is driven by both energy availability and 'object play' (Blackshaw *et al.*, 1997), which is an important developmental step leading to intake and consumption of solid food. A recent study (Hewitt *et al.*, 2023) showed large pellets of either low or high moisture content resulted in a greater number of pigs playing with feed, however, pigs were weaned at 19.8 days of age, before creep feed was being consistently consumed. This study furthered this work with an older wean age. We hypothesised that the combination of large pellets and high moisture feeds would improve post-weaning performance in pigs with a greater weaning age.

Material and methods One hundred and twelve litters from multiparous sows (2.9 ± 0.1) entered the experiment over three consecutive farrowing days. At 3 d of age, piglets were individually tagged and litters were allocated to one of four treatments. Treatments consisted of creep feeds of differing composition and size, in a 2×2 factorial design. Feed was offered as either a standard pellet (~10% moisture) or a softer semi-moist pellet (~20% moisture), presented as either a small (4 mm extrusion die) or large (12 mm die) pellet. At d 8 of age treatments commenced, starting with 250 g of feed placed on the creep mat twice a day, transitioning to *ad libitum* feeding from d 14. Creep feeds were then provided in bowls, with feed disappearance measured daily until weaning (26.4 ± 0.04 d). At weaning, piglets were placed into nursery pens (44 per pen) in their treatment groups and received respective diets *ad libitum* alongside a standard creep diet, for the first 8 d post-weaning. Pigs were weighed at d 8 and 21 of lactation, weaning and d 9 post-weaning. Feed delivery was recorded twice daily. Data were analysed using a linear mixed model in SPSS Statistics, v26.0 (IBM, Armonk, NY, USA), with size, type and the interaction as fixed effects, and crate for pre-weaning measures and pen for post-weaning measures as random factors. Percentage of pigs that entered but failed to exit the nursery was analysed using negative binomial regression with the same model.

Results There was no difference in growth rate, and thus weight, between treatments at d 21 of lactation (Table 1). From d 21 of lactation until weaning, piglets receiving the standard moisture pellets grew faster ($P < 0.001$) than those pigs consuming the semi- moist pellets. In the post-weaning period, there was an interaction between treatments with pigs fed large standard pellets having the highest growth rate and feed delivered with the small semi-moist treatment pigs having the slowest growth rate and feed delivered ($P = 0.002$ and $P = 0.008$, respectively; Table 1). Pigs fed large pellets grew faster than pigs fed small pellets, and pigs fed standard diets grew faster than pigs fed semi-moist diets in the first 9 d after weaning ($P < 0.001$).

Table 1. Performance of pigs offered a standard (10% moisture) or semi-moist (20% moisture) creep diet from day 8 of lactation (Lac) until day 9 post-weaning (Post) extruded as small (4 mm die) or large (12 mm die) diameter pellets.

	Small Standard	Large Standard	Small Semi-moist	Large Semi-moist	*P* value Size	*P* value Diet type	*P* value Interaction
D 8 Lac weight, kg	2.4 ± 0.03[a]	2.1 ± 0.03[c]	2.3 ± 0.03[b]	2.3 ± 0.03[b]	0.27	0.14	< 0.001
D 21 Lac weight, kg	5.1 ± 0.07	4.9 ± 0.07	5.0 ± 0.07	5.0 ± 0.07	0.43	0.87	0.087
Wean (W) weight, kg	7.4 ± 0.09[a]	7.0 ± 0.10[b]	6.7 ± 0.09[c]	6.9 ± 0.09[bc]	0.37	0.001	0.006
ADG d 8-21, kg/d	0.207 ± 0.004	0.207 ± 0.004	0.205 ± 0.004	0.203 ± 0.004	0.72	0.39	0.73
ADG d 21-W, kg/d	0.386 ± 0.006[a]	0.369 ± 0.007[b]	0.334 ± 0.006[d]	0.353 ± 0.006[c]	0.89	< 0.001	0.005
D 9 Post weight, kg	8.3 ± 0.10	8.4 ± 0.11	7.5 ± 0.10	7.7 ± 0.10	0.16	< 0.001	0.81
ADG W-d9, kg/d	0.110 ± 0.006[b]	0.160 ± 0.006[a]	0.082 ± 0.006[d]	0.095 ± 0.006[c]	< 0.001	< 0.001	0.002
W-d 9 pen feed, kg	48.0 ± 3.87[b]	85.5 ± 4.30[a]	44.6 ± 3.86[d]	57.5 ± 3.87[c]	< 0.001	0.001	0.008
Failed nursery*, %	4.7 (1.9-11.0)	4.3 (1.6-11.2)	8.4 (3.9-17.2)	5.6 (2.4-12.3)	0.56	0.33	0.71

[a,b,c, d]Means within a row with different superscripts differ significantly ($P < 0.05$); ADG, average daily gain; 95% confidence interval in parentheses; *pigs that entered but failed to exit nursery.

Conclusion and implications The lack of main effect performance difference up until day 21 of lactation is reflective of previous studies (Hewitt *et al.*, 2023), with Middelkoop *et al.* (2019) showing 75% of feed intake occurs after day 19 of lactation. The hypothesis of this study was partly supported with large pellet diameter supporting higher piglet average daily gain in the immediate post-weaning period, however, the standard pellet formulation resulted in higher average daily gain than high moisture pellets, likely a result of increased diet density and therefore nutrient availability as shown by the interaction in the post-weaning ADG. This study gives further support to the use of larger diameter pellets before and after weaning to help ease the weaning transition.

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1. Introduction

The weaning process is often associated with a period of anorexia as the piglet transitions from a liquid diet to solid feed (Bruininx et al., 2002). This low feed (energy) intake impacts the structure, function and health of the gastrointestinal tract (Heo et al., 2013) and leads to gut microbiota dysbiosis (Greese et al., 2017), and has the potential to significantly set back the growth of piglets, increasing variation in lifetime performance.

The impact of creep feeding, where specially formulated feed is offered to piglets during lactation, on post-weaning performance is equivocal (van Barneveld and Hewitt, 2016). It has been suggested that energy availability from milk affects the creep feed intake of the individual (Algers et al., 1990), i.e., the 'compensatory feeding hypothesis' suggests slower growing piglets within a litter compensate for lower energy intake in milk by consuming more creep feed and show a less severe nutritional challenge at weaning (Middlekoop et al., 2019). This is supported by anecdotal evidence of the 'better' piglets taking longer to eat after weaning and evidence that intermittently suckled litters had higher post-weaning performance than conventional litters (Kuller et al., 2004).

However, creep feed intake is not purely a result of lack of nutrient availability as a large percentage of piglets do not consume any feed prior to weaning, despite a sow's milk production reducing over time (Sulabo et al., 2010). Creep feeding also appears to be driven by the intrinsic exploratory behaviour of the piglet, eg nosing, rooting and chewing, as well as play behaviour. 'Object play' in piglets includes the holding or carrying of an object in the mouth as well as its manipulation (Newberry et al., 1988). The developmental pattern of exploratory and play behaviour is further evidence of their involvement in the advance of feed intake behaviour in suckling piglets, beginning in the first week of life and peaking around four weeks of age (Blackshaw et al., 1997).

Traditional thought is that pellet size should match the size of the animal eating it. It is common for a feeding program to utilise a 5 mm diameter pellet and present it in different forms, as a crumble in sucker and nursery pigs, as a short-cut pellet in weaners and as a full pellet in growers and finishers, with the thought that smaller feed diameters would promote intake; however, studies show little impact of pellet diameter on performance (Edge et al., 2005).

Large pellet sizes, mimicking food in nature and the sow's teat size, and allowing the piglet to express 'object play', have been investigated in various studies (eg van den Brand et al., 2014; Clark et al., 2016: Craig et al., 2021). Choice feeding studies (van den Brand et al., 2014) showed a threefold preference of a 12 vs a 2 mm diameter pellet from day 4 to 18 of lactation, whilst time spent and interest in feeding increased more over time in piglets offered a 10 mm diameter pellet when compared to a 2 mm diameter pellet. A third study reported within van den Brand et al. (2014) showed an increase in intake of a 12 mm diameter pellet from day 4 to 11 of lactation. This increase in intake wasn't conserved when fed after weaning, but those piglets fed the large diameter pellet during lactation showed a 30% increase in body weight gain during the first ten days after weaning.

Clark et al. (2016) saw similar impacts, with increases in average daily creep feed intake from day 17 to 21 and a significant improvement in average daily gain being observed in the first week after weaning when fed larger (0.5-inch diameter) pellets. A significant reduction in pre-weaning mortality was also observed. Craig et al. (2021) showed a larger pellet diameter offered to piglets in lactation decreased post-weaning removal rate and improved performance.

There are other alternative nutritional approaches that have been tried to improve the performance of pigs around the weaning period. Shelf-stable semi-moist creep feeds have been developed (van Barneveld et al., 2009), containing 20% moisture, to offer some of the advantages of liquid creep feeds. The use of semi-moist creep feeds has shown significant promise in reducing the post-weaning growth check, with piglets being significantly heavier at the end of the first week following weaning and a trend for reduced post-weaning mortality (van Barneveld and Hewitt, 2011; van Barneveld et al., 2011). We believe a semi-moist feed formulation can enhance the performance benefits of offering large pellets.

A previous APRIL investigation into the combination of large pellets and semi-most creep feeds (APRIL 6A-103) found that piglet performance did not differ between treatments during lactation, and exit weights at the end of the 28-day post-weaning period were also not different. However, piglets did show different behavioural responses to the treatments. Piglets played with the large pellets to a significantly greater degree than the small pellets, irrespective of whether the feed was in the standard or semi-moist form. This greater feed play behaviour translated to more interaction with other piglets, whilst the softer nature of the semi-moist pellet resulted in more eating observed in the large semi-moist pellet group.

The lack of difference in piglet performance in this study is likely due to the shorter lactation in this study (~20 days) compared to previous studies (25-28 days), with the consumption of creep feed generally occurring in the latter stages of these extended lactation lengths. Our behavioural observations did show that exploratory behaviour, and in particular, object play, was beginning to develop in these piglets, especially in the large pellet treatments. Object play involves the physical manipulation of a moveable item with the pig's environment where the item can be securely held in the pig's mouth allowing it to be carried around. The larger diameter of the pellets was evidently easier to hold and manipulate.

Despite the shorter lactation length in study 6A-103, behavioural observations indicated that piglets had a greater level of interaction with the larger pellets and showed clear indicators of object play, with the nutritional value of this edible substrate having functional significance to the animal, enriching the lives of the piglet.

This project (7C-006) seeks to confirm the findings of the previous study (6A-103) in a commercial setting with an older weaning age (~26 days), testing our primary hypothesis that piglets that receive semi-moist large pellets will have an increased body weight at day 28 following weaning, and secondly, that piglets receiving the semi-moist large pellet will have an improved growth performance in the first week after weaning.

2. Methodology

This experiment was approved by the PIRSA Animal Ethics Committee #11/21 and conducted in accordance with the *Australian code for the care and use of animals for scientific purposes*, 8th Edition.

One hundred and twelve (112) litters from multiparous sows (2.9 ± 0.1 parity) entered the experiment over three consecutive farrowing days. At day 3 of lactation, piglets were 'processed' as per normal commercial practice, individually tagged, and litters were allocated to one of four creep feeding treatments.

Treatments consisted of creep pellets that differed in presentation and in size, utilizing a 2x2 factorial design. Feed was offered either in the form of a standard pellet (~10% moisture) or as a softer, more palatable semi-moist extruded creep (SMEC) pellet (~20% moisture). These were then offered as either a small pellet, processed through a 4 mm die, or a large pellet, processed through a 12 mm die (Figure 1), resulting in four treatments:

a. Large diameter (12 mm) standard creep pellet 10-20 mm in length,
b. Small diameter (4 mm) standard creep pellet 5-10 mm in length,
c. Large diameter (12 mm) SMEC pellet ~12 mm in length, and
d. Small diameter (4 mm) SMEC pellet ~5 mm in length.

Figure 1 Treatment diets offered to piglets during lactation and the first week following weaning. Large standard formula pellet (a), small standard formula pellet (b), large semi-moist extruded creep (SMEC) pellet (c), and small semi-moist extruded creep (SMEC) pellet (d). Scale graduation 10 mm.

The technological requirements of the different feed production methods and the available raw materials meant that ingredients and specifications differed (Table 1), with further differences due to final moisture content.

Table 1 Dietary specifications, as formulated, of the standard and semi-moist extruded creep (SMEC) feeds.

	Standard creep	Semi-moist extruded creep
Digestible energy (DE) MJ/kg	14.3	14.8
Crude protein, %	19.2	21.9
Standardised ileal digestible lysine, g/kg	13.2	11.2
Standardised ileal digestible lysine per MJ DE, g	0.92	0.76

Feed was offered to piglets from day 8 of lactation. Initially feed, 250 g, was offered twice a day on the creep mat, before transitioning to *ad libitum* feeding from day 14. Creep feeds were then provided in round transition feeders, with feed disappearance measured daily until weaning (26.4 ± 0.04 days of age). At weaning, piglets were placed into nursery pens (44 per pen) in their treatment groups and received respective diets *ad libitum* in the same round transition feeders alongside a standard creep diet in a traditional fence line long trough feeder, for the first 8 d post-weaning. Pigs were weighed at days 8 and 21 of lactation, at weaning and at day 9 and 21 following weaning. Feed delivery was recorded twice daily until round transition feeders were removed.

The behaviours of a subset of litters were also monitored by video recording at day 16 (n = 40) and day 21 (n = 38) of lactation and a subset of pens on day 2 (n = 18) after weaning to assess piglets' interaction with feed, the feeder, and each other, for the 2 hours post-feeding based on a standard feeding behaviour ethogram adapted from Middelkoop et al. (2019, Table 2). Behaviours were observed from scan sampling a still image every 15 seconds, with observations summed into 30-minute blocks. Piglet behaviours were analyzed using a Generalized Linear Mixed Model (IBM SPSS Statistics for Windows, v25.0. Armonk, NY, USA), with pellet type, pellet size, time period, lactation stage and their interaction as effects, with significance accepted at $P < 0.05$. Growth data were analyzed using a GLM ANOVA (GenStat 21st Edition, VSN International, Hemel Hempstead, UK), with pellet form, pellet size and their interaction as effects, with significance accepted at $P < 0.05$ and considered a trend at a P-value between 0.05 and 0.1.

Table 2 Piglet behaviours observed during the period after the introduction of creep feeding treatments to piglets at day 16 or 21 of lactation (from Middelkoop et al., 2019).

Behaviour	**Description**
Exploring feeder	Sniffing, touching with snout, rooting, or chewing on the feeders.
Exploring feed	Sniffing, touching with snout or rooting the content (feed or feed + sand) of the feeders (snout is in the feeder) or sniffing or touching feed on the floor (snout is outside the feeders).
Playing with feed	Rolling feed over the floor, walking around the pen with feed item in mouth or shaking head whilst feed is in their mouth.
Playing with piglets	Playing, nosing or biting other piglets whilst around the feeder.
Eating feed	Eating or chewing feed from the feeders or the floor.
Nursing	Piglets observed manipulating udder when sow lying down.

3. Outcomes

Full tabulated research results can be found in the appendices, and the following charts highlight significant and interesting findings.

Production effects

Pellet size did not impact the weight of piglets during lactation (Figure 2); however, those piglets that received the creep feed were significantly heavier at weaning than those that received the semi-moist extruded creep (SMEC) feed (7.19 *vs* 6.78 kg, P=0.001). There was a significant interaction between treatments (P=0.006) in weaning weight with piglets in the small creep treatment being heavier than those in the large creep treatment, whereas the large SMEC-fed piglets were heavier than the small SMEC-fed piglets.

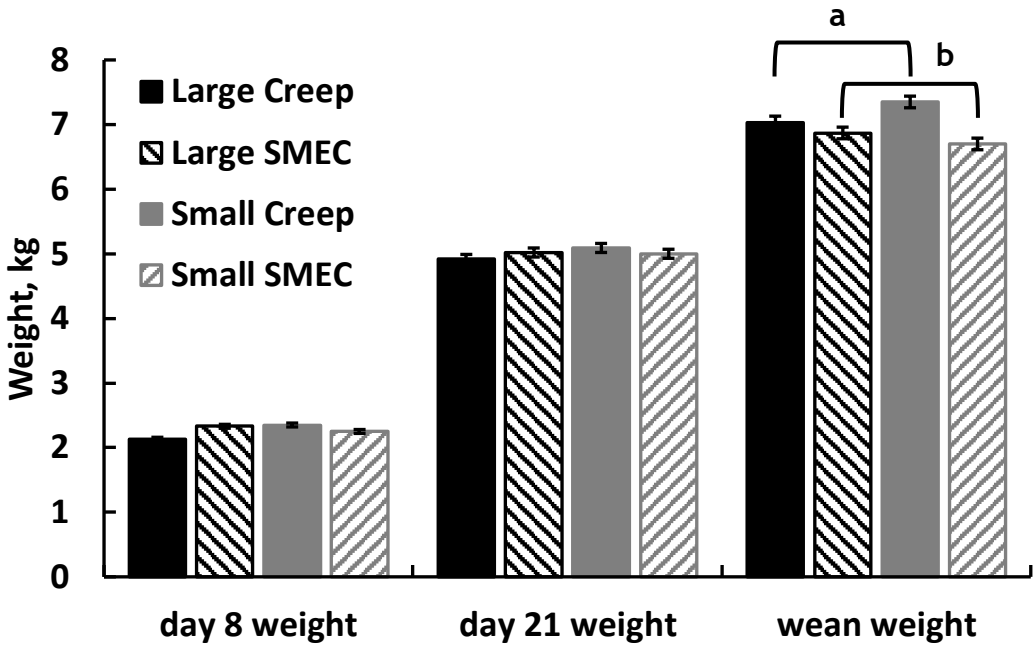

Figure 2 Weight (kg) of piglets at day 8 and 21 of lactation and at weaning (~d 26) that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation. ^{a,b} signifies statistical difference between treatments (P<0.05).

There was no difference in average daily gain from the start of creep feeding at day 8 of lactation through to day 21 (Figure 3). In the period from day 21 through to weaning (~d 26), pellet size had no significant impact on growth rate but those piglets receiving the standard creep feed grew significantly better than SMEC-fed piglets (378 *vs* 343 g/d, P<0.001), with the improved growth rate in this 5 day period large enough to significantly increase piglet growth rate across lactation (251 *vs* 231 g/d, P=0.006, Table 5).

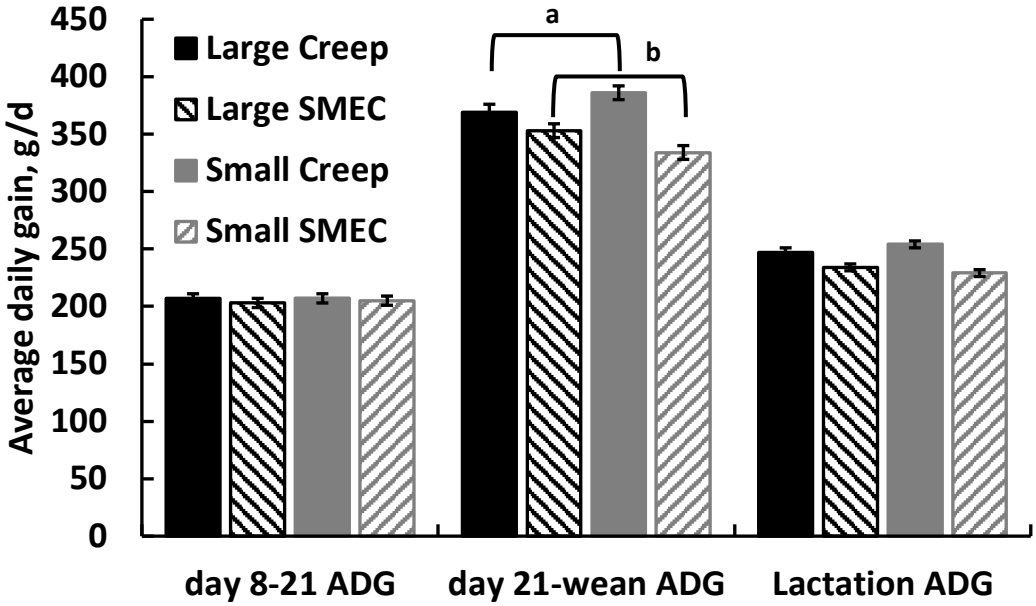

Figure 3 Average daily gain (g/d) of piglets between day 8 and 21 of lactation, between day 21 and weaning (~d 26), and for all of lactation, in piglets that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning. [a,b] signifies statistical difference between treatments ($P<0.05$).

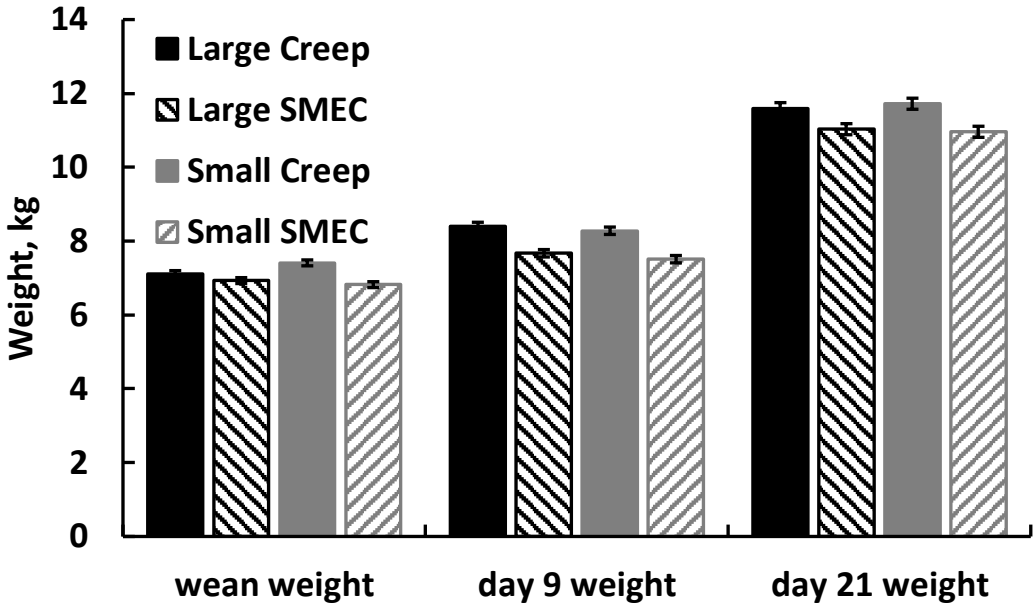

Figure 4 Weight (kg) of piglets at weaning (~26 days of age) and at days 9 and 21 after weaning that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning.

In the nursery phase, pellet size again had no impact on the weight of piglets at the end of the treatment period (d 9 after weaning) or at the end of the experiment (d 21, Figure 4). Those piglets that received the standard creep diet maintained their significant advantage at weaning (P<0.001) through to both days 9 (P<0.001) and 21 (P<0.001) after weaning. There was no interaction between treatments at day 9 or 21 after weaning.

Average daily gain in the first 9 days after weaning was significantly affected by both size and type of creep feed (Figure 5). Those piglets that received the large pellets in both lactation and the start of the nursery grew significantly faster than those receiving the small pellet (127 *vs* 96 g/d, P<0.001), whilst those piglets receiving the standard creep diet grew faster than those receiving SMEC (135 *vs* 88 g/d, P<0.001, Table 5). This had the effect of being additive with the large standard creep-fed treatment growing at 160 g/d in the first 9 days after weaning, compared to the small SMEC-fed piglets growing at 82 g/d (P=0.002, Table 5).

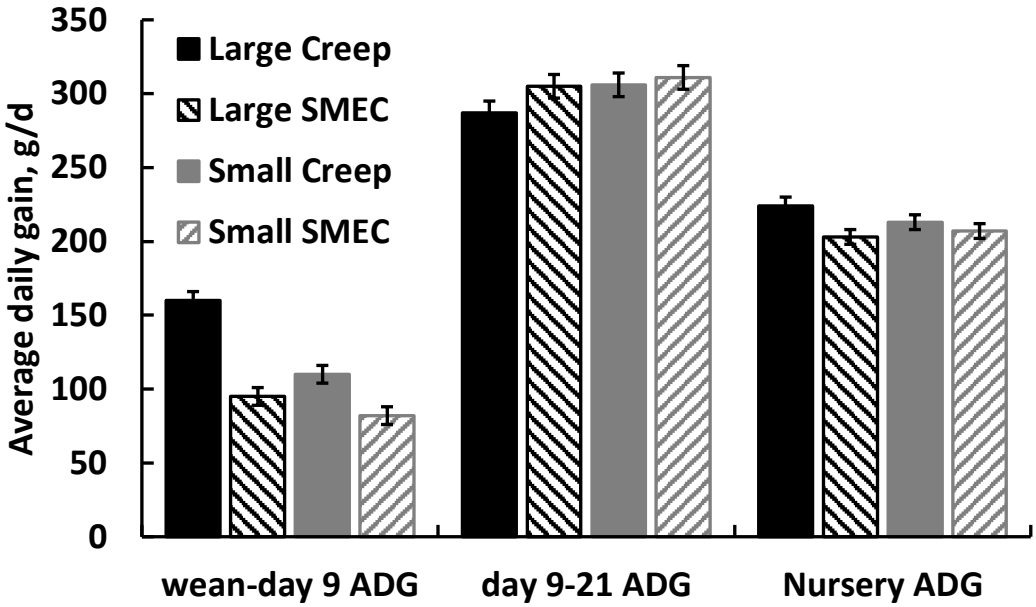

Figure 5 Average daily gain (g/d) of piglets between weaning (~26 days of age) and 9 days after weaning, between days 9 and 21 after weaning, and in the entire nursery period, that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning.

The amount of treatment feed delivered during the nursery phase reflected the average daily gain seen in the initial nursery phase (Figure 6). Significantly more large size (pellet) feed was delivered to feeders compared to the small feed (71.5 *vs* 46.3 kg, P<0.001), and significantly more standard creep was delivered compared to SMEC (66.7 *vs* 51.0 kg, P=0.001), with again the effect being additive (P=0.008, Table 4).

There were no significant differences between treatments when looking at piglets that failed to be weaned or failed to exit the nursery (Figure 7). The pattern of

those piglets that died or were removed for treatment or into the recovery stream during the nursery phase was the inverse of day 21 post-weaning weight.

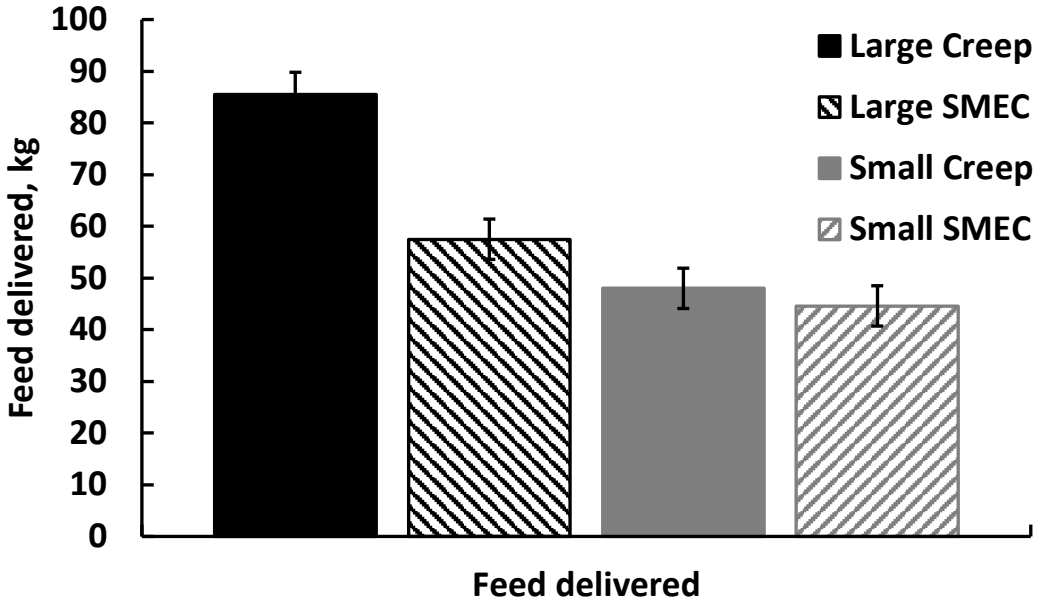

Figure 6 The mean amount of treatment feed delivered to nursery pens of piglets in the first 8 days after weaning that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for eight days after weaning.

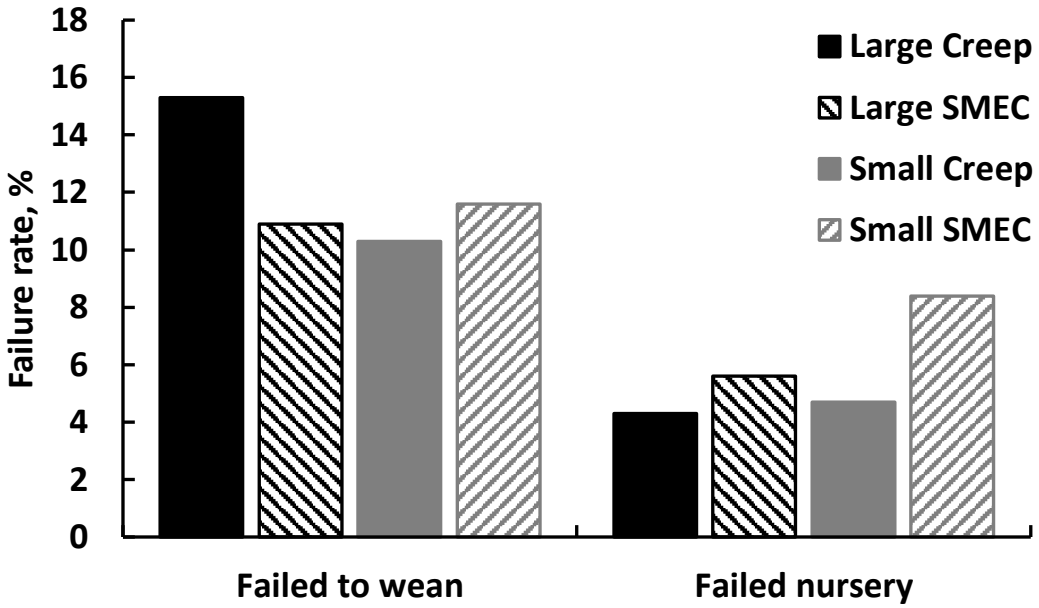

Figure 7 The percentage of piglets that entered the study but failed to be weaned (removals and deaths), or failed to exit the nursery, that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning.

Behavioural effects

When observed behaviours were analysed during lactation there was a tendency to see interactions between pellet size and the stage of lactation (Table 6). Piglets spent more time nosing the feeder that contained large pellets during early lactation (d 16) compared to late lactation (d 21, 19.8 *vs* 9.5), there was a smaller difference between small pellet treatments which were intermediate to large pellet treatments (13.0 *vs* 14.5, P=0.038, Figure 8).

When main effects only were examined, a significantly greater percentage of litters were observed playing with large pellets compared to small pellets (41.1 vs 8.6%, P=0.009); however, playing with feed was not observed to be different between early or late lactation (Figure 9).

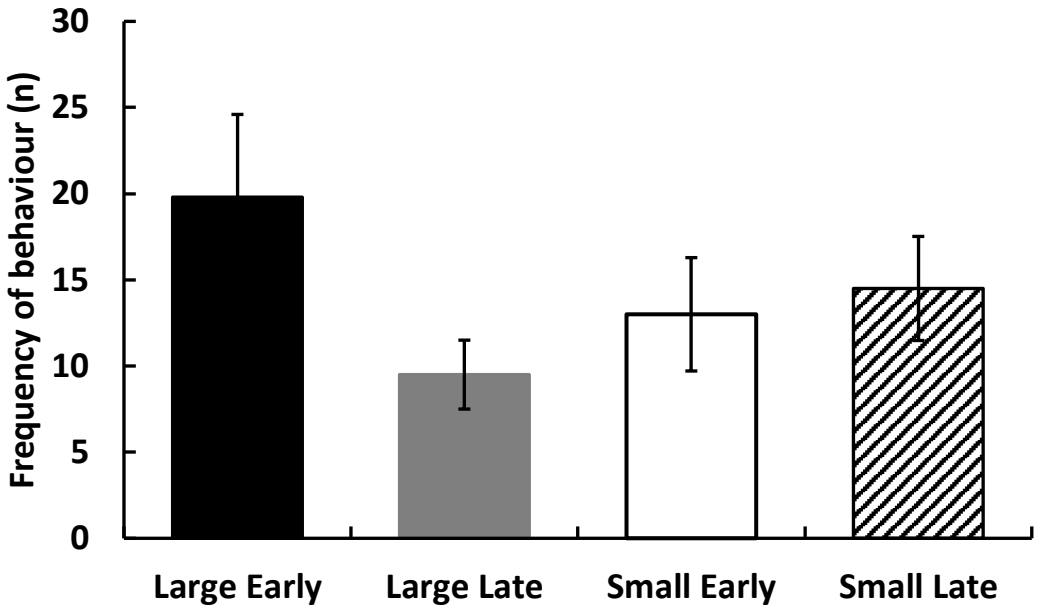

Figure 8 The incidence count within the recording period of nosing the feeder either Early (d 16) or Late (d 21) in lactation for pigs receiving feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation.

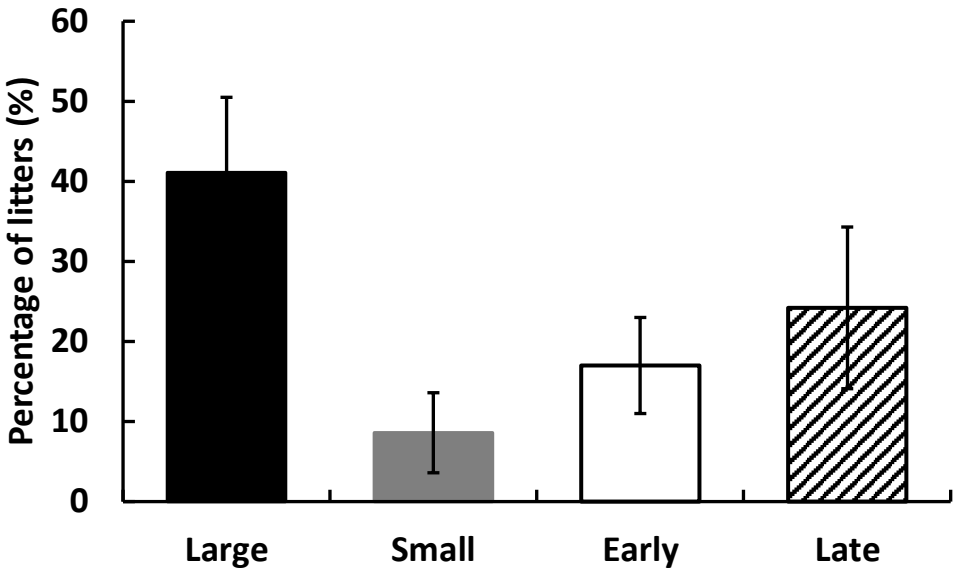

Figure 9 The percentage of litters playing with feed where piglets received feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation, and the percentage of litters playing with feed during Early (d 16) or Late (d 21) lactation.

During early lactation piglets offered large pellets were observed to interact with feed to a higher degree than those piglets that received the small pellet (Figure 10), with both nosing the feed and (active) playing with the feed being higher. Differences were also observed between feed types (Figure 11). There was no difference in nosing interactions with feed, but more pigs actively played with the standard creep compared to the SMEC. Piglet interactions were also higher (P=0.013) in those piglets with access to standard creep feed.

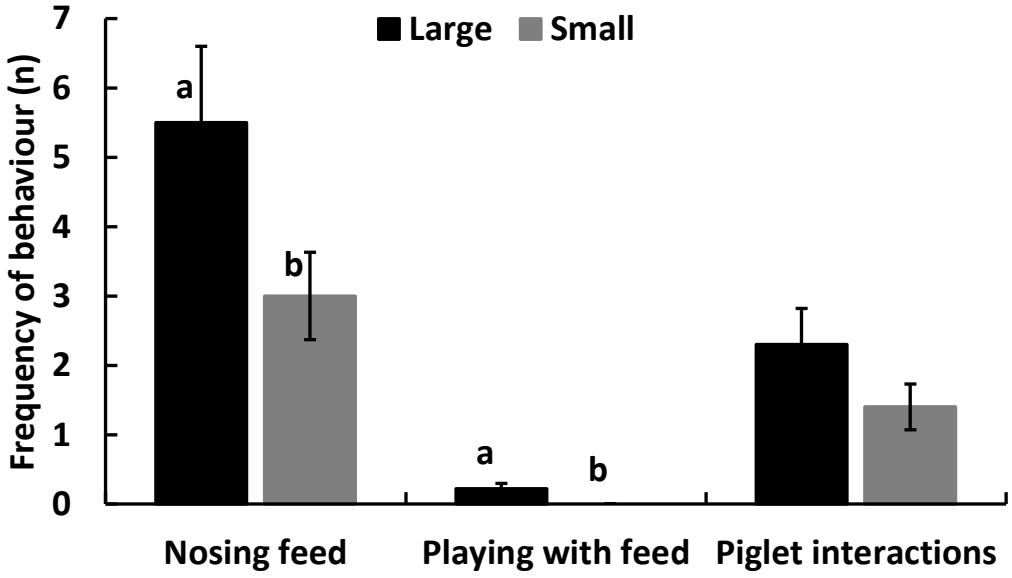

Figure 10 The incidence in early lactation (d 16) of piglets nosing feed, playing with feed, and interacting with other piglets for piglets that received feed presented as either a Large (12 mm diameter, black) or Small (4 mm diameter, grey) pellet during lactation. ^{a,b} signifies statistical difference between treatments ($P<0.05$).

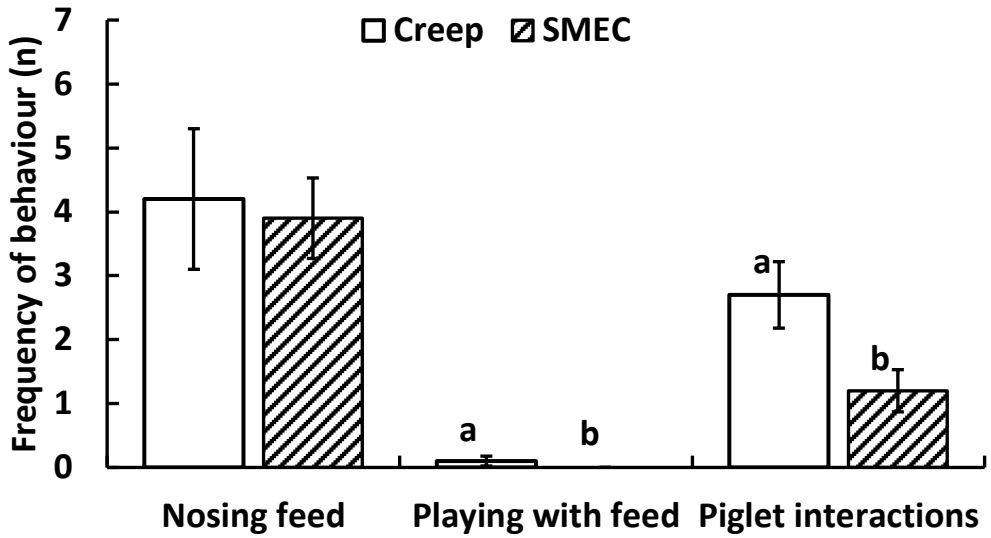

Figure 11 The incidence in early lactation (d 16) of piglets nosing feed, playing with feed, and interacting with other piglets for piglets that received either standard creep feed (white) or a semi-moist extruded creep (SMEC) feed (hatched).[a,b] signifies statistical difference between treatments (P<0.05).

An interesting observation was the impact of treatment on the incidence of piglets nursing (Figure 12). Piglets with access to the large pellet spent significantly less time nursing in the later stage of lactation (P=0.023) and tended to show a similar behaviour in early lactation (P=0.078). Feed type did not show any differences in early lactation, although in late lactation the difference was approaching a trend (P=0.12).

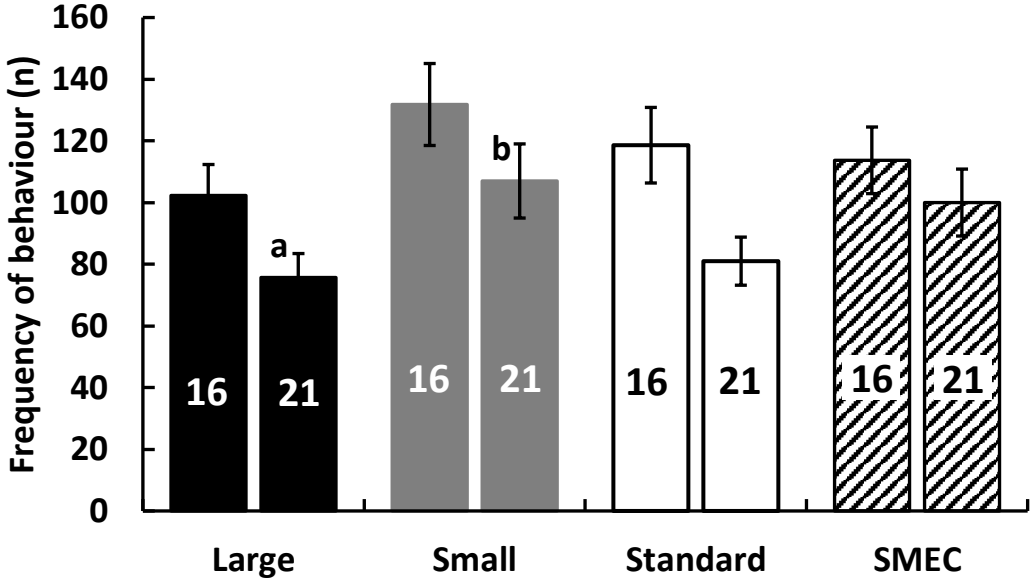

Figure 12 The incidence of piglets nursing during early (d 16) or late (d 21) lactation in piglets that received feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation, or in piglets that received either standard creep feed or a semi-moist extruded creep (SMEC) feed. [a,b] signifies statistical difference between treatments (P<0.05).

Piglet interactions were also observed to change with time after feeding (Figure 13) but differed between the two stages of lactation. Both interactions where piglets were exploring feed or the feeder with their nose showed a similar pattern, with a lower level of interaction in the early (d 16) period that was more consistent across the 2-hour observation period, whereas in later lactation (d 21) piglet interaction was greater in the first 30 minutes, with greatly reduced interactions after 30 minutes.

Observations from the post-weaning period (Table 9) showed minimal differences between treatments; however, an interesting observation was the interaction of piglets with the different feeders within the pen (Figure 14). The treatment feeder, i.e., the round transition feeder used in the farrowing crate that was transferred into the weaning pens, that the piglets were familiar with during lactation, had a higher number interactions (nosing) than the trough feeder containing the herd's commercial creep feed. It is not possible, however, to separate whether the familiarity of the feed or the feeder was the cause of this observation.

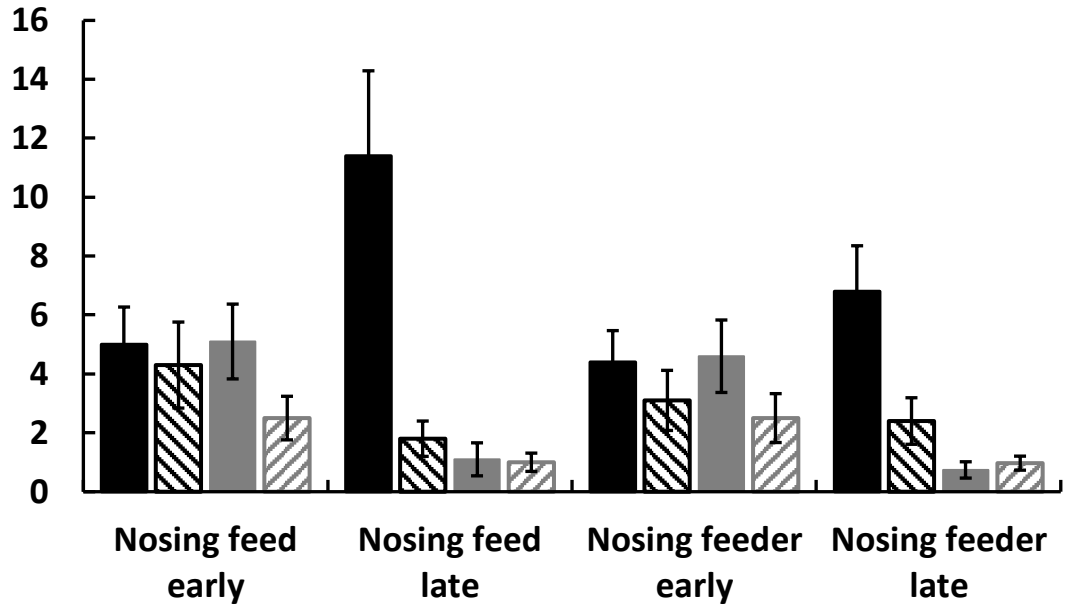

Figure 13 The incidence of piglets nosing feed and nosing the feeder in either early (d 16) or late (d 21) lactation in the four 30-minute periods after feed delivery for piglets that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning.

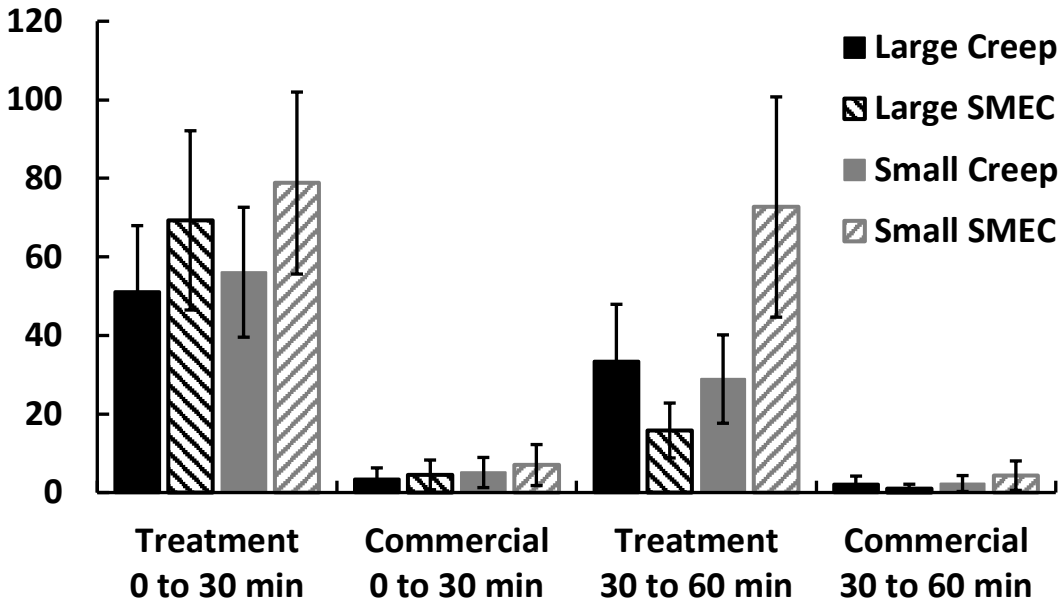

Figure 14 The incidence of piglets nosing the feeder containing the treatment diets and nosing the feeder containing commercial creep feed on day 2 after weaning during the first and second 30 minute periods after feed delivery for piglets that received either standard creep feed presented as a large (12 mm diameter, black) or small (4 mm diameter, grey) pellet or a semi-moist extruded creep (SMEC) feed presented as a large (12 mm diameter, black hatch) or small (4 mm diameter, grey hatch) pellet during lactation and for 8 days after weaning.

4. Application of Research

Unlike the previous study (6A-103) where the shorter lactation length restricted the ability of creep feeding to influence post-weaning performance, this project was able to show that using a large diameter pellet in a managed creep feeding program was able to positively influence post-weaning growth. This adds further support to previous studies showing positive responses when lactation lengths were greater than 25 days (~28 days, Edge et al., 2005; ~26 days, Pluske et al., 2019, Craig et al., 2021; 25-28 days, van den Brand et al., 2014). A larger percentage of pigs receiving the small pellets failed to exit the nursery, although this study was likely under-powered for determining differences between treatments in removals, however, the differences were consistent with those of Craig et al. (2021) who found piglets receiving large pellets tended to require less medication and subsequent removal.

Our behavioural observations in this study support the exploratory behaviour that we observed in the previous study (6A-103), where object play was beginning to develop in the piglets with access to large pellets. Within this current study a significantly greater percentage of litters were observed playing with large diameter pellets compared to small diameter pellets. The destructible nature of the pellets that deliver nutritional value to the pig means they are a more relevant form of enrichment than indestructible, inedible objects (Feddes and Fraser, 1993) and their ability to be picked up and carried is more likely to stimulate object play (Wood-Gush and Verstergaard, 1992). These large diameter pellets also have

advantages over more traditional sources of enrichment such as straw that are less compatible with slatted floors and liquid effluent systems (Greenwood et al., 2019).

A limiting factor on the application of this research is the willingness of feed mills to change to larger diameter dies for the smaller volumes of creep feed required, and the inclusion of shorter shelf-life raw materials such as milk powders means large production runs and subsequent storage is likely problematic. There are mills that currently produce larger diameter pellets for extensive pig production operations; however, the availability of raw materials and the ability to bag feed to extend shelf-life are some of the issues that likely require further work before commercialisation.

5. Conclusion

Pellet size did not impact the weight of piglets during lactation and despite there being no difference in weight of piglets at day 9 after weaning, those piglets that received the large diameter pellets during the transition period grew significantly faster that those receiving the small diameter pellet, which has been observed in other large pellet studies. There was also an observed difference in growth rate between the feed presentation types, with higher rates of piglet growth observed both in lactation and after weaning for piglets that received the standard creep compared to the SMEC feed with a lower dry matter content.

This project supports previous findings that large pellets are a readily adoptable technology that can help ease the weaning transition and enrich the lives of pigs coping with the various stressors associated with weaning.

6. Limitations/Risks

The adoption of large pellets to successfully ease the weaning transition is limited by weaning ages that match the development of exploratory behaviour, since as creep feed intake is limited before 19 days of age, a weaning age greater than 21 days will allow for higher interactions with creep feed. Furthermore, there is likely to be a degree of reticence amongst feed mill operators to change pellet dies to produce a larger pellet that will comprise a very small percentage of their total mill volume.

7. Recommendations

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

- Larger diameter creep feeds are a method to deliver enrichment and a post-weaning growth advantage to young pigs that does not result in adverse impacts on effluent systems and provides a biologically functional reward for their endeavour.

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Appendices

Appendix 1: Full data tables of performance and behaviour traits.

Table 3 Mean, and standard error difference of the mean (SEM), performance data of litters of piglets during lactation that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation.

	Overall		Size				Type				Size x Type								*P* value		
			Large		Small		Creep		SMEC		Large Creep		Large SMEC		Small Creep		Small SMEC				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Inter
Parity	2.9	0.1																	0.56	0.57	0.88
Total born	13.3	0.5																	0.71	0.55	0.22
Born alive	12.4	0.4																	0.84	0.54	0.25
Born dead	0.9	0.1																	0.46	1.00	0.73
D8 litter size	11.0	0.3	10.7	0.4	11.3	0.4	11.0	0.4	11.0	0.4	10.6	0.6	10.8	0.6	11.3	0.6	11.2	0.6	0.41	0.92	0.85
D8 litter weight, kg	24.9	0.5	24.4	0.7	25.5	0.7	24.7	0.7	25.2	0.7	23.1	1.0	25.9	1.0	26.4	1.0	24.6	1.0	0.33	0.66	0.031
D21 litter size	10.0	0.3	9.8	0.4	10.2	0.4	9.9	0.4	10.1	0.4	9.5	0.6	10.2	0.6	10.4	0.6	9.9	0.6	0.60	0.84	0.34
D21 litter weight, kg	49.9	1.1	48.9	1.6	50.9	1.6	49.7	1.6	50.2	1.6	46.7	2.2	51.2	2.2	52.6	2.2	49.2	2.2	0.37	0.81	0.079
		49.7		44.8		47.9		44.2		48.5		36.4		43.4		42.2		43.4			
Litters medicated*, %	61.5	-72.3	60	-73.8	62.9	-76.2	59.2	-73.0	63.7	-76.9	56.2	-74.6	63.7	-80.7	62.2	-79.3	63.6	-80.6	0.76	0.63	0.75
Piglet removals	0.8	0.2	0.9	0.2	0.7	0.2	0.8	0.2	0.8	0.2	1.1	0.3	0.8	0.2	0.6	0.2	0.8	0.2	0.15	0.97	0.16
Piglet deaths	0.6	0.1	0.5	0.1	0.7	0.2	0.7	0.2	0.5	0.1	0.5	0.2	0.4	0.2	0.8	0.3	0.5	0.2	0.35	0.36	0.73
Feed delivered																					
D-13	335	22	318	28	352	28	328	28	342	28	324	37	311	37	331	36	373	37	0.31	0.67	0.43
D-12	542	16	449	23	636	23	587	23	497	23	459	33	439	33	715	32	556	33	<0.001	0.007	0.036
D-11	527	16	426	23	627	23	578	23	476	23	477	32	376	32	679	32	576	32	<0.001	0.002	0.96
D-10	276	16	213	19	338	19	237	19	315	19	175	25	251	25	298	24	378	25	<0.001	<0.001	0.95
D-9	602	19	535	24	670	24	653	24	551	24	596	32	473	32	710	32	629	38	<0.001	<0.001	0.48
D-8	404	15	411	22	397	22	452	22	356	22	457	31	364	31	446	30	348	31	0.66	0.002	0.95
D-7	387	43	389	45	385	45	419	45	355	45	424	49	353	49	413	49	357	47	0.89	0.022	0.78
D-6	407	36	388	39	425	39	480	38	333	39	479	43	297	44	481	44	368	44	0.21	<0.001	0.24
D-5	608	19	552	27	664	27	681	27	536	27	681	39	424	39	682	38	647	39	0.004	<0.001	0.005
D-4	458	78	465	80	451	80	516	79	400	80	573	83	357	83	459	83	443	83	0.67	<0.001	0.002
D-3	418	32	397	36	438	36	416	36	419	36	396	43	399	44	437	43	439	44	0.24	0.93	0.99
D-2	714	21	678	29	749	29	784	29	644	29	767	47	589	41	801	41	698	41	0.085	<0.001	0.36
D-1	579	75	511	79	648	79	541	79	617	79	489	86	532	87	594	87	702	87	0.007	0.13	0.53

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 4 Mean, and standard error difference of the mean (SEM), performance data of pens of piglets during lactation and after weaning that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Overall		Size				Type				Size x Type								*P* value		
			Large		Small		Creep		SMEC		Large Creep		Large SMEC		Small Creep		Small SMEC				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Inter
Number in pen, wean	43.7	0.1	43.8	0.2	43.6	0.2	43.8	0.2	43.6	0.2	44.0	0.2	43.6	0.2	43.6	0.2	43.6	0.2	1.00	1.00	0.35
Number in pen, D9	43.4	0.2	43.8	0.3	43.0	0.3	43.5	0.3	43.3	0.3	43.5	0.5	44.0	0.4	43.4	0.4	42.6	0.4	0.63	0.11	0.74
Number in pen, D21	41.7	0.4	42.3	0.6	41.1	0.6	42.0	0.6	41.4	0.6	42.2	0.9	42.4	0.9	41.8	0.8	40.4	0.8	0.11	0.25	0.38
Pen weight, kg																					
D8 lactation	103.7	2.1	102.3	3.1	105.1	2.9	103.9	31	103.6	2.9	98.2	4.6	106.4	4.1	109.6	4.1	100.7	4.1	0.51	0.94	0.062
D21 lactation	223.9	5.4	223.0	7.8	224.8	7.4	227.7	7.8	220.1	7.4	221.5	11.5	224.5	10.4	233.9	10.4	215.6	10.4	0.87	0.49	0.34
Weaning	309.2	6.6	308.3	9.5	310.1	9.0	318.9	9.5	299.5	9.0	314.3	14.1	302.4	12.6	323.5	12.6	296.7	12.6	0.89	0.16	0.58
D9 post-weaning	346.3	8.4	351.8	12.2	340.9	11.6	363.7	12.2	328.9	11.6	365.6	18.1	338.0	16.3	361.9	16.3	319.9	16.3	0.52	0.056	0.67
D21 post-weaning	475.8	11.9	481.2	171	470.4	16.3	493.5	17.1	458.1	16.3	493.3	25.5	469.2	22.9	493.6	22.9	447.1	22.9	0.65	0.16	0.64
Average pig weight, kg																					
D8 lactation	2.36	0.05	2.33	0.07	2.40	0.07	2.36	0.07	2.37	0.07	2.23	0.11	2.42	0.01	2.49	0.10	2.31	0.10	0.46	0.97	0.085
D21 lactation	5.10	0.13	5.07	0.18	5.13	0.17	5.18	0.18	5.03	0.17	5.03	0.27	5.10	0.24	5.32	0.24	4.95	0.24	0.80	0.56	0.40
Weaning	7.08	0.15	7.04	0.22	7.12	0.21	7.29	0.22	6.88	0.21	7.14	0.3	6.94	0.30	7.43	0.30	6.82	0.30	0.79	0.21	0.52
D9 post-weaning	7.98	0.18	8.03	0.26	7.91	0.24	8.37	0.26	7.59	0.24	8.40	0.38	7.68	0.34	8.33	0.34	7.50	0.34	0.73	0.044	0.87
D21 post-weaning	11.39	0.24	11.37	0.34	11.42	0.32	11.73	0.34	11.06	0.32	11.66	0.51	11.07	0.46	11.79	0.46	11.05	0.46	0.91	0.18	0.88
Removals per pen	2.8	0.6	2.3	0.7	3.3	0.9	2.3	0.7	3.4	0.9	2.0	1.0	2.7	1.1	2.6	1.1	4.2	1.5	0.40	0.34	0.86
Feed delivered per pen, kg																					
D1	4.2	0.7	4.1	1.0	4.2	1.0	5.5	1.0	2.8	1.0	5.0	1.5	3.2	1.3	6.1	1.3	2.4	1.3	0.95	0.066	0.51
D2	4.3	0.3	3.5	0.5	5.1	0.5	4.6	0.5	3.9	0.5	2.9	0.7	4.1	0.7	6.4	0.7	3.7	0.7	0.032	0.29	0.013
D3	4.5	0.3	4.8	0.4	4.1	0.4	5.3	0.4	3.6	0.4	6.3	0.6	3.3	0.6	4.3	0.6	3.9	0.6	0.23	0.009	0.041
D4	8.5	0.7	10.2	1.0	6.7	0.9	10.1	1.0	6.8	0.9	12.9	1.5	7.6	1.3	7.4	1.3	6.0	13	0.019	0.026	0.18
D5	7.5	0.5	8.5	0.8	6.4	0.7	8.5	0.8	6.5	0.7	10.2	1.1	6.8	1.0	6.7	1.0	6.2	1.0	0.068	0.088	0.18
D6	7.4	0.6	8.5	0.9	6.4	0.8	8.4	0.9	6.5	0.8	9.5	1.3	7.5	1.2	7.3	1.2	5.4	1.2	0.093	0.12	0.97
D7	7.6	0.6	7.9	0.9	7.3	0.8	8.8	0.9	6.4	0.8	9.8	1.3	6.0	1.2	7.9	1.2	6.7	1.2	0.62	0.061	0.28
D8	15.0	0.7	23.9	1.0	6.1	0.9	15.4	1.0	14.6	0.9	28.8	1.4	18.9	1.3	1.9	1.3	10.3	1.3	<0.001	0.58	<0.001
Total	58.9	2.0	71.5	2.9	46.3	2.8	66.7	2.9	51.0	2.8	85.5	4.3	57.5	3.9	48.0	3.9	44.6	3.9	<0.001	0.001	0.008

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 5 Mean, and standard error difference of the mean (SEM), performance data of piglets (repeated measures analysis with the individual piglet as the unit, with litter or pen as a random term) during lactation and after weaning that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Overall		Size				Type				Size x Type								*P* value		
			Large		Small		Creep		SMEC		Large Creep		Large SMEC		Small Creep		Small SMEC				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Inter
Lactation																					
D8 weight, kg			2.23	0.02	2.30	0.02	2.24	0.02	2.29	0.02	2.13	0.03	2.33	0.03	2.35	0.03	2.25	0.03	0.27	0.14	<0.001
D21 weight, kg			4.97	0.05	5.02	0.05	5.00	0.05	4.99	0.05	4.92	0.07	5.02	0.07	5.09	0.07	5.00	0.07	0.43	0.87	0.087
Wean weight, kg			6.95	0.06	7.02	0.06	7.19	0.07	6.78	0.06	7.03	0.10	6.87	0.09	7.35	0.09	6.70	0.09	0.37	0.001	0.006
D8-21 ADG, g/d			205	3	206	3	207	3	204	3	207	4	203	4	207	4	205	4	0.72	0.39	0.73
D21-wean ADG, g/d			361	5	360	4	378	5	343	4	369	7	353	6	386	6	334	6	0.89	<0.001	0.005
Lactation ADG, g/d			240	3	241	2	251	3	231	2	247	4	234	3	254	3	229	3	0.82	<0.001	0.12
				9.8		8.1		9.5		8.4		10.5		7.1		6.7		7.7			
Failed to wean, %			12.9	-16.9	10.9	-14.5	12.6	-16.4	11.2	-14.9	15.3	-21.7	10.9	-16.2	10.3	-15.3	11.6	-17.1	0.48	0.58	0.25
Weaning age, d			26.3	0.04	26.4	0.04	26.5	0.04	26.3	0.04	26.6	0.06	26.1	0.06	26.4	0.06	26.5	0.06	0.13	<0.001	<0.001
Nursery																					
Wean weight, kg			7.02	0.06	7.11	0.06	7.26	0.06	6.88	0.06	7.11	0.09	6.93	0.08	7.41	0.08	6.82	0.08	0.28	<0.001	0.017
D9 weight, kg			8.04	0.07	7.89	0.07	8.34	0.07	7.59	0.07	8.40	0.11	7.67	0.10	8.28	0.10	7.51	0.10	0.16	<0.001	0.81
D21 weight, kg			11.31	0.11	11.34	0.11	11.65	0.11	10.99	0.11	11.59	0.16	11.03	0.15	11.72	0.15	10.96	0.15	0.84	<0.001	0.51
Wean-D9 ADG, g/d			127	4	96	4	135	4	88	4	160	6	95	6	110	6	82	6	<0.001	<0.001	0.002
D9-21 ADG, g/d			296	6	309	5	297	6	308	5	287	8	305	8	306	8	311	8	0.090	0.15	0.41
Nursery ADG, g/d			213	4	210	4	218	4	205	4	224	6	203	5	213	5	207	5	0.51	0.011	0.17
				2.3		3.9		2.3		3.9		1.6		2.4		1.9		3.9			
Failed nursery, %			4.9	-8.6	6.8	-11.8	4.5	-8.6	6.8	-11.8	4.3	-11.2	5.6	-12.3	4.7	-11.0	8.4	-17.2	0.56	0.33	0.71

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 6 Mean, and standard error difference of the mean (SEM), lactation behaviour data of pens of piglets during early (d16) or late (d21) lactation that received either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Size				Stage				Size x Stage								*P* value		
	Large		Small		Early		Late		Large Early		Small Early		Large Late		Small Late				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Stage	Inter
Rest	1,447.4	80.34	1,401.3	79.46	1,424.3	71.72	1,424.4	82.66	1,348.7	95.26	1,504.1	109.80	1,554.0	126.68	1,305.6	108.79	0.69	1.00	0.064
Active	311.4	36.77	284.6	34.29	284.8	26.98	311.2	41.33	331.5	44.06	244.7	33.68	292.5	54.54	331.0	63.05	0.60	0.58	0.18
Nursing	433.8	37.44	477.9	40.71	492.6	31.70	420.8	32.96	451.3	41.17	537.5	49.92	416.9	46.23	424.8	47.58	0.43	0.050	0.33
Nosing feed	23.3	4.67	17.8	3.63	19.9	3.69	20.9	3.91	28.0	7.26	14.1	3.81	19.3	5.10	22.6	6.05	0.36	0.83	0.088
Nosing feeder	13.7	2.48	13.8	2.49	16.1	2.79	11.7	1.73	19.8	4.80	13.0	3.29	9.5	2.00	14.5	3.02	0.99	0.12	0.038
Playing with feed	0.78	0.193	0.00	0.235	0.01	5.574	0.03	0.756	1.14	0.411	0.00	0.046	0.53	0.185	0.00	0.093	0.99	1.00	1.00
Piglet interactions	6.4	1.35	8.1	1.71	8.1	1.60	6.5	1.26	8.9	2.47	7.3	2.10	4.6	1.30	9.1	2.48	0.44	0.41	0.10
Piglet out of view	181.8	50.41	239.6	69.05	234.8	57.45	185.5	63.94	319.1	109.51	172.8	61.28	106.6	50.12	332.1	164.01	0.50	0.60	0.052
Total	2,486.5	15.85	2,494.2	16.01	2,507.8	5.18	2,473.1	20.98	2,502.1	7.27	2,513.5	7.54	2,471.0	29.48	2,475.1	29.89	0.73	0.103	0.86
% litters playing with feed	0.411	0.094	0.086	0.050	0.17	0.060	0.242	0.101									0.009	0.49	

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 7 Mean, and standard error difference of the mean (SEM), lactation behaviour data of pens of piglets during early (d16) lactation that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Size				Type				Period								*P* value		
	Large		Small		Creep		SMEC		0 to 30 min		30 to 60 min		60 to 90 min		90 to 120 min				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Period
Rest	316.3	26.10	377.5	32.02	323.3	28.09	369.4	29.50	318.7	25.03	340.3	24.74	354.9	28.74	370.3	33.48	0.14	0.27	0.46
Active	71.7	11.72	59.9	10.08	68.2	11.76	62.9	9.98	74.8	12.37	55.8	11.63	67.6	14.00	65.4	12.12	0.45	0.73	0.52
Nursing	102.3	10.04	131.8	13.29	118.6	12.25	113.7	10.80	119.4	15.94	125.7	14.03	108.9	17.38	111.3	15.61	0.078	0.77	0.80
Nosing feed	5.5	1.10	3.0	0.63	4.2	0.90	3.9	0.77	5.0	1.27	4.3	1.46	5.1	1.27	2.5	0.74	0.042	0.79	0.26
Nosing feeder	4.2	0.86	3.0	0.65	3.2	0.72	3.9	0.77	4.4	1.07	3.1	1.02	4.6	1.23	2.5	0.83	0.28	0.57	0.42
Playing with feed	0.22	0.077	0.00	0.002	0.10	0.069	0.00	0.003	0.05	0.052	0.01	0.004	0.03	0.022	0.02	0.016	<0.001	<0.001	0.002
Piglet interactions	2.3	0.52	1.4	0.33	2.7	0.63	1.2	0.27	2.4	0.72	1.33	0.41	1.7	0.46	1.7	0.73	0.13	0.013	0.56
Piglet out of view	53.8	11.23	38.1	8.19	40.5	8.93	50.5	10.22	37.0	10.73	59.7	16.58	54.3	15.68	34.9	11.42	0.26	0.47	0.48
Total	575.7	12.47	625.6	13.92	585.5	13.36	615.0	12.89	577.1	22.85	601.5	17.79	611.4	15.71	611.1	15.87	0.009	0.12	0.62
% litters playing with feed	0.098	0.038	0.003	0.003	0.065	0.040	0.004	0.004	0.046	0.041	0.016	0.012	0.024	0.024	0.004	0.004	0.005	<0.001	0.048

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 8 Mean, and standard error difference of the mean (SEM), lactation behaviour data of pens of piglets during late (d21) lactation that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Size				Type				Period								*P* value		
	Large		Small		Creep		SMEC		0 to 30 min		30 to 60 min		60 to 90 min		90 to 120 min				
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Period
Rest	318.3	21.81	338.5	25.32	370.0	24.09	291.2	21.04	232.7	27.15	350.8	28.19	383.1	28.44	371.1	27.00	0.54	0.010	0.002
Active	54.0	8.11	52.3	8.63	49.6	7.04	57.0	9.06	117.8	19.06	51.7	10.96	31.7	6.19	41.5	7.81	0.88	0.49	<0.001
Nursing	75.7	7.77	107.0	12.02	81.0	7.80	100.0	10.85	104.4	13.19	88.2	10.58	72.6	10.28	98.1	12.56	0.023	0.12	0.20
Nosing feed	2.9	0.76	1.7	0.54	1.6	0.45	3.1	0.83	11.4	2.89	1.8	0.60	1.1	0.56	1.0	0.31	0.20	0.079	<0.001
Nosing feeder	2.1	0.45	1.6	0.43	1.4	0.34	2.4	0.55	6.8	1.55	2.4	0.79	0.74	0.277	0.97	0.238	0.47	0.094	<0.001
Playing with feed	0.08	0.039	0.04	0.025	0.05	0.028	0.07	0.034	0.29	0.128	0.03	0.03	0.03	0.021	0.05	0.042	0.34	0.65	0.018
Piglet interactions	1.2	0.37	0.30	1.396	0.45	2.012	0.86	0.288	7.2	2.77	0.68	0.216	0.08	0.738	0.36	0.136	0.76	0.89	<0.001
Piglet out of view	69.3	15.43	56.7	13.00	43.6	10.00	90.0	20.05	76.9	20.90	63.3	20.32	52.2	18.25	60.6	20.76	0.53	0.024	0.84
Total	559.4	4.15	544.8	4.45	551.9	3.84	552.3	4.28	550.9	5.06	553.1	4.99	552.5	5.02	551.7	5.17	0.013	0.94	0.99
% litters playing with feed	0.000	0.008	0.000	0.009	0.000	0.009	0.000	0.008	0.200	0.070	0.029	0.029	0.057	0.041	0.000	0.000	0.91	0.92	0.16

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.

Table 9 Mean, and standard error difference of the mean (SEM), post-weaning (d2) behaviour data of pens of piglets that received either standard creep feed or a semi-moist extruded creep feed presented as either a Large (12 mm diameter) or Small (4 mm diameter) pellet during lactation and for eight days after weaning.

	Size x Type								*P* value					
	Large Creep		Large SMEC		Small Creep		Small SMEC							
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Size	Type	Time	Size x Time	Time x Type	Size x Type x Time
Rest														
0 to 30 min	1,456.0	389.59	1,286.5	344.26	1,506.5	360.50	1,026.9	245.90	0.43	0.69	0.11	0.54	0.70	0.12
30 to 60 min	1,585.7	336.83	2,167.8	460.36	2,108.3	400.46	1,489.6	283.04						
60 to 90 min	1,360.7	234.16	2,218.3	381.59	2,063.8	317.56	1,405.6	216.34						
90 to 120 min	1,649.6	331.57	2,092.3	420.46	1,580.1	284.07	1,215.9	218.67						
Active														
0 to 30 min	799.1	229.10	1,030.4	295.36	990.6	253.98	1,219.2	312.55	0.18	0.78	0.015	0.82	0.61	0.11
30 to 60 min	645.4	253.37	350.0	137.54	480.9	168.90	756.8	265.70						
60 to 90 min	887.2	339.70	339.3	130.07	478.1	163.84	856.4	293.28						
90 to 120 min	851.1	242.78	452.8	129.24	869.2	221.76	1,135.6	289.67						
Nosing treatment feeder														
0 to 30 min	51.1	16.86	69.3	22.82	56.1	16.54	78.8	23.17	0.056	0.56	0.002	0.23	0.077	0.013
30 to 60 min	33.4	14.53	15.8	6.99	28.9	11.25	72.7	28.04						
60 to 90 min	57.2	29.36	8.6	4.66	25.0	11.60	65.4	29.94						
90 to 120 min	65.2	26.48	17.8	7.35	74.0	26.82	80.2	29.05						
Nosing commercial feeder														
0 to 30 min	3.4	2.88	4.5	3.78	5.1	3.84	7.0	5.22	0.35	0.42	<0.001	0.63	0.070	0.097
30 to 60 min	2.1	2.09	1.0	1.12	2.3	2.03	4.3	3.75						
60 to 90 min	3.9	3.28	0.16	0.170	0.77	0.62	1.6	1.20						
90 to 120 min	1.6	1.37	0.16	0.167	2.1	1.57	1.4	1.10						

SEM, standard error of the mean, *Confidence interval displayed rather than SEM.