The effect of creep feed intake and starter diet allowance on piglets' gut structure and growth performance after weaning

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ABSTRACT: Diets offered to lactating and weaned piglets are the most expensive diets within pig production; however, the effect of these diets on lifetime pig performance is inconsistent. The objective of the current study was to investigate the impact of creep feed consumption during lactation and different starter diet allowances on piglets' gut structure and lifetime growth performance. In total, 320 pigs and 80 pigs (Landrace × Large White) were used after weaning in a 2 × 2 factorial arrangement to study growth performance and gut structure, respectively. At weaning, piglets that ate creep feed and piglets that were not offered creep feed during lactation were allocated to 2 kg/pig [low level (**LL**)] or 6 kg/pig [high level (**HL**)] of starter 1 diet (16.5 MJ DE/kg, 22.5% CP, and 1.7% total Lys) allowance. At weaning and at 1 and 3 wk after weaning, 8 piglets per treatment were sacrificed, and their small intestine morphology was evaluated (villus height and crypt depth). Piglets that ate creep feed had increased feed intake during the first week after weaning ($P < 0.05$), but no effect of creep feed intake was observed on piglets growth or gut structure during the postweaning period (both $P > 0.05$). Piglets that were fed HL after weaning had higher ADG and BW from weaning to 16 wk after weaning (both $P < 0.05$) and had lower feed conversion ratio (**FCR**) from weaning to 6 wk after weaning ($P < 0.05$). Piglets fed HL after weaning also had higher villi height and greater crypt depth than LL piglets at 3 wk after weaning (both $P < 0.05$). Creep feed consumption during lactation increases feed intake early after weaning, suggesting an improved capacity of piglets to cope with weaning, but did not influence their growth performance. Offering piglets 6 kg of starter diet enhances piglets' growth performance during the growing and finishing phase, probably by improving gut structure after weaning.

Key words: creep feed, feed intake, gut histology, pig, starter diet, weaning

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INTRODUCTION

Weaning is arguably the most stressful and challenging episode during the pig production cycle, resulting in anorexia, growth impairment, health problems, or impairment of gut structure (Pluske et al., 1995; Kim et al., 2012). Besides, growth performance after weaning it is known to influence piglets' performance until slaughter (Tokach et al., 1992; Magowan et al., 2011b).

Piglets are frequently offered a highly palatable and digestible diet (creep feed) during lactation. Despite highly variable creep feed consumption (Wattanakul et al., 2005), creep feed increases feed intake and BW gain early after weaning (Bruininx et al., 2004; Sulabo et al., 2010; van den Brand et al., 2014), suggesting that creep feed consumption might familiarize piglets with a solid diet (Bruininx et al., 2002). In addition, Kuller et al. (2007b) found that piglets eating creep feed during lactation had a higher small intestine net absorption capacity 4 d after weaning. However, there is a lack of research on the impact of creep feed intake on piglets' gut structure.

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Then, piglets are offered a first starter diet (up to 20% of lactic products) during the first 1 to 2 wk after weaning followed by a second starter diet (up to 10% of lactic products) offered until animals reach 15 kg BW. Previous studies found that feeding nutrient-dense diets improved piglets' performance early after weaning (Mahan et al. 1998; Whang et al., 2000; Lawlor et al., 2002; Wolter et al., 2003). However, it has been suggested that no benefit should be expected from feeding more than 1 kg/pig of starter diet during the first 2 wk after weaning (Leliveld et al., 2013).

Starter diets have an elevated cost and are usually offered ad libitum. Information on the optimum or minimum amount of starter diet allowance necessary to optimize postweaning feeding, and growth is relevant for producers to increase efficiency and productivity. However, there is a lack of scientific studies on the use of different starter diet allowances postweaning. Therefore, the study aims to investigate whether creep feed offered during lactation and the different starter diet allowance after weaning have an effect on piglet's gut structure and growth performance to slaughter.

MATERIALS AND METHODS

Experimental Design

The study was conducted at the 150-sow experimental farm on Agri-Food and Biosciences Institute (AFBI), Hillsborough (Northern Ireland), under the regulations of Department of Health, Social Services and Public Safety of Northern Ireland in accordance with the Animals (Scientific Procedures) Act of 1986 (The Parliament of the United Kingdom, 1986). The experimental farm operates on a 3-wk batch farrowing system. The experiment followed a 2 × 2 factorial arrangement with 10 replicates per treatment group. A total of 531 pigs from 51 sows (Landrace × Large White bred in the same farm) were initially used during lactation. From them, 400 piglets were finally used after weaning. The factors used were creep feed (no creep feed offered or creep feed offered during lactation) and postweaning starter 1 diet allowance level [low level (**LL**) or high level (**HL**) of a starter 1 diet allowance offered after weaning].

Animal Management

At day 109 of gestation, sows were moved to a climate controlled (21.0 °C) farrowing room and allocated to individual farrowing crates (0.5 by 2.2 m), each one placed at the center of a farrowing pen (2.3 by 1.5 m). The farrowing pens were equipped with a feeder for the sow and separate water drinkers for the sow and piglets. Attached to the front of each pen, there was a shelter box (1.5 by 0.6 m) for piglets with access from the top and equipped with a heating lamp (heated forward creep area). Sows were fed, 3 times a day, a commercial lactation diet (94.2% DM, 18.9% CP, 3.5% crude fat, 3.7% crude fiber, and 5.1% crude ash). On the farrowing day, sows were offered 2.5 kg of the lactation diet, and the amount offered increased by 0.5 kg daily until 10 kg/d was reached.

Sows were allowed to farrow naturally; drying paper and 2 heating lamps were placed at the back of the pen during the farrowing day. Within the first 12 h after birth, the piglets received 2 mL of an iron supplement (Uniferon; Virbac Ltd., Suffolk, UK), and their tails were docked and their teeth were clipped. The tail and umbilical area was sprayed with iodine. Cross-fostering of piglets between litters was performed within the first 24 h after birth to fix litters at 11 piglets. Piglets were weaned at 28 ± 2 d of age.

At weaning, the pigs were transferred to a nursery accommodation with plastic slatted floors. Room temperature was maintained at 28 °C on the first day after weaning and was reduced by 0.5 °C daily to a minimum of 18 °C. Weaned pigs were housed in pens in groups of 8 (0.38 m^2/pig); each pen had 1 dry multispace feeder (Etra Feeders, Northern Ireland) and 1 bowl drinker. At 10 wk of age, the pigs were transferred to a finishing accommodation with fully slatted concrete flooring, where they remained until slaughter (100 kg BW). Pigs were housed in pens in groups of 8 (0.61 m^2/pig). From 10 wk of age until slaughter, pigs were offered feed via a "wet and dry" single space shelf feeder (Verba, Verbakel, The Netherlands). Each pen had 1 single space shelf feeder and 1 bowl drinker. Pigs were exposed to natural lighting through windows and artificial lighting for 16 h/d.

Experimental Management

Piglets were individually identified with an ear tag and weighed at birth, at 10 d before weaning, and at weaning. Ten days before weaning, litters were allocated to 1 of the 2 treatments according to parity, litter size, litter weight, and average piglet weight: 1) no creep feed offered during lactation

(n = 22 litters) or 2) creep feed (16.5 MJ DE/kg, 22.5% CP, and 1.7% total Lys) offered ad libitum during the last 10 d of lactation (n = 29 litters). The creep feed (cooked wheat, lactose, whey powder, soya protein concentrate, cooked extruded soya, cooked oats, milk albumin, dextrose, fishmeal, soya oil, palm oil, vitamin, and trace minerals) was offered daily on the floor at the heated forward creep area. Both the amount of creep feed offered and the leftovers were recorded daily to obtain the daily creep feed intake of the litter. Chromium oxide (Cr_2O_3) was included in the creep feed at 1% as an indigestible marker. At days 23, 25, and 27 of lactation, the color of piglets' feces was examined on an individual basis after extraction using a fecal loop. Pigs with green feces on 2 out of the 3 occasions were classified as "eaters," piglets with green faces on 1 occasion were classified as "moderate eaters," and piglets not showing green faces any of the occasions were classified as "noneaters."

Growth Performance

At weaning, a total of 320 piglets were monitored to evaluate growth performance. The final number was obtained after selecting the piglets classified as "eaters" and "moderate eaters," and after excluding, all animals below 6.5 kg of live weight among the litters offered creep feed. As a result, 160 piglets from the litters offered creep feed were selected. Accordingly, 160 piglets from the litters not offered creep feed were also selected balancing treatments for live weight, sex, and parity of origin. Selected piglets were allocated to 1 of the 2 postweaning starter 1 diet allowance level according to their weight, sex, and litter of origin; LL pigs received 2 kg/pig of a starter 1 diet and HL pigs received 6 kg/pig of a starter 1 diet. The starter 1 diet used in the experiment was the same as the creep feed diet. After the animals consumed their respective amount of starter 1 diet, they were all offered 6 kg/pig of a starter 2 diet (16.3 MJ DE/kg, 21.5% CP, and 1.6% total Lys; wheat, lactose, cooked wheat, cooked extruded soya, cooked oats, fishmeal, calcium carbonate, vitamin, and trace minerals). Following the starter 2 diet, all pigs were offered a grower diet (14.0 MJ DE/kg, 18.6% CP, and 1.2% total Lys; wheat, soya based diet) to 6 wk after weaning (10 wk of age) and then a standard finisher diet (13.5 MJ DE/kg, 16.7% CP, and 0.95% total Lys; wheat barley, soya-based diet) to slaughter. Feed intake was measured from food disappearance of each pen, and it was recorded daily until day 12 after weaning and at 3, 6, 11, and 16 wk after weaning (7, 10, 15, and 20 wk of age, respectively). Pigs were individually weighed at 1, 3, 6, and 16 wk after weaning.

Gut Structure

In addition to the 320 piglets used to study growth performance, 40 additional piglets from the litters not offered creep feed and 40 piglets from the litters offered creep feed and classified as "eaters" were selected at weaning (80 piglets in total) to evaluate gut structure. Eight piglets from each group were sacrificed at weaning to examine the gut structure. The rest of the piglets (64 piglets in total) were allocated to 1 of the 2 postweaning starter 1 diet allowance levels according to the experimental design and as described in Growth Performance. Piglets were weighed at 1 and 3 wk after weaning (5 and 7 wk of age). At 1 and 3 wk after weaning, 8 piglets per group were sacrificed to examine the gut structure. Sacrificed piglets were first stunned by captive bolt and exsanguinated by incision of the jugular veins and carotid arteries. The entire gastrointestinal tract was immediately removed, and 3 transverse segments were taken from the proximal duodenum (10 to 15 cm from the pylorus), mid-jejunum, and distal end of the ileum (10 to 15 cm from the ileocecal junction). The transverse segments were placed into 10% neutral buffered formaldehyde (pH 7.4) and fixed for 48 h. Then, the transverse segments were prepared using standard paraffin embedding techniques. Finally, the transverse segments were sectioned at 5 µm thickness, stained with hematoxylin and eosin, and examined under a light microscope. On each stained section, villus height and crypt depth were measured using a calibrated eyepiece graticule. A minimum of 15 straight intact villi and crypts in each intestinal section were measured. Villi height was measured from the tip to the crypt–villi junction, and the depth of the crypt was measured from the crypt–villi junction to the base; then, the villi height-to-crypt depth (**V:C**) ratio was calculated.

Statistical Analysis

All data were checked for normality and homogeneity of variance before being analyzed by general linear mixed models. For the analysis of the data performed at weaning, creep feed administration was introduced as main effect. Piglet's sex was introduced as fixed factor when significant, and birth weight of the piglets was introduced as a covariate when significant. Sow was introduced as random effect and nested to treatment to correct for clustering of piglets within litters and to correct for confounding factors at the sow level. For data recorded after weaning, creep feed administration and postweaning starter 1 diet allowance were introduced as main effects in all the analysis. The interaction between the 2 main effects was also included. Farrowing or production batch number was introduced as fixed factor in all the models (for weaning and after weaning data). Weaning weight of the piglets was introduced as a covariate when significant. The effect of creep feed and starter 1 diet allowance on piglet's BW and feed intake after weaning was analyzed as repeated measures. For the effect of creep feed administration on gut morphology at weaning and 1 and 3 wk after weaning, weaning weight was introduced as a covariate when significant. The pen was considered as the statistical unit in all the analysis, except for the gut structure data in which the piglet was the statistical unit. The Genstat version 10.1 statistics package was used for the statistical analysis. The alpha level of significance was set at 0.05.

RESULTS

Growth Performance

The average preweaning mortality was 5.5%, and the average litter size at weaning was 10 ± 1.1; no creep feed effect was observed (*P* = 0.787 and *P* = 0.988, respectively). In litters offered creep feed from 10 d before weaning, 83% of the piglets were classified as "eaters" (41% boars and 42% gilts), 6% of the piglets were "noneaters," and 11% were "moderate eaters." Litters offered creep feed had an average creep feed intake of 6.2 ± 3.3 kg. Piglet's BW was 1.60 ± 0.059 kg at birth, 6.40 ± 0.192 kg at 10 d before weaning, and 9.41 ± 0.091 kg at weaning; no effect of creep feed was observed (*P* = 0.529, *P* = 0.894, and *P* = 0.144, respectively). Moreover, no effect of creep feed was observed for piglets ADG during the last 10 d of lactation (average value of 307 ± 8.9 g; *P* = 0.164).

Table 1. Effect of creep feed offered during the last 10 d of lactation and the effect of starter 1 diet allowance offered after weaning on piglets' BW, ADG, ADFI, and feed conversion ratio (FCR)

	Creep[1]		No creep[2]			*P*-values		
	LL[3]	HL[4]	LL	HL	SEM	Creep/no creep	LL/HL	Interaction
No. of piglets/no. of pens	*80/10*	*80/10*	*80/10*	*80/10*				
Body weight, kg								
Weaning	9.68	9.57	9.55	9.45	0.083	0.990	0.884	0.952
1 wk after weaning	10.73	10.53	10.37	10.40	0.138	0.870	0.917	0.418
3 wk after weaning	17.05	17.25	16.39	17.09	0.233	0.539	0.991	0.288
6 wk after weaning	30.55	30.70	29.18	30.67	0.481	0.588	0.554	0.175
16 wk after weaning	87.81	88.10	85.82	89.08	1.092	0.628	0.015	0.185
Average daily gain, g								
Wean—1 wk after wean	164	150	129	156	21.2	0.500	0.824	0.349
Wean—3 wk after wean	369	384	342	383	11.6	0.226	0.022	0.288
Wean—6 wk after wean	509	515	479	518	11.2	0.227	0.052	0.157
Wean—16 wk after wean	711	722	694	728	10.5	0.605	0.036	0.273
ADFI, g								
Wean—1 wk after wean	210	199	169	178	9.7	0.004	0.910	0.290
Wean—3 wk after wean	430	419	400	407	11.2	0.070	0.859	0.434
Wean—6 wk after wean	741	723	702	716	16.8	0.180	0.890	0.356
Wean—16 wk after wean	1,496	1,495	1,484	1,515	28.7	0.895	0.602	0.591
FCR								
Wean—1 wk after wean	1.55	2.33	1.79	1.16	0.534	0.393	0.889	0.194
Wean—3 wk after wean	1.17	1.10	1.18	1.07	0.029	0.766	0.005	0.489
Wean—6 wk after wean	1.46	1.40	1.47	1.38	0.027	0.915	0.013	0.576
Wean—16 wk after wean	2.11	2.07	2.14	2.08	0.024	0.340	0.054	0.664

[1]Creep = creep feed offered during lactation.

[2]No creep = no creep feed offered during lactation.

[3]LL = pigs received 2 kg/pig of a starter 1 diet.

[4]HL = pigs received 6 kg/pig of a starter 1 diet.

Treatment effects on piglets' BW, ADG, feed intake, and feed conversion ratio (**FCR**) are presented in Table 1. There was no effect of the interaction observed ($P > 0.05$). Creep feed offered during lactation had no effect ($P > 0.05$) on piglets' BW, ADG, or FCR after weaning. Nonetheless, piglets that ate creep feed during lactation had higher ADFI during the first week after weaning than piglets not offered creep feed ($P < 0.05$). However, the creep feed effect on ADFI was not maintained until the end of the experiment ($P > 0.05$). Figure 1 shows the effect of creep feed offered to piglets during the last 10 d of lactation on piglets' ADFI from the first day after weaning until day 12. Piglets that ate creep feed during lactation showed a tendency for higher feed intake on days 4, 10, and 11 after weaning (all $P < 0.10$). Piglets that ate creep feed during lactation also had higher feed intake on d 5, 6, and 12 after weaning (all $P < 0.05$).

Piglets offered HL of starter 1 diet had higher BW at 16 wk after weaning than LL piglets ($P < 0.05$). In addition, piglets offered HL of starter 1 diet had increased ADG from weaning up to 16 wk after weaning ($P < 0.05$), had lower FCR up to 6 wk after weaning ($P < 0.05$), and showed a tendency for reduced FCR from weaning to 16 wk after weaning ($P < 0.10$). However, no starter 1 diet allowance effect was observed from weaning to the first week after weaning for ADG or FCR (both $P > 0.05$). No starter 1 diet allowance effect was observed in piglets' ADFI during the experimental period ($P > 0.05$).

Gut Structure

No difference between pigs that ate creep feed and pigs that were not offered creep feed during lactation was observed at weaning: villi height was 468 vs. 501 ± 24.2 μm ($P = 0.357$), 303 vs. 335 ± 20.1 μm ($P = 0.278$), and 369 vs. 378 ± 15.8 μm ($P = 0.689$) at the duodenum, ileum, and jejunum, respectively; crypt depth was 221 vs. 223 ± 11.2 μm, 142 vs. 158 ± 9.0 μm, and 181 vs. 189 ± 12.1 μm at the duodenum, ileum, and jejunum, respectively; V:C ratio was 2.15 vs. 2.33 ± 0.104, 2.14 vs. 2.14 ± 0.087, and 2.07 vs. 2.06 ± 0.142 at the duodenum, ileum, and jejunum, respectively.

Treatment effects on piglets' gut structure obtained from the duodenum, jejunum, and ileum sections measured at 5 and 7 wk of age (1 and 3 wk after weaning) are presented in Table 2.

At 1 wk after weaning, there was an interaction effect on the V:C ratio in the jejunum and ileum sections (both $P < 0.05$). Piglets that ate creep feed during the last 10 d of lactation and were HL after weaning had a higher ileum V:C ratio than piglets that ate creep feed and were LL after weaning and piglets that were not offered creep feed and were HL after weaning (both $P < 0.05$). On the other hand, piglets that ate creep feed and were HL after weaning had a lower jejunum V:C ratio than piglets that were not offered creep feed and were HL after weaning ($P < 0.05$).

At 3 wk after weaning, pigs offered HL after weaning had higher duodenum villi height (536 vs. 461 ± 16.2 μm; $P < 0.05$) and higher crypt depth (216 vs. 200 ± 5.6 μm; $P < 0.05$) than pigs offered LL. Pigs offered creep feed during lactation showed lower jejunum villi height (330 vs. 364 ± 10.3 μm; $P < 0.05$) than pigs that did not eat creep feed. No interaction or main effects were observed on the rest of the gut structure parameters measured after weaning.

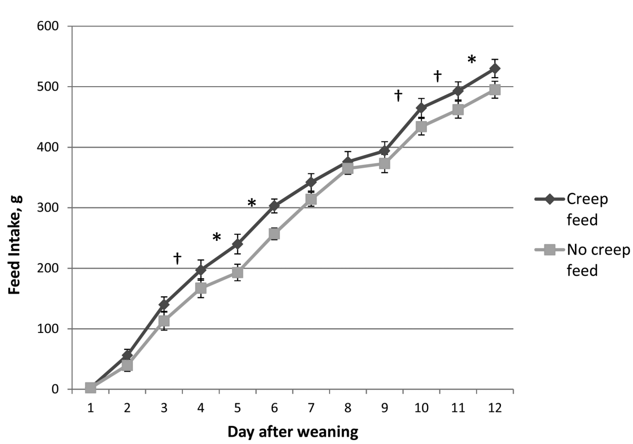

Figure 1. Effect of creep feed offered to piglets during the last 10 d of lactation on piglets' ADFI from the first day after weaning until day 12. *Values in the figure significantly differ ($P < 0.05$); †values in the figure tend to differ ($P < 0.10$).

DISCUSSION

Growth Performance

In the present study, piglets that ate creep feed during lactation did not differ from piglets not offered creep feed in their BW, ADG, or FCR after weaning. Nonetheless, creep feed consumption positively influenced ADFI during the first 3 wk after weaning, especially during the first 12 d. However, feed intake from weaning to the end of the experiment was not affected by creep feed offered to piglets during lactation. As we observed in the present study, it is usually assumed that creep feed does not have an impact on piglet growth at weaning but might contribute to familiarize piglets with a

Table 2. Effect of creep feed offered during the last 10 d of lactation and the effect of starter 1 diet allowance offered after weaning on piglets' gut structure obtained from the duodenum, ileum, and jejunum sections measured at 5 and 7 wk of age (1 and 3 wk after weaning)

	Creep[1]		No creep[2]			*P*-values		
	LL[3]	HL[4]	LL	HL	SEM	Creep/no creep	LL/HL	Interaction
Duodenum 5 wk of age								
Villi height, µm	421	448	447	467	25.4	0.390	0.355	0.889
Crypt depth, µm	197	190	195	202	8.4	0.586	0.995	0.391
Villi:crypt ratio	2.14	2.36	2.30	2.36	0.093	0.417	0.132	0.376
Duodenum 7 wk of age								
Villi height, µm	446	514	476	558	22.9	0.115	0.003	0.755
Crypt depth, µm	198	208	202	225	7.9	0.175	0.048	0.422
Villi:crypt ratio	2.30	2.50	2.36	2.50	0.100	0.808	0.104	0.758
Ileum 5 wk of age								
Villi height, µm	311	323	310	324	11.3	0.990	0.254	0.976
Crypt depth, µm	161	155	153	167	5.4	0.750	0.463	0.070
Villi:crypt ratio	1.93[b]	2.10[a]	2.03[ab]	1.95[b]	0.050	0.615	0.428	0.018
Ileum 7 wk of age								
Villi height, µm	360	363	340	351	13.3	0.225	0.619	0.765
Crypt depth, µm	172	169	162	182	6.5	0.875	0.200	0.100
Villi:crypt ratio	2.10	2.16	2.11	1.96	0.070	0.183	0.561	0.151
Jejunum 5 wk of age								
Villi height, µm	325	334	346	382	14.5	0.026	0.125	0.375
Crypt depth, µm	176	198	190	193	8.6	0.634	0.157	0.280
Villi:crypt ratio	1.84[ab]	1.70[b]	1.83[ab]	1.99[a]	0.058	0.022	0.847	0.014
Jejunum 7 wk of age								
Villi height, µm	388	431	409	410	12.7	0.994	0.098	0.113
Crypt depth, µm	198	211	217	204	10.79	0.614	0.975	0.255
Villi:crypt ratio	1.99	2.07	1.91	2.02	0.083	0.459	0.253	0.899

[1]Creep = creep feed offered during lactation.

[2]No creep = no creep feed offered during lactation.

[3]LL = pigs received 2 kg/pig of a starter 1 diet.

[4]HL = pigs received 6 kg/pig of a starter 1 diet.

solid diet [see reviews of Muns Vila and Tummaruk (2016) and Solà-Oriol et al. (2016)]. Similar to our study, it has been found that piglets eating creep feed during lactation had higher feed intake and BW gain during the first days after weaning but did not affect piglet's growth up to slaughter (Bruininx et al., 2002, 2004; Kuller et al., 2004, 2007a; Sulabo et al., 2010; van den Brand et al., 2014). However, in the present study, no effect of creep feed on BW after weaning was observed. The low amount of feed consumed during the first week after weaning, although differing between groups, could explain the lack of creep feed effect on piglet's BW after weaning.

In the present study, there was no effect of starter 1 diet allowance after weaning on piglets ADFI. Nonetheless, piglets offered HL of starter 1 diet allowance had reduced FCR after the first week after weaning, resulting in higher ADG and BW at 16 wk of age. In 2 similar studies, with very similar production and environment conditions, Magowan et al. (2011a,b) also observed an increased ADG and reduced FCR from weaning to 6 wk after weaning in piglets offered a high allowance of starter diet. In their study, a slightly less dense starter diet (15.8 MJ DE/kg, 20% CP, and 1.6% Lys) was used and pigs were fed 6 or 12 kg of starter diet allowance. In those 2 studies, and also in Lawlor et al. (2002), the increase in FCR was also linked to a reduction in ADFI (attributed to the higher allowance of a more nutrient-dense diet received by HL pigs after weaning). However, in the present study, it was not observed a reduction in ADFI. The improved FCR in our study could be related to an improvement of piglets' capacity to obtain nutrients from diets, as suggested by the allowance effect on duodenum gut structure at 7 wk of age. However, no improvements in the gut structure were observed at the other segments or sampling times, and therefore, future work would be required to understand why FCR was improved without observing a reduction in ADFI. In another study, Lawlor et al. (2002)

observed an improved FCR, ADG, and reduced ADFI at 26 d after weaning in pigs offered 10 vs. 4 kg of a starter diet (16.1 MJ DE/kg and 1.7% Lys). Other studies monitoring piglets until slaughter also reported that high-quality or complex diets offered after weaning improved ADG and FCR up to 8 wk after weaning but had no influence on piglets performance at slaughter (Whang et al., 2000; Wolter et al., 2003). The differences in the designs and the genetic improvements with time make those results difficult to compare with the present study. In the present study, the high-allowance treatment (6 kg of starter 1 diet per pig) was lower than most of the starter diet-allowance treatments used in the studies mentioned above, and still, an improvement in piglets' growth performance up to 16 wk after weaning was observed. Our results show that it is not necessary to provide starter diet allowances up to 10 or 12 kg/pig after weaning to observe a long-term impact on pigs FCR, but that to provide only 2 kg/pig might not be enough. Our results are in agreement with the recent study of Leliveld et al. (2013), which suggests that nutrient specification of phase 1 and phase 2 diets currently used in the United Kingdom and Ireland are unnecessarily high. However, Leliveld et al. (2013) reported little effect of any of their allocation levels of phase 1 and phase 2 diets on postweaning performance. The discrepancy could be attributed to the fact that they allocated pigs in pairs rather than in bigger commercial-like groups. Pigs in bigger pen groups, with competition around the feeder, might benefit from higher allocations levels of postweaning diets. Provision of creep feeding during lactation could also be an influencing factor, but we cannot be sure whether they gave creep feed or not, and the lack of interaction effect after weaning observed in the present study does not support it.

Gut Structure

Piglets usually exhibit villus atrophy and crypt hyperplasia (reduced villus height, crypt depth, and V:C ratio) after weaning due to a sudden change in the diet and very low feed intake (Pluske et al., 1995). Miller et al. (1986) observed a reduction of villi height in piglets weaned at either 4 or 6 wk of age compared with unweaned piglets of the same age. Pluske et al. (1997) and Kim et al. (2012) also identified a reduction in villi height in piglets after weaning.

In the present study, a higher V:C ratio in the ileum was observed at 1 wk after weaning in piglets that ate creep feed during lactation and were offered HL of starter 1 diet allowance compared with piglets not offered creep feed and that were offered LL of starter 1 diet and to piglets that were not offered creep feed and had HL of starter 1 diet. On the contrary, a lower V:C ratio in the jejunum was observed in piglets that ate creep feed during lactation and were offered HL of starter 1 diet compared with piglets that were not offered creep feed and had HL of starter 1 diet. Creep feed offered to piglets during the last 10 d of lactation had no effect on piglet's gut structure at any of the 3 sampling times during the experiment. The contradictory nature of the interaction effect observed at the ileum and jejunum for the V:C ratio at 1 wk after weaning together with the lack of treatment effects on villi height and crypt depth on all the gut segments at 1 wk after weaning might suggest that creep feed consumption and/or higher allowance of starter 1 diet do not mitigate the gut atrophy that occurred due to the weaning process. In agreement with the present study, Bruininx et al. (2004) found that creep feed did not prevent the damage of the gut mucosa despite improving piglets' early postweaning performance. In another study, Kuller et al. (2007b) observed increased in vitro net absorption in the small intestine of weaned piglets that ate creep feed during lactation. However, the present results suggest that creep feed intake during lactation does not reduce gut structure atrophy due to weaning but familiarizes piglets with solid feed, hence increasing postweaning feed intake.

On the other hand, at 3 wk after weaning, piglets offered HL of starter 1 diet allowance had higher villi height than piglets offered LL of starter 1 diet, irrespective of the creep feed consumption. The observed improvement in gut morphology is consistent with the lower FCR and higher BW at 16 wk after weaning also observed in the present study. Together with the improved ADG and lack of effect on ADFI from weaning to 16 wk after weaning suggest a better capacity of the piglets to obtain nutrients from diets. The temporary anorexia that piglets experience after weaning mainly due to the introduction of a dry less-digestible diet and the physical separation from the dam are pointed to as the main causes of the alterations in the gut epithelial structure (Pluske et al., 1995). We did not measure intestinal pH or lactic acid concentration, we suggest that offering piglets a highly digestible diet, rich in lactic products, at 6 kg/pig instead of 2 kg/pig after weaning could contribute to creating a gut environment more suitable for epithelial cell proliferation (e.g., less substrate available for pathogen growth and/or reduced ammonia nitrogen production).

CONCLUSIONS

To our knowledge, this is one of the first studies on the effect of creep feed consumption on gut structure at weaning and after weaning. Nonetheless, the limited evidence suggests that the benefits of creep feed consumption during lactation on piglets' early postweaning performance is not related to a reduction of the gut structure atrophy, but it confirms the importance of creep feed intake on the acceptance and intake of solid feed after weaning. Although creep feed intake during lactation does not influence piglet's growth until slaughter, the increase in feed intake early after weaning proves the importance of creep feed intake in helping piglets to cope with weaning, presumably with a positive impact on piglet's welfare. Our results confirm the importance of offering piglets a highly digestible starter diet, rich in lactic products, to improve piglets' growing and finishing growth performance. Besides, the starter diet allowance of 6 kg/pig used in the present study (a lower "high level" of starter diet allowance than the ones studied in the recent literature) demonstrates that there is scope for action in optimizing postweaning feeding without compromising piglets' performance. Nonetheless, further studies on the costs and benefits associated with offering differing feed allowances and diet densities after weaning are of great interest to identify the best strategies.

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