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ANIMAL SCIENCE

Relationship between creep feeding intake and piglet's performance in the nursery phase

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Abstract: The objective of this study was to evaluate the effects of creep feeding during the pre-weaning stage on the performance of piglets at nursery phase, as well as to estimate the economic viability of its application. A total of 125 piglets were exposed to creep feeding and evaluated qualitatively regarding diet intake and quantitatively regarding weight gain. After determining the eaters and non-eaters' piglets, 48 of these animals were evaluated in the nursery phase. Piglets are blocked (initial weigh and sex) and divided into eaters (E, n=24) and non-eaters (NE, n=24). Time to start feed intake, growth performance data and economic viability were analyzed. At pre-weaning phase no weight difference was observed, and only 24.5% of piglets consumed the creep feed after 12 days of exposure. At nursery phase, the E group presented a 250% faster consumption in the first 24 hours of housing, 18.3% greater daily feed intake and 22.0% greater daily gain for whole experimental length, when compared to NE group. The economic evaluation demonstrated a 269% and 225% greater economic profit and return on investment for E. Therefore, the application of creep feeding in pre-weaning improves the piglets' performance during nursery phase and is economically viable.

Key words: management, nutrition, swine, weaning, weight gain.

INTRODUCTION

The annual number and kilograms of piglets weaned per sow is a crucial indicator of the success of a pig production system. This metric holds significant relevance in determining the overall productivity of the system (Bell et al. 2015). In recent decades, this indicator has seen an increase due to genetic improvements, with a focus on hyperprolific sows and shorter lactation periods. As a result, there has been a progressive decrease in weaning age, particularly in more intensive production farms, which can make the weaning process even more stressful for the piglets. Campbell et al. (2013) pointed out that weaning is naturally associated with immunological, intestinal and behavioral changes, that comes from transportation, social hierarchy, contact with pigs from other litters, different environments, increased pathogens exposure and dietary stressors. Of all the stressors that piglets face during the weaning process, nutritional challenges are particularly noteworthy. These challenges can lead to poor performance, decreased gut health, and reduced nutrient digestion and weight gain (Torrallardona 2012, Kim & Duarte 2021), which, consequently, generate economic losses.

According to Campbell et al. (2013), promoting rapid adaptation of piglets to stressors is crucial for maximizing productivity. One strategy that can facilitate this adaptation is creep feeding, as noted by Tokach et al. (2020). Creep feeding involves offering a solid diet to piglets while they are still suckling, which allows them to become familiar with the type of food that will be provided in the nursery phase. Additionally, creep feeding has been shown to improve pre-weaning performance in some cases, as highlighted by Oliveira et al. (2021) and Muro et al. (2023). This management approach is particularly important for large litters as it promotes greater uniformity among the pigs (Solà-Oriol & Gasa 2017).

Moreover, as shown by Bian et al. (2016), the provision of creep feed has been found to be crucial for the adaptation and development of piglet intestinal microbiota after weaning, which can contribute to a lower incidence of diarrhea and better utilization of the diet. According to Muro et al. (2023), these factors – lower incidence of diarrhea and better utilization of the diet - can help reduce the nutritional challenge of the nursery, since creep feed intake is associate with better activity of carbohydrate and protein-digesting enzymes. Despite the benefits of creep feeding, there is inconsistency in the literature regarding its real impacts on piglet's performance due to the various ways in which this management strategy can be applied.

In this sense, the objective of the present study was to evaluate the effects of using creep feeding during the pre-weaning phase on the performance of the piglets in the nursery phase, as well as to demonstrate the economic viability of its application.

MATERIALS AND METHODS

This experiment was approved by the Ethic Committee on Animal Use (CEUA) of the School of Veterinary Medicine and Animal Science (FMVZ) of the University of São Paulo (USP) (CEUA N° 6414020522). The study was conducted on the Swine Research Laboratory (LPS) at FMVZ/USP, located in Pirassununga (21°56'56.9"S 47°27'16.1"W), São Paulo, Southeastern Brazil, between the months of June and July of 2022.

The experiment was divided into two phases of analysis: i) pre-weaning; and ii) nursery. For the pre-weaning phase, litters of 10 sows from the M3 genetic lineage (Choice Genetics) were used, totaling N = 125 piglets. All pigs used in the study were identified using numbered tags. The piglets were monitored in the pre-weaning phase from the seventh day of life, which was the moment when creep feeding was introduced (D0), until weaning, performed at 21 days of age (D14). The creep feed, was presented in mash form, offered *ad libitum* in trough-type feeders, and its composition was the same as the pre-starter 1 diet, also used in the first week of the nursery phase.

The second experimental phase consisted of 16 days of evaluation, during the nursery phase. For this, a total of 48 piglets, from the first phase, were placed in 24 pens with two (2) pigs each, divided into two groups: creep feed eaters in the pre-weaning phase (E) and non-eaters (NE). The 48 piglets used in the nursey phase were selected so that it was possible to block the animals by weight and sex, keeping the same number of E and NE. The experimental unit consisted of the average of the pen (two piglets), totaling 12 replicates per treatment. Two diets were offered during nursery phase for all piglets, the first being pre-starter 1, offered from weaning to the seventh day of nursery, and then pre-starter 2, from the eighth day to the end of the experiment. All diets (Table I) were formulated to meet or exceed the nutritional requirements for the swine category as recommend by NRC (2012).

To determine which piglets were consuming feed in both pre-weaning and nursery phases, rectal swab tests were conducted along with the provision of a solid diet containing 1% ferric oxide in the total feed composition. Ferric oxide

Table I. Ingredient composition and nutrient content of diets.

Composition	Diet	
	Pre-starter 1	Pre-starter 2
Corn 7.8 CP (%)	40.00	50.00
Soybean meal 46,5 CP (%)	20.00	25.00
Pre-starter 1 premix (400 kg/ton) (%)	40.00	-
Pre-starter 2 premix (250 kg/ton) (%)	-	25.00
Total	100.00	100.00
Crude protein (%)	19.971	19.168
Crude fat (%)	3.522	4.041
Crude fiber (%)	1.702	1.983
Mineral materia (%)	4.427	4.448
Metabolizable energy (Kcal/kg)	3400.000	3380.000
Lactose (%)	10.000	6.000
Total calcium (%)	0.652	0.698
Total phosphorus (%)	0.512	0.492
Available phosphorus (%)	0.402	0.350
Total lysine (%)	1.473	1.361
Total methionine (%)	0.477	0.476
Methionine + cystine (AAS) total (%)	0.882	0.812
Total threonine (%)	1.007	0.933
Total tryptophan (%)	0.302	0.276
Total valine (%)	0.983	0.920
Total arginine (%)	1.115	1.142
Total isoleucine (%)	0.812	0.794
Total leucine (%)	1.688	1.610
Ileal digestible lysine (%)	1.352	1.250
Ileal digestible methionine (%)	0.456	0.457
Ileal digestible AAS (%)	0.812	0.750
Ileal digestible threonine (%)	0.876	0.813
Ileal digestible tryptophan (%)	0.272	0.250
Ileal digestible valine (%)	0.876	0.813
Ileal digestible arginine (%)	1.099	1.101
Ileal digestible isoleucine (%)	0.718	0.703
Ileal digestible leucine (%)	1.517	1.443
Phytase (U/kg)	500.000	500.000
Xilanase (U/kg)	1000.000	1000.000
Synthetic vitamin A (KUI/kg)	13.500	13.500
Synthetic vitamin D3 (KUI/kg)	3.000	3.000
Synthetic vitamin E (UI/kg)	81.000	81.000
Synthetic vitamin K3 (mg/kg)	6.000	6.000
Synthetic thiamine (mg/kg)	2.702	2.702
Synthetic riboflavin (mg/kg)	7.500	7.500
Synthetic pyridoxidine (mg/kg)	4.350	4.350
Synthetic cyanocobalamin (mcg/kg)	45.000	45.000
Synthetic pantothenic acid (mcg/kg)	31.500	31.500
Synthetic niacin (mg/kg)	60.000	60.000
Synthetic folic acid (mg/kg)	0.675	0.675
Synthetic biotin (mcg/kg)	240.000	240.000
Choline choridle (mg/kg)	450.000	450.000
Inorganic manganese (mg/kg)	55.000	55.000
Inorganic zinc (mg/kg)	2700.000	2350.000
Inorganic iron (mg/kg)	110.001	110.001
Inorganic copper (mg/kg)	200.000	200.000
Total iodine (mg/kg)	1.100	1.100
Inorganic selenium (mg/kg)	0.600	0.600

has no nutritional value and is not digested during gastrointestinal transit, allowing for its subsequent visualization through a change in fecal color. Rectal swab analysis during the pre-weaning phase was conducted on days 3, 6, 10, and 12 after initiating creep feed supply. Pigs with a reddish-colored swab in at least one analysis were classified as E, while piglets with swabs of other colors or no color at all were classified as NE of creep feed. Moreover, rectal swab analysis was conducted during the first four days of the nursery phase to determine the number of days it took for pigs to begin consuming solid feed after weaning and to examine whether this characteristic was influenced by previous consumption of creep feed.

To evaluate productive performance, individual weighing was conducted using a Welmy® (Santa Bárbara d'Oeste, Brazil) anthropometric digital scale. Weighing during the pre-weaning phase took place on days 0 (the day of diet insertion), 3, 6, 10, and 12. In the nursery period, weighing was conducted on the seventh (D21) and sixteenth day (D30).

During this period, the variables of average daily gain (ADG), average daily feed intake (ADFI) and feed to gain ratio (F:G) were calculated. Feed to gain ratio was calculated as the ratio between feed consumed and weight gain in each period, while ADFI was determined by the difference between the amount of feed offered and leftovers, which were measured daily for each pen.

At the end of the trial, an economic analysis was carried out to assess the feasibility of using creep feeding and its economic impact on the subsequent performance of the piglets. The method by Alves et al. (2022a) for allocation of production costs and calculation of economic indicators was used. The analyzed variables were cost of acquisition of piglets; feed costs; other costs; total cost of production; cost per kilogram of slaughtered piglet; total revenue; gross margin of the activity; economic profit per slaughtered pig sold; benefit/cost ratio and return on investment, according to market data from the São Paulo Swine Production Cost Index (ICPS) for the month of November 2022 (Alves et al. 2022b).

The "Feed cost" considered the amount of pre-starter feed 1 and 2 consumed during the nursery phase, per pig. The item "Other costs" is composed of costs with labor, sanitary and reproductive management, consumer goods, transportation and insurance, maintenance, depreciation, electricity and fuel, telephony and internet, fees and taxes and costs of opportunity of capital and land. It is important to point out that the value for "Other Costs" was considered the same for all pigs, given that the only item that varied between treatments was the amount consumed from the same diet. For the composition of the item "Acquisition cost", was considered the weight of the weaned piglet and the commercialization price for this category in the state of São Paulo. As well as for the composition of the activity's revenue, the average value of the sale of the pig in this category was also considered, stipulated in the swine stock market of the "Associação Paulista dos Criadores de Suínos" for November 2022. The conversion of economic analysis variables from Brazilian currency *"reais"* (R$) to US dollars was executed utilizing the exchange rate as of November 30, 2022, where 5.2941 Brazilian R$ were deemed equivalent to 1 US dollar.

Statistical analyzes were performed using SAS software version 9.4 (SAS/STAT, SAS Institute Inc., Cary, NC). All data were tested for normality with the Shapiro-Wilk test, and variables that did not follow a normal distribution were transformed using the SAS RANK procedure. The PROC RANK instruction with the NORMAL option was used to produce a normalized transformed variable. The treatment effect was analyzed by ANOVA, using the SAS MIXED procedure, with each piglet as the experimental unit in the pre-weaning phase, and pen as the experimental unit in the nursery phase. The model included the initial weight of the piglets as a random effect. All data were described as LSMEANS and the largest standard error (SEM) of each variable was presented. Differences between mean values were considered statistically significant when $P < 0.05$, and tendency for P values between 0.05 and 0.10. Means were compared by t test with $P < 0.05$.

RESULTS AND DISCUSSION

After a period of 12 days of exposure to creep feeding, feed intake was observed in 21.43% of the piglets (Figure 1). As elucidated by Solà-Oriol & Gasa (2017) and Byrgesen et al. (2021), the consumption of creep feeding can be influenced by several factors, among them the time of offering, the composition and disposition of the feed, the pre-weaning phase management of the farm and the size of the litter.

The low feed intake found in the present study can be explained by a short exposure time. In this experiment, the piglets were weaned at 21 days of age, totaling 14 days for diet consumption. However, Sulabo et al. (2010)

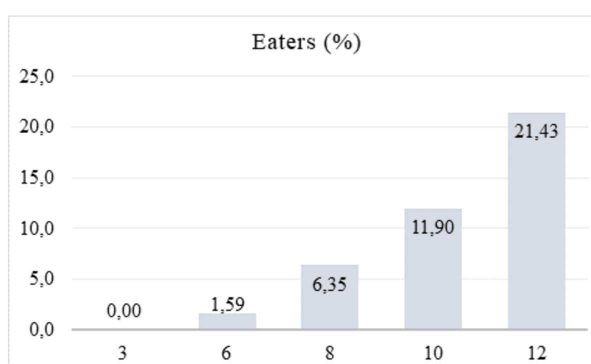

Figure 1. Percentage of pre-weaning piglets classified as eaters according to days after offering creep feed.

reports that greater consumption is observed in longer periods of offering and later weaning. According to their study, litters that were fed with creep feed for 13 or 6 days had greater intake than those fed for only 2 days. Additionally, they pointed out that since creep feed intake is associate with digestive maturity, it can be favored by higher weaning ages. Callesen et al. (2007) noted that piglets weaned at 33 days old consumed significantly higher amounts of creep feed, ranging from 137% to 266% more, compared to piglets weaned at 27 days old. Similar results of increased consumption proportionally to exposure time were found by Pajor et al. (1991). Furthermore, results found by Kuller et al. (2010) show a greater intake of creep feed when the feed is placed in non-conventional feeders, which arouse curiosity in the piglets, instead of the traditional feeders, such as the trough feeders, used in this research. Another important point to mention is that the feed position on the pen can influence the feed intake, since Oliveira et al. (2021) found that the creep feeders near the head of the sow promote great consumption by the piglets.

The last four days of analysis showed a significant increase in the percentage of consuming piglets. This finding is also evidenced by Solà-Oriol & Gasa (2017), who described that approximately 60% to 80% of consumption occurs in the last week of pre-weaning phase, for litters weaned between 21 and 28 days of age.

As reported by Sulabo et al. (2010) and Kuller et al. (2007), in this experiment, no significant difference in weight (P = 0.155) was observed during the pre-weaning phase for pigs considered E and NE of creep feeding (Table II). However, these results differ from those found by Middelkoop et al. (2020) and Lee & Kim (2018), in which a greater weaning weight was found in litters exposed to creep feeding. The greater weaning weight reported in these studies was probably due to the longer exposure time, especially when compared to the study by Middelkoop et al. (2020), in which the piglets received creep feed over the course of 26 days. It is important to highlight that in these studies there was a control group, in which creep feeding was not offered, and comparison of different times of offer in the study by Lee & Kim (2018), methodologies different from the present study. However, in the present study, the objective of performing weaning at 21 days and, consequently, exposing the pigs for less time to creep feed, was to approximate the reality of weaning management carried out in Brazilian commercial farms and to observe if the exposure

Table II. Performance of suckling piglets classified as eaters (E) or non-eaters (NE).

Variable	Treatments		SEM	CV, %	p-value
	Eater	Non-eater			
Initial weight, kg	4.661	4.681	0.271	21.22	0.894^{ns}
Weight at 3d, kg	5.328	5.423	0.305	20.91	0.590^{ns}
Weight at 6 d, kg	6.067	6.249	0.346	20.97	0.368^{ns}
Weight at 10 d, kg	7.431	7.263	0.423	20.84	0.462^{ns}
Weight at 12 d, kg	7.783	7.981	0.456	20.95	0.421^{ns}
ADG 0-12 d, kg	0.260	0.275	0.017	25.33	0.155^{ns}

E: Piglet that had at least 1 positive rectal swab before starting the nursery phase; NE: Piglet that did not show any positive rectal swab before starting the nursery phase; d: Days of the experiment; ADG: Average daily gain; SEM: Standard error of the mean; CV: Coefficient of variation; ^{ns}: Not significant.

to feed prior weaning was able to affect the subsequent performance of piglets.

One of the most significant challenges when starting the nursery period is to stimulate feed intake in piglets. Prolonged fasting can have numerous negative effects, including impaired weight gain, health problems, intestinal epithelium degradation, and stress, ultimately leading to fallbacks (Caron & Beirão 2020, Byrgesen et al. 2021). In this experiment, it was observed that E piglets showed greater adaptation to the diet (Table III) represented by faster feed intake in the nursery phase (250.00%, *P* =0.036) in the first 24 hours, when compared to those in the NE group. The difference in the number of piglets consuming feed in the nursery phase between the two groups was significant from the first day. This finding supports the hypothesis that prior exposure to solid food may facilitate faster adaptation to the nursery phase diet.

In the same way that Muns & Magowan (2018) observed in their study, pigs that consumed creep feeding during pre-weaning phase had a greater ADFI during the first week after weaning (48.53%, *P* = 0.008), which reflected in a 45.89% greater weight gain in the period (*P* = 0.005) for the E group, when compared to the NE group (Table IV). This was also a finding by Kuller et al. (2007), in which a positive relationship was observed between creep feed consumption and ADFI and weight gain in the first days of the nursery phase. Although there are inconsistencies in the literature about the influence of creep feeding in the long term, in this experiment the pigs in group E showed superior performance during the entire period analyzed in the nursery phase, represented by a greater ADFI (18.33%, *P* = 0.001) and greater ADG (22.00%, *P* = 0.0003), when compared to NE.

As pig farming is primarily a commercial activity, the feasibility of implementing new management practices, such as creep feeding, is dependent on their economic viability. In this study, the piglets in group E had a higher feed cost during the analyzed period of the nursery phase (Table V), which was expected due to their increased consumption. However, despite the higher cost, pigs consuming creep feed generated a total revenue 8.75% greater (*P* = 0.0002) compared to NE, as they exhibited greater weight gain during the phase.

From an economic point of view, gains in scale are crucial to enable the viability of implementing strategies in pig production, such as the adoption of creep feeding (Alves 2021). The present study showed that the greater weight gain observed in group E, coupled with the higher sale price and greater dilution of fixed costs, neutralized the higher feed cost, demonstrating the feasibility of adopting creep

Table III. Positive swabs in the first four days of nursery according to piglets classified as eaters (E) or non-eaters (NE).

Variable, %	Treatments		CV, %	p-value
	Eater	Non-eater		
Day 1	29.17	8.33	131.88	0.036*
Day 2	83.33	41.67	58.98	0.003*
Day 3	100.00	75.00	25.28	0.003*
Day 4	100.00	95.83	10.42	0.328^{ns}

E: Piglet that had at least 1 positive rectal swab before starting the nursery phase; NE: Piglet that did not show any positive rectal swab before starting the nursery phase; CV: Coefficient of variation; *: Significant; ^{ns}: Not significant.

feeding during the pre-weaning period. An economic evaluation conducted for the first 16 days of the nursery period showed that the higher investment generated by the application of creep feeding was returned through greater economic profit (268.97%, P = 0.016), a better benefit-cost ratio (2.73%, P = 0.009), and positive return on investment (225.43%, P = 0.014), all benefits resulting from better performance.

No other studies were found in the literature that evaluated the economic viability of creep feeding. In general, economic analyzes are not included in these research methodologies due to the difficulty of measuring the consumption of feed on the pre-weaning phase, making it harder to assess the real cost of applying creep feeding. Still, there is another gap for the application of the analyzes that assess the economic viability of introducing new feed sources, which are the different methodologies for cost analysis and the lack of knowledge on how to apply them as variables in studies.

Based on the aforementioned results, creep feeding can not only improve performance and reduce nutritional stress during the pre-weaning-nursery transition but also increase economic profit, particularly for producers who sell pigs to growth and finishing units. Therefore, the implementation of creep feeding can provide a viable strategy for maximizing both animal performance and economic returns in pig farming.

CONCLUSIONS

Piglets that consume creep feed in pre-weaning phase have greater performance in the early nursery phase when compared to non-consumers, which contributes to a greater profit and its economic viability. It is necessary to look for ways to stimulate the consumption of creep feed in the pre-weaning phase.

Table IV. Performance of piglets in the first 16 days of the nursery phase classified as eaters (E) or non-eaters (NE).

Variable	Treatments		SEM	CV, %	p-value
	Eater	Non-eater			
Initial weight, kg	8.423	8.423	0.529	21.26	0.700 ^{ns}
Weight at 7 d, kg	10.538	9.871	0.536	18.11	0.007*
ADG 0-7 d, kg	0.302	0.207	0.022	34.97	0.005*
ADFI 0-7 d, kg	0.606	0.408	0.043	34.99	0.008*
F:G 0-7 d	1.997	3.087	0.816	111.07	0.520 ^{ns}
Weight at 16 d, kg	15.254	14.027	0.727	17.36	0.0002*
ADG 7-16 d, kg	0.524	0.462	0.025	18.80	0.001*
ADFI 7-16 d, kg	1.524	1.370	0.046	12.08	0.001*
F:G 7-16 d	2.936	3.049	0.126	14.46	0.631 ^{ns}
ADG 0-16 d, kg	0.427	0.350	0.017	18.10	0.0003*
ADFI 0-16 d, kg	1.123	0.949	0.040	15.77	0.001*
F:G 0-16 d	2.638	2.733	0.062	8.05	0.137 ^{ns}

E: Piglet that had at least 1 positive rectal swab before starting the nursery phase; NE: Piglet that did not show any positive rectal swab before starting the nursery phase; d: Days of the experiment; ADG: Average daily gain; ADFI: Average daily feed intake; F:G: Feed to gain ratio; SEM: Standard error of the mean; CV: Coefficient of variation; *: Significant; ^{ns}: Not significant.

Table V. Economic evaluation of piglets in the first 16 days of the nursery phase classified as eaters (E) or non-eaters (NE).

Variable	Treatments		SEM	CV, %	p-value
	Eater	Non-eater			
Purchase cost, US$	24.24	24.24	1.522	21.26	0.700^{ns}
Feed costs, US$	14.45	12.05	0.547	16.78	0.001*
Other costs, US$	4.51	4.51	0.000	0.00	-
Total cost, US$	43.20	40.80	1.893	15.54	0.0005*
Cost per kg, US$	6.34	7.40	0.281	15.93	0.0004*
Total revenue, US$	43.91	40.37	2.093	17.36	0.0002*
Gross margin, US$	5.22	4.09	0.423	33.20	0.016*
Economic profit, US$	0.71	-0.42	0.423	1066.03	0.016*
Benefit-cost ratio	0.19	0.18	0.010	3.62	0.009*
Return on investment, %	1.445	-1.152	1.004	2489.26	0.014*

E: Piglet that had at least 1 positive rectal swab before starting the nursery phase; NE: Piglet that did not show any positive rectal swab before starting the nursery phase; SEM: Standard error of the mean; CV: Coefficient of variation; *: Significant; ^{ns}: Not significant.

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