Consequences of intermittent suckling for performance in the pig

To eat or not to eat, that's the question!

Wikke Kuller

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Consequences of intermittent suckling for performance in the pig

De gevolgen van tijdelijk spenen voor de voeropname en groei van biggen
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. J.C. Stoof , ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op dinsdag 5 februari 2008 des middags te 4.15 uur

door Wikke Iduna Kuller

geboren op 28 februari 1977 te Naarden

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Voor Barend.

Contents

Chapter 1

General Introduction

General introduction

In this thesis the hypothesis will be tested that early adaptation of solid piglets to a solid diet for young piglets during lactation by imposing an intermittent suckling regimen during lactation will improve performance of weanling pigs.

In modern pig industry in Europe, piglets are usually weaned between 3 and 5 weeks of age. This abrupt weaning confronts the weanling pig with several changes, like environmental, and social and dietary ones. As a result of these changes, feed intake shortly after weaning is low and growth is impaired (Pluske et al., 1997). In addition, piglets become more vulnerable to develop (mild or severe) post weaning diarrhoea and even occasionally die (Taylor, 1999). The period of fasting shortly after weaning is detrimental for gut morphology (Pluske et al., 1997; Spreeuwenberg et al., 2001; Verdonk et al., 2001) and it is known that irregular feed intake shortly after weaning may hamper the smooth development of (protein) digestive capacity after weaning (Makkink, 1993). So, not only the lack of digestive or absorptive capacity of the recently weaned piglet hampers growth, but also the low feed intake after weaning contributes to the growth check. It is suggested that offering creep feed during lactation could prepare the young piglets more adequately for a life separated from the sow (Aherne et al., 1982; Pluske et al., 1996). English (1980) showed that the piglets offered creep feed consumed on average 610 g.piglet^{-1} during lactation and had better performance after weaning than the control piglets without access to creep feed during lactation. Nabuurs (1996) showed that offering creep feed (although not quantified) to temporarily weaned piglets during lactation partially prevented the decrease in villous height and the concomitant decrease in net absorption normally observed after weaning. Bruininx (2002) showed that familiarity with creep feed during lactation encouraged piglets to start eating shortly after weaning. So, stimulation of creep feed intake during lactation is important to enhance feed intake after weaning thereby minimizing changes in the gastro-intestinal tract and optimizing performance of piglets after weaning. However, creep feed intake during lactation is usually low and is also highly variable between and within litters (Aherne et al., 1982; Appleby et al., 1992; Barnett et al., 1989) and therefore a management technique to stimulate feed intake during lactation is needed. This thesis answers the question if a management system of intermittent suckling (IS) can stimulate creep feed intake in young suckling piglets. In the IS regimen used this thesis, sow and piglets will be separated for 12 h/day (0930 to 2130 h) during the last 11 days of a 25 day lactational period. It is

hypothesised that the imposed reduction in exposure to the udder will result in les total milk intake during 24 hours and will therefore stimulate creep feed intake by the piglets during lactation.

Questions addressed in this thesis are:

1. Does intermittent suckling (IS) stimulate *creep feed intake* during lactation and after weaning?
    a. Does IS increase average feed intake at a litter level during lactation and after weaning?
    b. Does IS reduce the number of litters with low creep feed intake during lactation?
    c. Does IS affect the number of eaters and non eaters within litters during lactation?
    d. Does IS affect feeding behaviour of piglets during lactation and shortly after weaning?
2. Does IS affect *weight gain* of piglets during lactation and after weaning?
3. Does IS affect *piglet behaviour* in general of piglets during lactation and shortly after weaning?

The first experiment (Chapter 2) will focus on the question if IS applied during lactation stimulates creep feed intake in suckling piglets during lactation and shortly after weaning (first 7 d after weaning). The distribution of litters over various categories of feed intake will also be determined. Further, the effects of IS on weight gain of the piglets and on reproductive performance and weight change of the sow will be reported.

In the second experiment (Chapter 3, 5 and 6), the effects of IS applied during lactation on performance (weight gain and feed intake) of pigs until slaughter and on behaviour of piglets during lactation and shortly after weaning will be studied. Moreover, a marker (chromic oxide) will be added to the creep feed in order to distinguish creep feed eating piglets (eaters) from non creep feed eating piglets (non eaters) within litters during lactation (Chapter 3). In this way, distribution of eaters and non eaters within litters can be determined and performance of eaters and non eaters can be assessed until slaughter (Chapter 3). The third experiment (Chapter 4) was designed to further evaluate the use of chromic oxide as a marker to select eaters and non eaters during lactation.

Chapter 5 describes the feed intake and nursing behaviour of piglets in the control and intermittent suckling group as well as of litters with high and low feed intake. Frequency, average time per event and total time per day of each feeder visit and nursing will be

assessed from video recordings. Also non feeding related behaviour/activity of piglets will be quantified. The results of the non feeding related behaviour such as exploring (at any place in the pen), redirected oral behaviour (manipulating or biting another piglet) and fighting will be presented and discussed in the General discussion, because they are beyond the scope of Chapter 5.

Our results of the first and second experiment on weight and weight gains suggested a relationship between IS and/or creep feed intake and gut physiology. Therefore, a pilot study on the relation between feed intake and net absorption is presented in Chapter 6. Piglets designated as eaters or non eaters during lactation are selected at day 4 after weaning and submitted to a small intestine segment perfusion test (Nabuurs et al., 1993) in order to study net absorption in the small intestine. The added value of the experiment described in Chapter 6 will be that piglets with a known history of eating versus non eating will be used whereas Nabuurs (Nabuurs et al., 1996) investigated the effect of creep feeding during lactation on net absorption but actual creep feed intake was not assessed.

Finally, in the General Discussion results from the different experiments are integrated and discussed. Not only effects on piglet performance and behaviour but also the effects of IS on the reproductive performance of the sow will be discussed and suggestions for further research will be given.

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Chapter 2

Intermittent suckling: effects on piglet and sow performance before and after weaning

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ABSTRACT

An experiment was conducted to study effects of intermittent suckling on creep feed intake and weight gain of litters. Loss of weight and backfat during lactation, as well as reproductive performance, were also measured. Batches of multiparous sows (parity 1 to 12, 4.1 on average) were either suckled intermittently (IS, 8 batches; n = 50) or continuously (control, 8 batches; n = 62). Litters were weaned at 27 d ± 2 of age on average. Litter size (11.1 ± 0.2 piglets on average) was standardized within a batch within 3 d of birth**.** All litters had free access to creep feed and water from 1 wk of age onwards. In the IS group, litters were separated from the sow for a period of 12 $h.d^{-1}$ (0930 to 2130), starting 11 d before weaning. Rectal ultrasonography was applied at d 3 after weaning to check the ovaries for follicle development or presence of corpora lutea. Creep feed intake of the litters during lactation was higher in IS litters than in control litters (686 ± 57 vs 314 ± 42 $g.piglet^{-1}$, $P < 0.01$). The distribution of creep feed intake shifted from a skewed one, with a majority of litters consuming less than 250 $g.piglet^{-1}$ in control litters, to a normal distribution with an average creep feed intake of 500 to 750 $g.piglet^{-1}$ in IS litters. During the 7 d after weaning, creep feed intake in IS litters was also higher (281 ± 15 vs. 204 ± 9 $g.piglet^{-1}.d^{-1}$, $P < 0.01$). ADG of piglets during lactation was negatively affected by IS, resulting in lower weight at weaning (7229 ± 140 vs. 7893 ± 145 $g.piglet^{-1}$, $P < 0.05$). During the 7 d after weaning, however, ADG was higher in IS litters (255 ± 10 vs 177 ± 8 $g.piglet.d^{-1}$, $P < 0.01$) and 7 d after weaning, the weights of the litters were similar (9011 ± 167 vs 9132 ± 164 $g.piglet^{-1}$, $P = 0.81$). IS litters that consumed little or no feed during lactation had an ADG after lactation that was higher than in control litters with comparable creep feed intake during lactation: 204 $g.d^{-1}$ vs 136 $g.d^{-1}$. Body weight loss of the sows during lactation was lower in IS sows (-10 ± 2 vs –16 ± 1 kg, $P < 0.05$). A higher percentage of IS sows ovulated during lactation (22 vs 3 %, $P < 0.01$) and also weaning to ovulation interval (excluding sows with lactational ovulation) was shorter in IS sows (4.7 ± 0.2 vs 5.3 ± 0.2 d, $P < 0.05$). We conclude that IS increased creep feed intake during lactation and that IS increased ADG after weaning, despite lower weaning weights. Ovulation during lactation was induced in 22% of the IS sows.

Keywords: Feed intake, Growth, Pig, Reproductive performance, Sow, Suckling

Introduction

In the modern pig industry, piglets are usually weaned before 4 wk of age, thus changing abruptly from a diet of highly digestible milk to a relatively poorly digestible starter diet. As a result, feed intake and growth are reduced after weaning and piglets are more vulnerable to develop diarrhea. Intake of a sufficient amount of creep feed during lactation creates a more gradual transition at weaning and can reduce post weaning disorders (English, 1980). However, creep feed consumption during lactation is usually low and is also highly variable between piglets and litters (Aherne et al., 1982; Barnett et al., 1989; Appleby et al., 1992).

One way to increase feed intake during a lactation period of 3 to 4 wk weeks could be intermittent suckling (IS), a management technique in which piglets are separated from the sow during a number of hours every day in the second part of lactation. Intermittent suckling could also improve reproductive performance of the sows by diminishing the negative energy balance of the sow during lactation and by diminishing the suckling stimulus (Foxcroft, 1992). Previous work on IS was performed during lactation periods longer than 35 d (Henderson and Hughes, 1984; Grinwich and McKay, 1985; Appleby et al., 1991) or using short separation times ranging from 3 to 6 h/d (Newton et al., 1987; Costa and Varley, 1995) and extensive research on both piglets and sow was never integrated in a single experiment.

The objective of this study was to determine the effects of intensive (12 $h.d^{-1}$) intermittent suckling during the last 11 d of a 27 d lactational period. Effects of IS on creep feed intake and weight gain of the piglets and on reproductive performance of the sow were integrated into a single experiment.

Materials and methods

Animals and housing

The experimental design was approved by the Ethical Committee of the Veterinary Faculty of Utrecht University (The Netherlands).

One hundred and twelve sows were used (Dutch Landrace (DL; n = 17), Yorkshire (Y; n = 22) and crossbred (DL x Y; n = 73)) between November, 1999, and June, 2000 . Parity ranged from 1 to 12 and was 4.1 ± 0.3 on average. During lactation, the sows were housed individually in pens (2.40 x 1.80 m) in farrowing crates (2.40 x 0.65 m). The farrowing pen consisted of 1.95 m^2 solid floor and 2.37 m^2 slatted floor. At the front of the pen there was a

piglet nest (1.08 x 0.85 m) with an infrared lamp (150 W). Control and intermittent suckling (IS) batches were housed in separate rooms during lactation. After weaning, sows were moved to a mating room and the piglets stayed in the pen. Sows were fed a commercial lactational feed based on tapioca, palm kernel expeller, soy beans (extracted), sunflower seed (extracted), rape seed (extracted)and wheat middling (9.1 MJ NE.kg^{-1}, 139 g.kg^{-1} CP, lysine 8 g.kg^{-1}) at a level of 1 % of bodyweight at farrowing plus 500 g per piglet (Dutch feeding tables, 1995), divided over three meals a day. Water was available ad libitum. Lights were on between 0730 and 2330 .

To synchronize the start of intermittent suckling within a batch, d 0 was designated as the start of data collection. intermittent suckling always started 14 d after d 0 and 11 d later (d 25) weaning took place. Piglets were born between 6 d before and 4 d after d 0. At weaning piglets were 27 ± 2 d old, on average. Litter size at birth varied from 7 to 17 piglets, but was standardized within 3 d after birth by cross- fostering within each batch (maximum range at weaning 7 to12 piglets). Litter size was 11.1 ± 1.9 after cross fostering and 10.3 ± 1.4 at weaning. Within the first 3 d after birth, piglets received an injection of 1cc of iron dextran, were identified by tattooing and males were castrated.

Creep feed that was based on milk products (34 %), soy beans, corn, sugar, vegetable oil, premix (12.8 MJ NE.kg^{-1}, 21.7 % CP, 1.46 % lysine; as-fed basis) was offered to the piglets ad libitum from d 7 onwards and given in a round piglet trough. From d 14 to d 21 a piglet feeder with two feeding spaces was used. During d 21 to d 23 a gradual change (respectively 40 %, 60 % and 100 % replacement) to another creep feed based on milk products (18.5%), barley, soy beans, corn, sugar, vegetable oil, premix (11.4 MJ NE.kg^{-1}, 17.9 % CP, 1.25 % lysine; as-fed basis) was made. This feed was given until the end of the experiment (7 d after weaning) in a feeder with four feeding places. Drinking nipples were used to give ad libitum water to the piglets.

Treatments

There were two treatments, control and intermittent suckling (IS). Sixteen weekly farrowing batches were alternately allocated to each treatment: eight control batches (total of 62 sows) and eight intermittent suckling batches (total of 50 sows). Each batch consisted of four to nine sows. In the control treatment piglets had access to the sow for 24 h/d. In the IS treatment, the piglets were separated from the sow for 12 h each day (0930 until 2130) during d 14 to d 25. Separation did not allow physical or visual contact, although sow and piglets remained in the same pen. During separation piglets were kept on approximately 2.0 m^2, including a piglet nest, a drinking nipple and a feeder.

Measurements

Piglets were weighed individually at birth, at d 0, d 7, d 14, d 21, d 25 (weaning) and 7 d after weaning, and ADG was calculated. Creep feed residuals were assessed at 2- to 3- d intervals. Because no food wastage was observed (feeder was placed on a solid floor), disappeared creep feed was considered eaten. General health parameters were checked daily. Use of medication was monitored.

Sows were weighed and P2 backfat thickness (65 mm from the midline over the last rib) was measured within a few hours after farrowing and at the day of weaning (d 25). Detection of estrus was performed two times each day from weaning onwards, at 0830 and 1600. A sow was considered in estrus when showing a standing response induced by a back pressure test in the presence of a boar. Ovarian status (follicle size, presence of corpora lutea) was assessed by using transrectal ultrasonography at d 3 after weaning and this was repeated if the sow had not shown estrus by d 7 after weaning. Detection of estrus and transrectal ultrasonography was performed by two persons. Sows were mated at first observed estrus after weaning. If weaning to mating interval was longer than 7 d and the ultrasound scan at d 3 after weaning showed the presence of corpora lutea, the weaning to ovulation interval was calculated as the weaning to mating interval minus 21 d. In animals that did not have corpora lutea on d 3 after weaning, weaning to mating interval was considered the same as weaning to ovulation interval such that the day of ovulation was the day of mating.

Statistical analysis

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Variation between sows within a batch was not regarded independent. Furthermore, only one treatment was applied per batch. Therefore, batch was the experimental unit. Treatment effects were tested against variation between batches. Data were obtained on a litter basis, but were expressed on piglet basis. Average daily creep feed intake (ADCFI) of the piglets, ADG of the piglets and piglet weight were analyzed as litter characteristics using the following model: $Y_{ij} = \mu + T_i + B_j (T_i) + a + bw + e_{ij}$ with T_i = treatment, B_j = batch (nested within treatment), a = age of the piglets in relation to d 0 and bw= birth weight of the piglets. ADCFI of the piglets during lactation tended to affect ADG of the piglets after weaning differently in the two treatment groups ($P = 0.06$). This interaction (T_i x ADCFI) was therefore included in the analysis for ADG after weaning. Weight change of the sow, weaning to mating- and weaning to ovulation interval were analyzed using the following model:

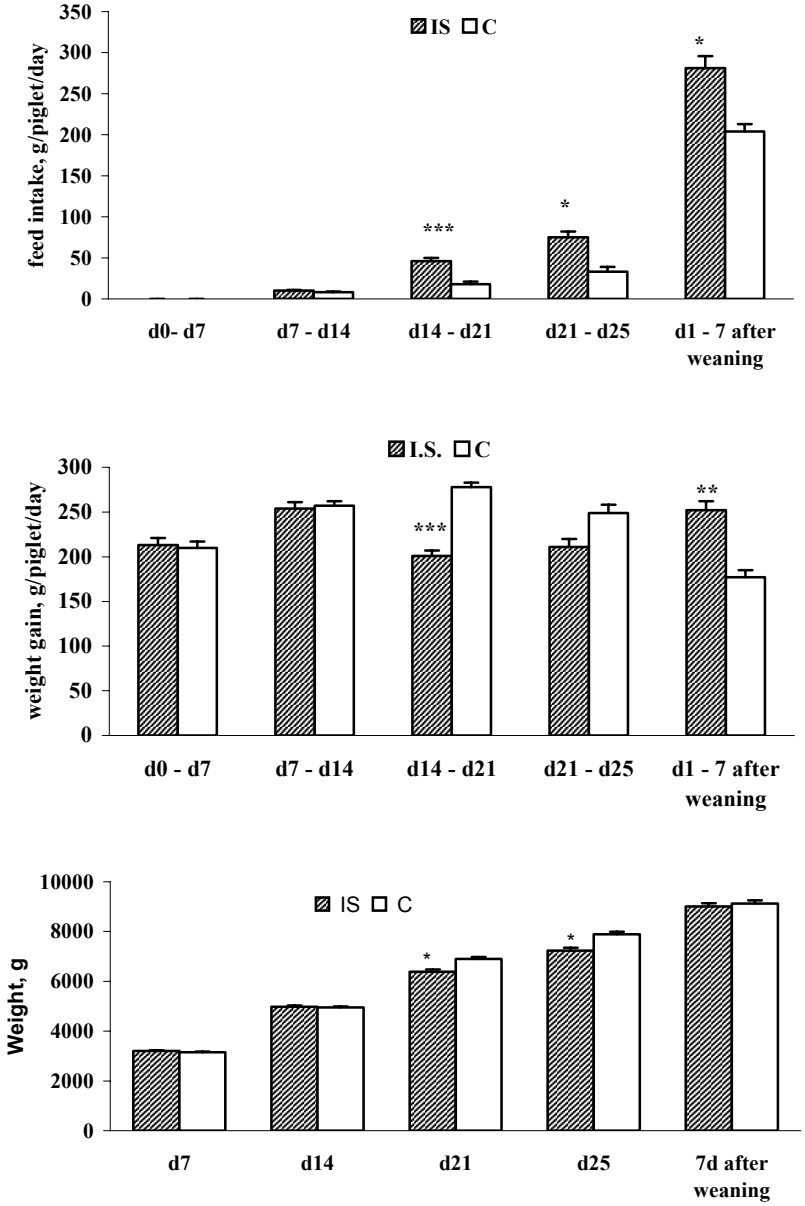

Figure 1 Feed intake (as-fed basis), weight gain and weight of piglets (Means ± SE) during lactation and during the first 7 days after weaning. IS= intermittent suckling, C= control. The experiment started on d 0, IS began on d 14 and weaning took place on d 25. † $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

$Y_{ij} = \mu + T_i + B_j (T_i) + e_{ij}$ with T_i = treatment, B_j = batch (nested within treatment). Weight of the sow after farrowing was included as a covariate in the analysis of weight change of the sow. Sow body weight and sow back fat was also analyzed with parity as a covariate. Sows were classified either as parity one and two, or as parity three and higher. Relevant two way interactions were not significant. Only for sow body weight loss the interaction T_i x parity (two classes) was significant and included in the model. Blood line of the sow was never significant and omitted from the model. Correlations between variables were calculated using the CORR procedure of SAS. Data on the number of sows that ovulated during lactation were analyzed using the χ^2 test in the FREQ procedure. Data were presented as Means ± SE. Differences are considered to be significant if $P < 0.05$.

Results

Piglet survival

No difference was found between treatments in number of piglets at birth (11.8 ± 0.4 vs. 11.6 ± 0.3; P = 0.59), d 0 (11.3 ± 0.3 vs. 11.0 ± 1.8; P = 0.64), at weaning (10.4 ± 0.2 vs. 10.2 ± 0.2; P = 0.69) and 7 d after weaning (10.3 ± 0.2 vs. 10.1 ± 0.2; P = 0.81). Therefore, mortality did not differ between treatments (9 % vs. 9.1 %; P = 0.997). Illness (diarrhea, lameness) and treatment for illnesses did not differ between IS and control piglets.

Piglet feed intake

Before start of IS, there was no difference in creep feed intake of the litters between the treatments (Figure 1). After starting IS at d 14 however, creep feed intake was higher in IS litters between d 14 and d 21 and between d 21 and d 25 . Average total creep feed intake during lactation was 686 ± 57 $g.piglet^{-1}$ for the IS treatment and 314 ± 42 $g.piglet^{-1}$ for the control treatment ($P < 0.01$). Distribution of creep feed intake during lactation was shifted from a skewed one, with a majority of litters (66%) consuming less than 250 g in the control piglets, to a normal distribution with average creep feed intake during lactation between 500 to 750 g in IS piglets (Figure 2). Also during the 7 d after weaning creep feed intake was higher in the IS piglets .

Creep feed intake was quite variable between litters of different sows. Total creep feed intake during lactation ranged from 54 $g.piglet^{-1}$ to 1817 $g.piglet^{-1}$ in the IS litters and from 20 $g.piglet^{-1}$ to 1439 $g.piglet^{-1}$ in the control litters. Irrespective of treatment, variation in creep feed intake between litters was fairly consistent over the lactation period. Correlations of

creep feed intake between one week and another ranged from 0.55 to 0.76 ($P < 0.01$). This consistency continued after weaning ($r = 0.67$, $P < 0.001$). Thus, piglets with higher creep feed intake during lactation had higher feed intake after weaning (Figure 3). Intermittent suckling litters with low creep feed intakes during lactation, had creep feed intakes after weaning that were higher than those of control litters with comparable creep feed intakes during lactation, although the interaction treatment x creep feed intake of the piglets during lactation was not significant: intercept 1381 vs. 1103 $g.piglet^{-1}$ ($P = 0.12$) (Figure 3).
Piglets that were older at d 0 had higher creep feed consumption during lactation ($r = 0.30$, $P < 0.01$). Similarly, piglets with higher birth weights had higher creep feed intakes during lactation ($r = 0.23$, $P < 0.05$).

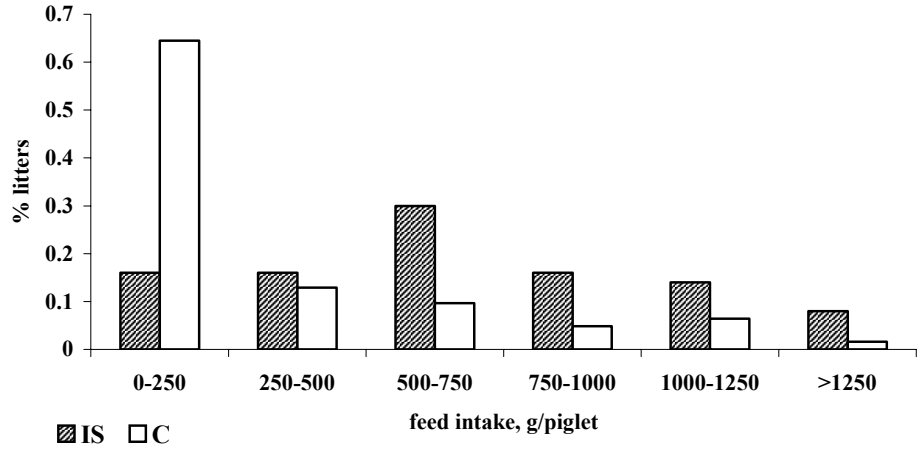

Figure 2 Distribution of litters over the various categories of total feed intake during lactation. IS = intermittent suckling, C = Control

ADG and weight of the piglets

Variation in ADG between litters of different sows was considerable and total weight gain during lactation ranged from 3953 g to 7630 g in IS piglets and from 4183 g to 9850 g in control piglets. During the 7 d after weaning, ADG ranged between 74 $g.d^{-1}$ and 422 $g.d^{-1}$ for the IS piglets and between 31 $g.d^{-1}$ and 307 $g.d^{-1}$ for the control piglets. Piglet ADG (Figure 1) did not differ between IS and control piglets during the first 14 d of the experiment, when IS had not yet started. Between d 14 and d 21 (first 7 days of IS), ADG was lower in the IS

piglets. Between d 21 and d 25, ADG was also lower. After weaning ADG, was higher in the IS piglets.

After weaning, ADG was positively related to the total amount of creep feed consumed during lactation (r = 0.63, P < 0.001). This relation tended to be different for the two treatments (creep feed intake x treatment interaction, P = 0.06) (Figure 4). Intermittent suckling litters that consumed little or no creep feed during lactation nonetheless had an ADG after lactation that was higher than in control litters with comparable creep feed intake during lactation: intercept 204 $g.d^{-1}$ vs. 136 $g.d^{-1}$ (P <0.001).

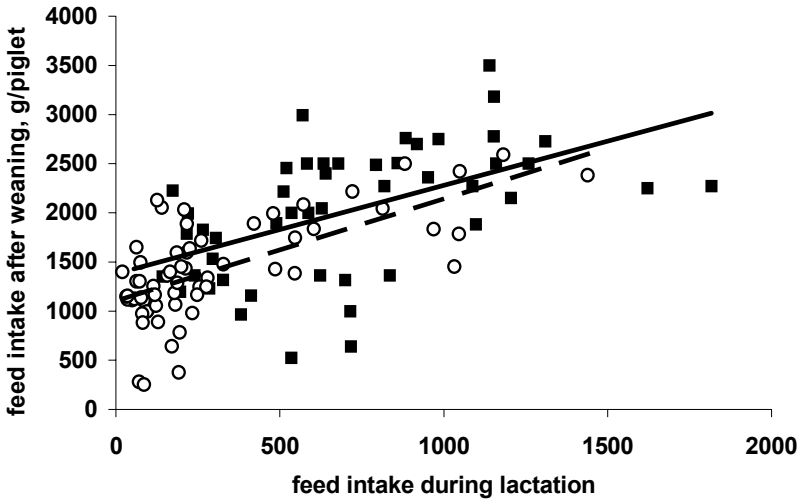

Figure 3 Feed intake (as- fed basis) of the piglets during lactation, in relation to feed intake during the 7 days after weaning. Regression of the intermittent suckling group and the control group are represented by solid (y = 1,381+0.898x (R^2 = 0.28)) and dashed (y = 1,103+ 1.04x (R^2= 0.45)) lines, respectively. Black square = intermittent suckling, white circle = control.

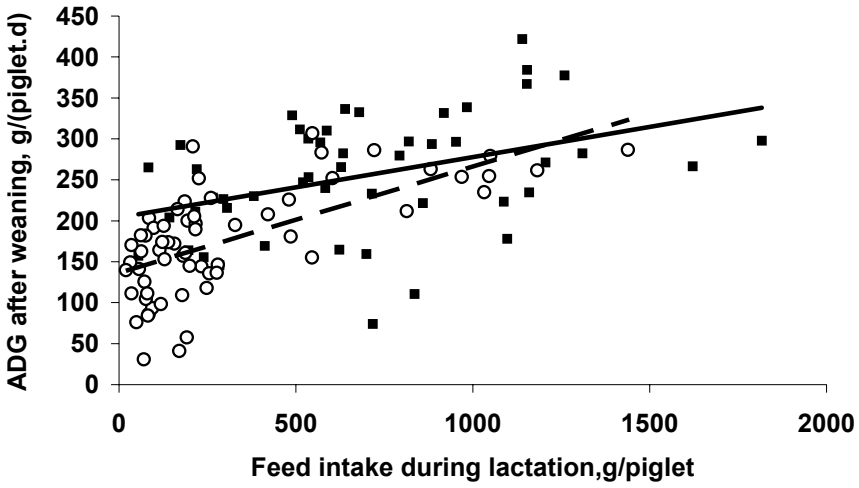

Figure 4 Feed intake (as-fed basis) of the piglets during lactation, in relation to the weight gain of the piglets after weaning. Regression of the intermittent suckling group and the control group are represented by solid (204.1+0.074x (R^2 = 0.17)) and dashed (y=136.2+0.13x (R^2=0.43)) lines, respectively.Black square = intermittent suckling, white circle = control.

Weight of the piglets (Figure 1) did not differ between treatments at d 14 (P = 0.72). As a result of the reduced growth of the IS piglets during d 14 to d 21 however, their weight at d 21 was lower than that of the control piglets. At weaning piglet weight was still lower in the IS piglets. However, 7 d after weaning this difference had disappeared (P = 0.81).

Sow weight and back fat thickness

Sow body weight after farrowing (Table 1) did not differ between treatments. At weaning however, weight loss was lower in the IS sows and thus body weight after weaning was higher in the IS sows. This difference in sow weight loss was not apparent in sows of parity 1 and 2 (IS: -12.7 ± 2.7 kg (n = 25) vs. control: -14.6 ± 2.2 kg (n = 16); P = 0.48), but was significant in sows of parity 3 or higher (IS: -8.9 ± 1.9 kg (n = 33) vs. control: -16.5 ± 1.8 kg (n = 33); P < 0.001). In these two parity groups (younger and older sows) no effect of treatment was found on total growth of the litters during lactation (young: 6074 ± 180 vs. old: 6168 ± 128 g.piglet^{-1}; P = 0.30) nor on creep feed intake of the litters during lactation (young: 411 ± 53 vs. old: 522 ± 53 g.piglet^{-1}; P = 0.12). Weight change of the sow was correlated

with weight of the piglets at weaning (r = -0.26; P < 0.01) and number of piglets weaned (r = -0.28, P < 0.01).

No difference was found in back fat thickness between the IS group and the control group after farrowing or at weaning. Back fat loss tended to be higher in younger sows (parity 1 and 2) than in older sows (parity 3 and higher) (-2.5 ± 0.2 vs. -1.8 ± 0.2 mm; P = 0.09).

Table 1. Body weight and backfat thickness in sows after farrowing and at weaning

	IS[a]	control
Number of sows	50	62
BW[b] after farrowing, kg	221 ± 2.0	221 ± 2
BW after weaning, kg	212 ± 2[d]	205 ± 2[e]
Weight change during lactation, kg	-9 ± 2[d]	-17 ± 2[e]
BF[c] after farrowing, mm	12.3 ± 0.4	12.8 ± 0.4
BF after weaning, mm	10.3 ± 0.3	10.6 ± 0.3
BF change during lactation, mm	-2.0 ± 0.2	-2.2 ± 0.2

[a] IS= intermittent suckling; [b] BW= Body Weight sow; [c] BF= Back Fat thickness;

[d, e] Different superscripts in one row indicate differences between treatment (P < 0.05)

Values are means ± SE

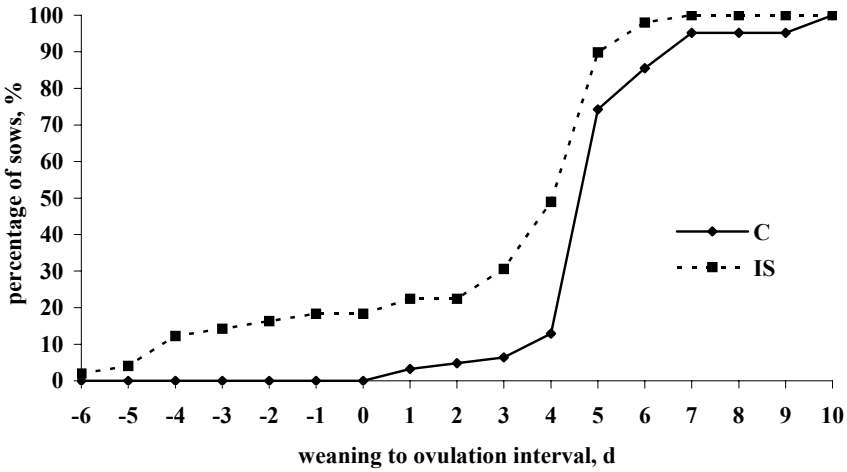

Figure 5 Cumulative percentage of sows ovulating relative to day of weaning.
IS= intermittent suckling; C= Control

Weaning to mating and weaning to ovulation interval

A higher percentage of IS sows (22 %; 11 of 49) than control sows (3 %; 2 of 61) had an ovulation during lactation. Therefore the calculated weaning to ovulation interval was shorter in IS sows (2.9 ± 0.5 vs. 5.1 ± 0.2 d; $P < 0.01$) (Figure 5). Even when excluding sows with lactational ovulation, weaning to ovulation interval was shorter in IS sows (4.7 ± 0.2 vs 5.3 ± 0.2 d; $P < 0.05$). Sows that had lactational ovulation returned to estrus and were mated on average at d 18 ± 0.6. As a consequence, the distribution of weaning to mating interval was dichotomous with the majority of sows being mated between d 4 and d 6, and the rest of the sows at d 18. Overall, weaning to mating interval was 8.1 d ± 0.9 in IS sows and 6.9 d ± 0.9 in control sows. None of the variables measured in this experiment (parity, weight change sow, piglet weight at weaning, creep feed intake piglets, number of piglets weaned) had a significant effect on weaning to ovulation interval or weaning to mating interval. Considerable differences in weaning to ovulation interval were found between batches. In one IS batch, 50 % (5 of 10) sows had lactational ovulation. The other six IS sows with lactational ovulation were divided over 4 batches. Sows that experienced lactational ovulation did not differ with respect to parity, weight of the piglets at weaning, sow body weight- or back fat change, number of piglets weaned or creep feed intake of the piglets.

Discussion

Intermittent suckling (IS) increased creep feed intake during lactation with 218 % on average. This increase is in agreement with results of an early study (Thompson et al., 1981), in which IS almost doubled creep feed intake in one experiment and tripled it in another during a 33 d lactation. In another study (Plagge and Van der Peet-Schwering, 1998), IS had no effect, probably due to the fact that IS and control piglets were housed in the same room. Nursings are accompanied by noise and are synchronized within one room. Intermittent suckling piglets that do not have access to the sow, can hear these nursings but can not start drinking. This probably resulted in a high level of restlessness and did not encourage piglets to go to the feeder. In our experiment, this restlessness was possibly prevented by separating the IS and control sows into different rooms.
During lactation, IS resulted in an increase in creep feed intake although it did not prevent the usual high variation in creep feed intake between litters (Aherne et al., 1982; Barnett et al., 1989; Appleby et al., 1991; Pajor et al., 1991; Delumeau and Meunier-Salaun, 1995). Sixty percent of the IS litters had an average creep feed intake per piglet during lactation of more than 600 g, a level which is needed for better performance after early weaning as suggested by English (1980). In the control litters, in contrast, only 20 % consumed more than 600 g.piglet^{-1} during lactation and 66 % of the litters consumed less than 250 g.piglet^{-1}. So, IS resulted in a shift in the distribution of creep feed intake and improved creep feed intake especially in litters with an otherwise low creep feed consumption.

The higher creep feed intake caused by IS resulted in better performance after weaning: IS litters had higher creep feed intake and higher ADG after weaning. The higher ADG after weaning compensated the negative effects of IS on ADG during lactation, which had led to lower weaning weights of IS litters. The growth check during lactation as a result of IS was in agreement with results from previous studies (Thompson et al., 1981; Henderson and Hughes, 1984), although others found no effects on weight gain (Newton et al., 1987). Apparently, IS reduced the milk intake in our study, and piglets failed to compensate for their milk intake deficit during the 12 h that they were with the sow. When separation takes place for only 6 h/d (Newton et al., 1987) milk intake is possibly not reduced or can be compensated and will thus not affect weight gain during lactation. The lower weaning weights in our experiment did not negatively affect growth during the first 7 d after weaning.

So growth shortly after weaning seems to depend on adaptation of the piglet to solid food rather than on weaning weight.

Weight gain and feed intake of the litters after weaning was positively related to creep feed intake during lactation. However, IS litters that had little or no creep feed intake during lactation still tended to have a weight gain after weaning that was 68 $g.d^{-1}$ higher than control litters with comparable creep feed intake during lactation. Also feed intake after weaning tended to be higher in IS litters than control litters with comparable creep feed intake during lactation, although this was not significant. Apparently, positive effects of IS on growth and feed intake of the litters after weaning were also mediated by some other mechanism than by increased creep feed intake during lactation. Possibly, IS litters experienced weaning as a less stressful event, because they were already used to separation from the sow.

Weaning is associated with withdrawal of nutrients from sow milk and intake of a starter diet can be delayed for 4 to 20 h in pigs that eat during lactation and up to 48 h in pigs that do not eat (Bruininx et al., 2002). The withdrawal of nutrient supply to the small intestine, together with the stress of weaning, results in a transient shortening of the small intestinal villi and a reduction in the absorptive capacity (Marion et al., 2002). Nabuurs et al. (1996) showed that offering creep feed during lactation in combination with IS, partly prevents piglets from the usual decrease in villus height and net absorption in the small intestine that occurs after weaning. So IS could result in a healthier gut of the piglet after weaning by increasing creep feed intake during and after lactation and possibly by reducing stress at weaning. As a result, the risk of developing post weaning diarrhea might be decreased and litter performance could be improved. In this experiment however, the influence of IS on diarrhoea after weaning could not be assessed because incidence of post weaning diarrhoea was already low in the control group.

The method of IS is only acceptable if sow reproductive performance is not compromised. Therefore, the effects on reproductive performance of the sow were also studied in this experiment. Ovulation was advanced by IS, resulting in lactational ovulation in a number of sows and shortened weaning to ovulation interval. Reproductive performance is affected by the metabolic state of the sow and the suckling stimulus of the piglets (Foxcroft, 1992). As a result of lactation, the sow often becomes catabolic, which can result in sub optimal reproduction after weaning (Foxcroft, 1992; Einarsson and Rojkittikhun, 1993; Foxcroft et al.,

1996). In our experiment, weight loss of the sows was significantly reduced during the 11 d of IS. This probably resulted from lower milk production in IS sows because piglet weight gain, which is highly correlated with milk nutrient production (Noblet and Etienne, 1989) was lower in IS sows.

In our experiment, however, no relationship was found between weight loss of the sow and weaning to ovulation interval, although both were decreased in IS sows. This is in contrast with a review by Foxcroft (1996) who reported that a catabolic state has a negative effect on weaning to estrus interval . In our study sows lost less than 8% of there body weight, which was probably not enough to result in prolonged weaning to estrus interval. Vesseur (1994) showed that weaning to estrus interval was prolonged when weight loss exceeded 12.5%, especially in first parity sows. It was suggested earlier (Foxcroft, 1992) that 'in sows with a reasonable energy balance, the inhibitory effects of suckling are more potent inhibitors of LH secretion than the metabolic demands of milk production'. Suckling of piglets blocks GnRH secretion by the hypothalamus (Britt et al., 1985; Armstrong et al., 1988) and thereby blocks follicular development during lactation. In agreement with these findings, IS increased the incidence of lactational ovulation in our experiment. Costa and Varley (1995) did not find lactational ovulation, possibly because of the short duration of separation (3 $h.d^{-1}$, during 9 d). Even higher percentages of sows showing lactational ovulation can be achieved by increasing duration of separation (Grinwich and McKay, 1985) or increasing lactation length (Crighton, 1970; Stevenson and Davis, 1984). So in our experiment IS decreased weaning to ovulation interval probably mainly by decreasing the suckling stimulus and not by decreasing the negative energy balance.

Further research should be done on the effect of IS on behaviour and welfare of the piglets, the performance of the piglets until slaughter and the development of the gastro- intestinal tract. More research is also needed on the effect of IS on ovarian activity during lactation and the (hormonal) mechanisms behind it.

Implications

Intermittent suckling increases feed intake and growth in piglets after weaning, partly by enhancing creep feed intake during lactation. In addition, intermittent suckling probably affects growth and feed intake after weaning independent of creep feed intake during lactation. Metabolic stress in the sow and the suckling stimulus of the piglets was reduced

by intermittent suckling. This can result in shortened weaning to mating interval, but also in lactational ovulation. In practice however, lactational ovulation can only be useful if sows can be mated during lactation.

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Chapter 3

Effects of intermittent suckling and creep feed intake on pig performance from birth to slaughter

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ABSTRACT

An experiment was conducted to determine if the improved creep feed intake observed during intermittent suckling is of major importance for post weaning performance. Therefore, creep feed intake of litters was assessed. and within litters, eaters and non-eaters were distinguished using chromic oxide. Batches of sows were either suckled intermittently (IS, 7 batches; n = 31) or continuously (control, 7 batches; n = 31). In the IS group, litters were separated from the sow for a period of 12 h/d (0930 to 2130), beginning 11 d before weaning. Litters were weaned at 4 wk of age. Litters had free access to creep feed from 1 wk of age onward. Five days after weaning, the piglets were moved as a litter to weanling pens. At 8 wk of age, 2 barrows and 2 gilts were randomly chosen from each litter and moved to a finishing facility. Feed intake was improved by IS during the last 11 d of lactation (IS: 284 ± 27 vs. C: 83 ± 28 g/piglet; $P < 0.001$) and after weaning during the first (IS: 201 ± 24 vs. C: 157 ± 25 g· piglet^{-1}· d^{-1}; $P < 0.05$) and second wk (IS: 667 ± 33 vs. C: 570 ± 35 g· piglet^{-1}· d^{-1}; $P < 0.05$). Thereafter, no differences were found to slaughter. Weaning BW was lower in IS litters (IS: 7.1 ± 0.01 vs. C: 8.1 ± 0.01 kg/piglet; $P < 0.05$), but 7 d after weaning BW was similar (IS: 8.5 ± 0.2 vs. C: 8.7 ± 0.2 kg/piglet; $P = 0.18$), and no differences were found to slaughter. The percentage of eaters within a litter was not increased by IS during lactation (IS: 23 ± 4.5 % vs. C: 19 ± 4.1 %; $P = 0.15$). Weaning BW did not differ between eaters and non-eaters (eater: 7.7 ± 0.1 vs. non-eater: 7.5 ± 0.08 kg/piglet; $P = 0.63$). From 1 until 4 wk after weaning, piglets that were eaters during lactation had heavier BW than non-eaters (eater: 20.3 ± 0.3 kg vs. non-eater: 18.2 ± 0.2 kg; $P < 0.05$). The influence of eating creep feed during lactation on BW and gain and the influence of suckling treatment never showed an interaction. We conclude that IS increases ADFI during lactation on a litter level and improves ADG in the first and ADFI in the first and second week after weaning. No long-term effects on ADFI or ADG were observed throughout the finishing period. In the current experiment, in which creep feed intake was low, the percentage of eaters within a litter was not increased, suggesting that creep feed intake of piglets that were already eating was stimulated by IS. Further, piglets that were eaters during lactation had heavier BW up to 4 wk after weaning.

Key words: creep feed, feed intake, growth, performance, pig, weaning

Introduction

In the modern pig industry, piglets are usually weaned before 4 wk of age, thereby changing abruptly from a diet of highly digestible milk to a less digestible starter diet. As a result of this change and other stressors related to weaning, feed intake and growth are reduced after weaning (English, 1980) and piglets are more vulnerable to develop diarrhea and edema disease (van Beers-Schreurs et al., 1992). Intake of a sufficient amount of creep feed during lactation creates a more gradual transition at weaning and can reduce the occurrence of post-weaning disorders (English, 1980). However, creep feed consumption during lactation is usually low and is also highly variable among piglets in a litter and between litters (Barnett et al., 1989; Pajor et al., 1991; Kuller et al., 2004b).

Although a review by Matte et al. (1992) showed contradictory results, previous work (Kuller et al., 2004b) demonstrated that intermittent suckling (**IS**), a management technique in which piglets are separated from the sow during a number of hours every day in the second half of lactation, increased creep feed intake before weaning and feed intake and growth shortly after weaning. However, in that study creep feed intake was determined at the level of the litter. Individual variation within the litter in relation to post weaning performance has not been studied. Also, long- term effects of IS on piglet performance have not been investigated.

The objective of the current study therefore was to determine if the improved feed intake found during intensive (12 h/d) intermittent suckling is important for post weaning performance of piglets until slaughter. Creep feed intake of litters was assessed and, within litters, eaters and non-eaters were distinguished using chromic oxide as an indigestible marker. These creep feed intake characteristics were related to post weaning performance.

Material and methods

Animals and Housing

The experimental design was approved by the Ethical Committee of the Veterinary Faculty of Utrecht University (The Netherlands). Sixty-two sows (12 Dutch Landrace, 5 Yorkshire, and 45 Dutch Landrace x Yorkshire) were used between February and October 2002. Parity was 3.5 ± 0.3 in the control treatment and 3.8 ± 0.3 in the intermittent suckling treatment and ranged from 1 to 11. Genotype and parity were equally distributed across treatments. During

lactation, sows were housed individually in farrowing crates (2.4 x 1.8 m). The farrowing pen consisted of 1.95 m^2 solid floor and 2.37 m^2 slatted floor. This space included a piglet nest with infrared lamp, a piglet drinking nipple, and a piglet feeder. Litter size at birth varied from 3 to 16 piglets, but was standardized within 3 d after birth by cross fostering within each batch. Litter size was 10.6 ± 0.2 after cross-fostering (range 9 to 13) and 9.7 ± 0.2 at weaning (range 7 to 13). Within the first 3 d after birth, piglets received an injection of 1 cc of iron dextran, were identified by ear tags, and males were castrated.

The experiment began on treatment d 0 (T0). In order to synchronize the beginning of IS within a farrowing batch, T0 was designated as the start of data collection. Piglets were born on 2.4 ± 0.3 d (range 1 to 5) before T0 in the control treatment and 2.0 ± 0.4 d (range –1 to 7) before T0 in the intermittent suckling treatment. Maximum range of age within a farrowing batch was 4 d. Intermittent suckling always begun on d 14 of the treatment (T14) and weaning took place 11 d later (T25). Because weaning took place in the early morning, T25 was considered the first day after weaning. At weaning, sows were moved to a mating room and piglets remained in the pen (weanling pigs). Five days after weaning, piglets were moved as a litter to weanling pens with 4 feeding spaces and 1 drinking nipple, with floor space allowance according to Dutch animal welfare legislation (0.4 m^2/ pig, until 30 kg live weight). At 8 wk of age (fattening pigs), 2 barrows and 2 gilts were randomly chosen from each litter and were transported to a finishing facility at another location in the Netherlands. In this facility, 4 to 8 pigs were housed together, depending on the size of the available pens. Each pen consisted of partly slatted, concrete floor with 2 drinking nipples and 1 feeding place, with floor space allowance according to Dutch animal welfare legislation (1 m^2/ pig, until 110 kg live weight). Average group size was 7.2 ± 0.1 in the control treatment and 7.3 ± 0.1 in the intermittent suckling treatment. Allotment to pens was based on BW within treatment (control vs. IS), with 1 treatment per pen. Pigs were slaughtered when their BW was approximately 107 ± 0.3 kg.

Treatments

There were 2 treatments, control and IS. Fourteen weekly farrowing batches were alternately allocated to each treatment: 7 control batches (31 sows total) and 7 IS batches (31 sows total). Each batch consisted of 4 to 5 sows. The batches were housed in separate rooms during lactation. The rooms (size, lights, flooring), equipment (size of the farrowing crates, feeders, drinking nipples) and environments (controlled climate) were comparable among all farrowing batches, and they were at the same facility. Only 1 treatment was applied per batch to avoid any influence by suckling in control sows, because suckling is

highly synchronized between animals in a barn. In the control treatment, piglets had access to the sow for 24 h/d. In the IS treatment, piglets were separated from the sow for 12 h each day (0930 until 2130) during T14 to weaning (T25). The piglets were separated by a removable wooden partition (height 65 cm) that was attached on both sides to the farrowing crate of the sow. During separation, IS piglets were allowed extra space at the back of the pen to create comparable floor space with that of the control piglets (IS: 3.75 m^2 vs. C: 4.32 m^2 (including sow)). Although the sow and piglets remained in the same pen, separation did not allow physical contact. During lactation, lights were on between 0730 and 2330. After weaning, lights were on between 0730 and 1630.

Feeding

The sows were fed a commercial lactational feed (9.1 MJ NE/kg, 139 g/kg CP, lysine 8 g/kg; as-fed basis) at a level of 1 % of BW at farrowing, plus 500 g/piglet (Dutch feeding tables, 1995), divided over 3 meals daily. Water was available ad libitum. Creep feed based on milk products (34 %), soybeans, corn, sugar, vegetable oil, and a premix (12.8 MJ NE/kg, 21.7 % CP, 14.7 % crude fat, 2.0 % crude fiber, 5.2 % ash, 1.46 % lysine, 0.86 % Ca, 0.58 % P, 160 mg/kg Cu, 500 units/kg phytase; as- fed basis) was offered to the piglets ad libitum from T7 onwards and given in a round piglet trough. From T14 onwards, a pig feeder with 4 feeding spaces was used. During T21 to T23, a gradual change (respectively 40 %, 60 %, and 100 % replacement) to a weaner diet based on milk products (18.5%), barley, soy beans, corn, sugar, vegetable oil, and a premix (11.4 MJ NE/kg, 17.9 % CP, 10.7 % crude fat, 2.9 % crude fiber, 5.8 % ash, 1.25 % lysine, 0.77 % Ca, 0.59 % P, 160 mg/kg Cu, 500 units/kg phytase; as-fed basis) was made, which was given until T31 of the experiment. From T32 onwards, a series of 4 finishing diets were given. Drinking nipples provided ad libitum water to the piglets. Feed residuals were assessed at a 7-d interval. Because no food wastage was observed (feeders were placed on a solid floor), disappeared feed was considered eaten.

Measurements

Individual piglet BW was assessed at birth and from T0 onward every week, until 4 wk after weaning (T52). Thereafter and until slaughter, pigs were weighed every 4 wk. The ADG was calculated. At slaughter, lean meat percentage was calculated using muscle- and backfat thickness, measured on carcasses with the Hennessy Grading Probe (Engel and Walstra, 1993). Creep feed residuals were weighed per litter at 7 d intervals. After weaning, feed

intake was determined weekly per pen. No food wastage was observed (feeder was placed on a solid floor). During lactation, creep feed was supplemented with 1% chromic oxide, which colored piglet feces if creep feed was eaten (Barnett et al., 1989; Bruininx et al., 2002). At T17, T21, T23, and T24, fecal samples were taken at 1100, using fecal loops (Instruvet, Amerongen, The Netherlands). Color of the samples was determined visually. Piglets with green feces were considered to have eaten creep feed (Barnett et al., 1989; Bruininx et al., 2002). Classification of piglets into eaters and non- eaters was based on Bruininx et al. (2002) and previous experimental data (W. I. Kuller, unpublished data). One point was given to piglets that had green feces at time of sampling and 0 points when no green color was observed. When color of feces was inconclusive, 0.5 point was given. Piglets that had 0 points were non-eaters. Piglets that had a sum of 1.5 points or higher for the 4 samples during lactation were designated as eaters.

Statistical Analysis

General.

All data were tested for normality using the UNIVARIATE procedure of SAS (SAS Inst. Inc., Cary, NC). Data were analyzed using the GLM and MIXED procedure of SAS. Correlations between variables were calculated using the CORR procedure of SAS. Data are presented as LSMeans ± SEM. Differences are considered significant if $P < 0.05$. Relative two- way interactions that are not mentioned were not significant.

IS vs. Control: Suckling and Weanling Period.

Arcsine- transformed values of mortality rate per litter were normally distributed and analyzed in the following model (PROC MIXED): $Y_{ijk} = \mu + T_i + B_j (T_i) + L_k + e_{ijk}$ with T_i = treatment, B_j = batch (nested within treatment) and L_k= litter as random effect. The ADFI and ADG of the piglets and piglet BW were analyzed as litter characteristics using the following linear model (PROC MIXED): $Y_{ijk} = \mu + T_i + B_j (T_i) + L_k + a_{ijk} + e_{ijk}$ with T_i = treatment, B_j = batch (nested within treatment), L_k= litter as random effect and a_{ijk} = age of the piglets at T0. From T14 onwards, feed intake between T7 and T14 and BW of piglets at T14 (start of IS) was also used as a covariate in modeling ADFI. Breed and parity of sow were never significant and were therefore omitted from the model.

IS vs. Control: Fattening Period.

The ADG and BW were analyzed on piglet level using the following linear mixed model (PROC MIXED): $Y_{ijkl}= \mu + T_i + a_{ijk} + w14_{ijk} + gender_j + pen_k + e_{ijkl}$ with T_i = treatment, a_{ijkl} = age of the piglets at T0, $w14_{ijkl}$ = BW of the piglets at T14 (start of IS) and pen_k = pen as a random effect. In the analysis of slaughter BW and percentage of lean meat, duration of the fattening period was also included as a covariate. Feed intake during the entire fattening period (on a pen level) was analyzed in a linear model (PROC GLM): $Y_{ij}= \mu + T_i + ts_{ij} + e_{ij}$ with T_i = treatment and ts= time to slaughter. In the analysis of mortality, ts_{ij} was omitted from the model. Feed to gain ratio during the entire fattening period was calculated (on a pen level) as the feed disappearance in a pen divided by the total BW gain of the pigs in this pen. Feed to gain ratio was analyzed in a general linear model: $Y_{ij}= \mu + T_i + ts + e_{ij}$ with T_i = treatment and ts = time to slaughter. Group size was never significant and was therefore omitted from the model.

Eaters vs. Non- Eaters.

The ADG and BW of piglets were analyzed using the following linear mixed model (PROC MIXED): $Y_{ij}= \mu + Eater_i + a_{ijkl} + bw_{ijkl} + gender_j + SP_k + e_{ijkl}$ with $Eater_i$ = eater or non- eater, a_{ijkl} = age of the piglets in relation to T0, bw_{ijkl} = BW of piglets at T14 (start of IS) or BW at slaughter and SP_k = sow (for the suckling period) or pen (for the weanling and fattening period) as random effect. Treatment and the interaction treatment * eater were never significant ($P > 0.5$) and therefore omitted from the model. In the analysis of BW at slaughter and percentage of lean meat, duration of the fattening period was also included as a covariate. Differences in number of eaters in both treatments were tested using the χ^2 - test in SAS.

Results

Piglet Mortality

No difference was found between treatments in number of piglets at birth (IS: 11.3 ± 0.3 vs. C: 11.1 ± 0.5), at weaning (IS: 9.7 ± 0.2 vs. C: 9.5 ± 0.2) or at the end of the weanling period (IS: 9.1 ± 0.3 vs. C: 8.7 ± 0.3). Piglet mortality per litter from birth to weaning did not differ between the treatments (IS: 4.6 ± 0.1% vs. C: 5.6 ± 0.1 %; $P = 0.66$). In both treatments, the main cause of death of piglets from birth to weaning was crushing by the sow and death because of weakness (small piglets). Mortality per litter from weaning until T52 did not differ between treatments (IS: 1.7% ± 0.2 vs. C: 2.2% ± 0.2; $P = 0.68$). Mortality and culling (Table

1) in the finishing period was high (IS: 7.4 % vs. C: 11.4 %) for Dutch standards, but was not affected by treatment (*P* = 0.30).

Table 1 Causes of mortality and culling of fattening pigs (d 52 to slaughter).

	Number of pigs	
	Control	IS[1]
Heart disease [2]	3	-
Lung disease [2]	1	-
Meningitis [2]	2	1
Sudden death	3	-
Miscellaneous	3	6
Lameness	2	2
Total	14	9

[1] In the control group, piglets were continuously with the sow during lactation. Piglets in the intermittent suckling (IS) treatment were separated from the sow for 12 h/d (0930 to 2130), starting 11 d before weaning at 4 wk.

[2] Diagnosis on basis of post mortem examination

Feed Intake

Total creep feed intake during lactation ranged from 8 to 1,056 g/piglet in the IS litters and from 9 to 513 g in control litters. Piglets that were younger at T0 had lower ADFI during lactation (r = 0.30, *P* < 0.02) and at the start of IS, ADFI (although still very low) was greater in control litters (Table 2). Therefore, ADFI was corrected for age at T0 and for creep feed intake before treatment. Average daily feed intake was also corrected for BW at T14, because this was significant in the model. After starting IS at T14, ADFI was greater in IS litters than in C litters between T14 and T21 and between T21 and T24. Total creep feed intake during the treatment period (T14 to T24) was 284 ± 27 g/piglet in IS litters and 83 ± 28 g/piglet in C litters (*P* < 0.001; corrected for feed intake during T7 to T13). The ADFI of the weanling pigs was greater (*P* < 0.05) in IS- litters from T25 (weaning) to T31 and from T32 to T38 (Table 2). No difference was found from T39 to T52 (weanling period) or from T52 to slaughter (fattening period) (IS: 2.2 ± 0.1 vs. C: 2.0 ± 0.1 g piglet^{-1}· d^{-1}; *P* = 0.46).

Correlation coefficients of creep feed intake between 1 wk and the next week varied from 0.38 to 0.83 ($P < 0.01$), irrespective of treatment. Therefore, litters with greater feed intake in 1 wk, had greater feed intake in the following week. The following relationship between creep feed intake during lactation ($ADFI_{lact}$) and feed intake in the first week after weaning ($ADFI_{aw}$) was found: $ADFI_{aw} = 136 + 0.26 \times ADFI_{lact}$ ($R^2 = 0.69$). The interaction treatment*$ADFI_{lact}$ was not significant ($P = 0.11$).

Table 2. Feed intake ($g \cdot piglet^{-1} \cdot d^{-1}$) during lactation and in the weanling period (LSM ± SE).

	Treatment[1]			
ADFI , g $piglet^{-1}$ d^{-1}	Control, n = 31[2]	SE	IS, n = 31	SE
T7 to T13 [2]	6 [a]	1	4 [b]	1
T14 to T20	2 [a]	1	15 [b]	1
T21 to T24 (weaning)	12 [a]	5	31 [b]	5
T25 to T31	157 [a]	25	201 [b]	24
T32 to T38	570 [a]	35	667 [b]	33
T39 to T45	697	33	760	28
T46 to T52	891	35	919	32

[a,b] Different superscripts within a row indicate significant differences ($P < 0.05$).

[1] In the control treatment, piglets were continuously with the sow during lactation. Piglets in the intermittent suckling (IS) treatment were separated from the sow for 12 h/d (0930 to 2130), starting 11 d before weaning at 4 wk.

[2] The data were analysed as litter characteristics

[3] Data collection started on treatment d 0 (T0). Piglets were born on 2.4 ± 0.3 d (range 1 to 5) before T0 in the control treatment and 2.0 ± 0.4 d (range –1 to 7) before T0 in the IS treatment. This time sequence applies also to the other times.

ADG and Weight of Piglets

The ADG of piglets did not differ between treatments before the beginning of IS at T14 (IS: 232 ± 29 vs. 235 ± 29 g/ piglet; $P = 0.79$). The ADG was lower in the IS treatment during T14 to T20 (IS: 198 ± 40 vs. C: 308 ± 40 g/ piglet; $P < 0.001$) and during T21 to T24 (IS: 176 ± 10 vs. C: 246 ± 10 g/ piglet; $P = 0.005$). The first week (T25 to T31) after weaning, however, ADG was greater in IS piglets (IS: 177 ± 14 vs. C: 106 ± 14 g/ piglet; $P < 0.001$). No difference was found between treatments from T31 to T52 (IS: 755 ± 77 vs. C: 765 ± 77

g/ piglet; *P* = 0.97) or thereafter until slaughter (IS: 795 ± 17 vs. C: 789 ± 17 g/ piglet; *P* = 0.8).

Weight of piglets at T14 did not differ between treatments (Table 3). At T21 and at weaning (T25), piglet BW was less in the IS treatment. Within 7 d after weaning, however, this difference in piglet BW had disappeared. No differences in BW were found during the remainder of the weanling or fattening period.In both treatments, piglets that had greater BW gains during the lactational period also had greater BW gains during the weanling period (IS: r = 0.36, *P* = 0.04 and C: r = 0.52; *P* < 0.001). This positive relationship also existed between the weanling and the fattening period in the control treatment (r = 0.52, *P* < 0.001) and tended to exist in the IS treatment (r = 0.16; *P* = 0.09). A positive relationship was found between litter creep feed intake during lactation ($ADFI_{lact}$) and litter ADG during the first week after weaning (ADG_{aw}; IS: r = 0.57, *P* < 0.01 and C: r = 0.66; *P* < 0.001). This relationship can be described according to the following formula: $ADG_{aw} = 95 + 0.24 * ADFI_{lact}$ ($R^2 = 0.59$). No interaction was found between treatment and ADG_{aw} (*P* = 0.12). In the control treatment, this relationship was also found between litter creep feed intake and litter ADG during T32 to T38 (r = 0.45, *P* < 0.013) and in the IS treatment during T39 to T45 (r = 0.36, *P* = 0.05). Gain to feed ratio during the fattening period was 0.39 ± 0.01 in the IS treatment and 0.37 ± 0.01 in the control treatment (*P* = 0.26). No differences were found among IS and control piglets in lean meat percentage (Table 3).

Eaters vs. Non- Eaters

The effect of treatment and the interaction between treatment and eater were not significant in the analysis of ADG and BW and were therefore omitted from the model. In the IS treatment, 85 pigs had more than 1.5 points (eaters), 168 pigs had 0 points (non- eaters) and 48 pigs had 0.5 or 1 point (non- classified). In the control treatment, this distribution was 67, 190, and 40 pigs respectively. On average, an IS litter consisted of 23.0 ± 4.5 % eaters, 62.8 ± 3.9 % non- eaters, and 13.9 ± 1.9 % of non classified piglets. A control litter consisted of 19.0 ± 4.1 % eaters, 69.8 ± 3.2 % non- eaters, and 11.3 ± 2.0 % non-classified piglets. Overall distribution of eaters, non- eaters, and non-classified piglets within litters did not differ between treatments (*P* = 0.15). Overall, more gilts than barrows were designated as eaters (30 % of females vs. 21 % of males, *P* = 0.03). From this point onwards, focus will be only on eaters and non- eaters.

Table 3. Body weight (kg), time to slaughter, and lean meat percentage of piglets in the control and intermittent suckling treatment, and of eaters and non-eaters, at different days in the suckling, weanling and fattening period

	Suckling treatment[2]			Consumption category[3]		
Item[1]	Control	IS	SE	Eater	Non eater	SE
Birth	1.5	1.5	0.04	1.6	1.5	0.04
T0	1.8	1.9	0.06	1.9	1.9	0.06
T7	3.3	3.3	0.09	3.3	3.4	0.1
T14	5.1	5.3	0.14	5.1 [w]	5.3 [x]	0.05
T21	7.4 [z]	6.6 [y]	0.03	6.7	6.7	0.08
T25	8.1 [z]	7.1 [y]	0.13	7.7	7.5	0.1
T32	8.7	8.5	0.2	9.0 [w]	8.3 [x]	0.1
T39	11.6	11.5	0.2	12.3 [w]	11.2 [x]	0.2
T46	15.3	15.1	0.3	15.9 [w]	15.0 [x]	0.3
T53	19.1	18.9	0.3	20.3 [w]	18.2 [x]	0.3
T81	39	39	1.0	40	39	0.7
T109	62	61	1.3	63	62	0.9
T137	86	85	1.2	86	85	0.7
Slaughter	107	108	0.5	108	107	0.6
Lean meat, %	56.3	56.0	0.2	56.0	56.3	0.3

[a, b] Row values within suckling treatment or within a consumption category with different superscripts differ ($P < 0.05$).

[1] Data collection started on treatment d 0 (T0). Piglets were born on 2.4 ± 0.3 d (range 1 to 5) before T0 in the control treatment and 2.0 ± 0.4 d (range –1 to 7) before T0 in the IS treatment. This time sequence applies also to the other times.

[2] In the control treatment, piglets were continuously with the sow during lactation. Piglets in the intermittent suckling (IS) treatment were separated from the sow for 12 h/d (0930 to 2130), starting 11 d before weaning at 4 wk. T0 to T53: data based on 31 litters; T81 onwards: data based on 112 piglets.

[3] Creep feed was supplemented with 1% chromic oxide, which colored piglet feces green if creep feed was eaten. Four feces samples were taken: green feces = 1 point; no green color = 0 points; inconclusive color = 0.5 point. Non-eaters: 0 points in 4 samples; Eater: 1.5 points or higher for the 4 samples. Eaters: T0 to T53: data based on 152 piglets; T81 onwards: data based on 62 piglets. Non eaters: T0 to T53: data based on 358 piglets; T81 onwards: data based on 134 piglets.

The ADG tended to be greater in non-eaters from T0 to T6 (eater: 249 ± 21 vs. non-eater: 259 ± 21 g/ piglet; *P* = 0.09) and from T7 to T13 (eater: 341 ± 25 vs. non-eater: 353 ± 25 g/ piglet; *P* = 0.07). From T14 to T20, no difference in ADG was found (eater: 316 ± 38 vs. non-eater: 325 ± 37 g/ piglet; *P* = 0.3). During the last days of lactation (T21 to T24) ADG was greater for eaters (eater: 243 ± 18 vs. non-eater: 209 ± 17 g/ piglet; *P* = 0.007). After weaning ADG was greater for eaters during T25 to T31 (eater: 199 ± 11 vs. non-eater: 106 ± 8 g/ piglet; *P* = 0.001), T32 to T38 (eater: 463 ± 11 vs. non-eater: 411 ± 7 g/ piglet; *P* = 0.002), T39 to T45 (eater: 529 ± 19 vs. non-eater: 467 ± 14 g/ piglet; *P* = 0.003) and, T46 to T52 (eater: 608 ± 21 vs. non-eater: 544 ± 17 g/ piglet; *P* = 0.009) No difference was found in ADG during the fattening period (eater: 792 ± 16 vs. non-eater: 794 ± 13 g/ piglet; *P* = 0.9).
During the suckling period, no difference in BW was found between eaters and non- eaters except for T14, where the non- eaters where heavier (Table 3). During the weanling period (T25 to T52), however, eaters were at all times heavier than non- eaters. From T81 onwards, 4 wk after piglets had been moved to the finishing facility, no difference was observed in BW among eaters and non- eaters in the IS treatment. No differences were found among eaters and non-eaters in lean meat percentage (Table 3).

Discussion

Intermittent suckling increased creep feed intake by suckling piglets during the last 11 d of lactation, which is in agreement with a previous study (Kuller et al., 2004a). As expected, IS resulted in lower BW at weaning (Thompson et al., 1981; Henderson and Hughes, 1984; Kuller et al., 2004a). This initial growth check during lactation in the IS group was compensated during the first week after weaning. Previous studies did not investigate long-term effects of IS on piglet performance (Chapple et al., 1989; Costa et al., 1995; Grinwich and McKay, 1985). Moreover, sometimes piglets were weaned at an age of 49 d (Smith, 1960), which is not compatible with current production methods. One study mentioned that time needed to reach 90 kg live BW was not influenced by IS (Henderson and Hughes, 1985), but details about ADG and ADFI were not provided. In our experiment, IS improved ADG during the first week and increased ADFI during the first and second week after weaning, but had no further positive effects on performance (BW gain and ADFI) during the fattening period and meat percentage at slaughter. The latter might be a result of the overall

lower feed intake in the current experiment and the small difference in creep feed intake between the control and the IS treatment.

Intermittent suckling did not increase the percentage of eaters within a litter as was expected; the percentage of eaters in control litters was 19% and 23% in IS litters. Apparently, IS increased creep feed intake of piglets that were already eating before the period of separation, instead of increasing the number of eating piglets within a litter. Animals within a litter that were eating consumed considerable amounts of creep feed. Considering that in the IS and in the control treatment only 23 and 19 % of the animals were classified as eaters, IS piglets that were eaters consumed 1,235 g and control piglets that were eaters ate 437 g, the first being greater than the 600 g reported by English (1980). The question remains whether the percentage of eaters would be increased in experiments in which greater litter creep feed intakes were found.

Creep feed intake was much less in the current experiment than in a previous experiment (Kuller et al., 2004a) in both IS (231 vs. 686 g) and control piglets (147 vs. 314 g). The reason for these low feed intakes in the current experiment is not clear. The experiment was carried out 2 yr later in the same season, on the same farm and with the same population of sows with comparable litter size and weaning weights. Weight loss of the sow was on average 3 kg greater in the current than in our previous experiment (Kuller et al., 2004a, c). This suggests that milk intake per piglet might have been greater in the current experiment, which would decrease the need for creep feed. However, such a supposed greater milk intake did not result in heavier piglets at weaning, as might be expected. The lower intakes cannot be attributed to the chromic oxide added to the feed, because chromic oxide does not affect palatability (W.I. Kuller, unpublished data).

Piglets designated as eaters during lactation had heavier BW and ADG than non- eaters until 28 d after weaning. This agrees with findings of Bruininx et al. (2002) who studied the effect of pre-weaning creep feed consumption on post-weaning performance. In a previous experiment (Kuller et al., 2004b), piglets that were designated as eaters also had greater net absorption in the small intestine at d 4 after weaning. So, stimulation of creep feed intake during lactation may improve performance of newly- weaned piglets. The effect of creep feed intake, however, on post weaning diarrhea was difficult to assess in the current experiment because it is rarely observed on this farm.

In a previous experiment (Kuller et al., 2004a), IS litters with little or no creep feed intake during lactation tended to have greater BW gains after weaning than control litters with comparable feed intakes. We, therefore, speculated that these positive effects might be mediated by reduction in stress at weaning in IS piglets. In the current experiment, however, the relationship between pre-weaning feed intake and feed intake and growth shortly after weaning were not affected by treatment. Thus, increased performance of IS piglets shortly after weaning (increased feed intake and ADG) may not have been influenced by reduced stress at weaning. Possibly, the combination of the overall lower creep feed intake and the absence of an eater x treatment interaction on performance after weaning may have resulted in the fact that intermittent suckling did not have positive or negative effects on long- term performance to slaughter.

The percentage of animals classified as eaters is dependent on classification criteria and method of classification. Classification of animals as eaters, non-eaters, and non-classified was based on visual assessment of green coloring of feces, which resulted from intake of creep feed that contained chromic oxide (Barnett et al., 1989, Bruininx et al., 2002, W.I. Kuller, unpublished data). In the latter experiment (W.I. Kuller, unpublished data), piglets were forced fed during 2 successive days of lactation at different levels of creep feed and then excretion patterns of chromic oxide were assessed by visual examination of the feces. That experiment showed that piglets eating considerable amounts of creep feed could be distinguished accurately as eaters, because excretion of green feces was abundant. Animals with a low feed intake, however, often had 1 or more inconclusive samples (W.I. Kuller, unpublished data). In order to guarantee selection of animals that consumed considerable amounts of creep feed in the present experiment, animals were considered eaters when, out of 4 samples, they had at least 1 positive and 1 inconclusive sample or 3 inconclusive samples. Unfortunately, no alternative or more accurate marker is currently available to identify eaters and non-eaters or to measure individual creep feed intake in suckling piglets under farm conditions.

Intermittent suckling increased ADFI during lactation and shortly after weaning. Piglets consuming substantial amounts of creep feed (designated as “eaters”) showed greater BW gains and BW during the first 4 wk after weaning. However, IS did not increase the percentage of eaters within a litter during lactation and no long- term effects on ADG or ADFI were observed throughout the finishing period.

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Chapter 4

Addition of chromic oxide to creep feed as a fecal marker for selection of creep feed eating suckling pigs

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ABSTRACT

Objective—To determine whether the addition of chromic oxide (Cr_2O_3) to creep feed could be used as a visual marker in feces for selection of creep-feed–eating suckling pigs.

Animals—20 suckling pigs.

Procedures—Via syringe, 5 pigs (2 to 3 days old on day 0; 1/treatment) from each of 4 litters received oral administrations of 10, 20, 30, or 40 g of creep feed containing 10 g of $Cr_2O_3 \bullet kg^{-1}$ on each of 2 consecutive days (days 20 and 21) or 30 g of creep feed containing 10 g of $Cr_2O_3 \bullet kg^{-1}$ on day 20 and 30 g of Cr_2O_3–free creep feed on day 21. On days 21 through 24, 6 fecal samples were collected from each pig at regular intervals between 08:00 AM and 6:00 PM. Green-colored feces were considered indicative of creep feed consumption (eaters). Data analyses were based on single and multiple fecal samples.

Results—On day 22, evaluation of 1 fecal sample/pig and multiple fecal samples/pig resulted in identification of as many as 40% and only 15% of the feed-treated pigs wrongly as non-eaters, respectively. Repeated sampling over multiple days would identify 99% of eaters accurately. Pigs erroneously identified as non-eaters were those administered either low amounts of Cr_2O_3–supplemented creep feed for 2 days or Cr_2O_3–supplemented creep feed on only 1 day.

Conclusions and Clinical Relevance—Data suggest that addition of Cr_2O_3 to creep feed enables selection of individual creep-feed–eating suckling pigs via examination of feces, provided that repeated fecal samples are evaluated.

Introduction

To investigate effects of creep feed intake during lactation on performance and maturity of the intestinal tract of an individual newly weaned pig, it is necessary to know whether this individual pig within a litter has actually consumed creep feed during lactation. It is, however, still not possible to determine individual creep feed intake of suckling pigs at a feeding station, and creep feed intake is usually determined at the level of the litter. Inert markers added to creep feed can be used to identify pigs within a litter that eat creep feed by detection of the marker in the feces, but such markers should be easy to detect. Chromic oxide (Cr_2O_3) has been added to creep feed and used as a visual fecal marker with which young pigs within a litter that had consumed the creep feed were identified.[1,2] In those studies, fecal samples from each pig in a litter were collected once or twice daily; the

authors assumed that collection of samples of green feces indicated that the pig had eaten creep feed and that the absence of green coloration in the feces was indicative of no creep feed consumption. However, the suitability and reliability of Cr_2O_3 as a visual marker in feces for detection of creep-feed intake in suckling pigs was never validated. The purpose of the study reported here was to determine whether the addition of Cr_2O_3 to creep feed could be used as a visual marker in feces for selection of creep-feed–eating suckling pigs, and whether the accuracy of this selection was dependent on assessment of single or multiple samples of feces.

Material and Methods

The experimental design and use of pigs were approved by the Ethical Committee of the Faculty of Veterinary Medicine of Utrecht University, The Netherlands.

Pigs and housing

Four first-parity sows and their litters (*Finnish Landrace X Great Yorkshire*) were obtained from a commercial breeding company. The sows were housed individually in farrowing pens (each 2.30 X 1.80 m). At the front of each pen, there was a nest that was warmed by use of an infrared lamp for the litter. The day on which data collection was started was designated as day 0; parturition occurred between days -3 and 2. At weaning, the mean ± SE age of the pigs was 24.8 ± 0.5 days. Within the first 3 days after birth, pigs received a 1-mL injection of iron dextran and were ear tagged; males were castrated at this time. Mean weight of the pigs was 1,838 ± 94 g at birth and 7,983 ± 334 g at weaning. Mean weight gain was 269 ± 11 $g.pig^{-1}.d^{-1}$. Mean litter size was 9.4 ± 0.5 after cross-fostering within 3 days after birth and 9.3 ± 0.4 at weaning (day 25).

Feeding

From day 7 to weaning at day 25, pigs had ad libitum access to creep feed without Cr_2O_3, except for days 20 and 21. Creep feed was provided in a round trough and was based on milk products (340 $g.kg^{-1}$), soybeans, corn, sugar, vegetable oil, and a premix preparation (12.8 MJ of net energy kg^{-1}, 217 g of crude protein kg^{-1}, and 14.6 g of lysine kg^{-1}). From day 14 to weaning, a feeder with 4 feeding spaces was used. Drinking nipples were used to provide water ad libitum.

On days 20 and 21, the 5 heaviest pigs from each of the 4 litters were administered creep feed with or without Cr_2O_3 orally on 3 occasions. The 5 heaviest pigs were selected because the creep feed treatments could be administered to them with far less spillage, compared with their lighter littermates. The creep feed was made liquid by grinding it and then mixing it with water (1:1). Each oral administration of liquid feed was accomplished by 2 individuals: 1 restrained the pig with its head lifted and 1 fed the pig by use of a syringe containing the liquid feed. The liquid feed was administered slowly into the mouth of the pig, allowing the animal time to swallow. In this way, spillage of creep feed during syringe administration was minimal. No additional creep feed was provided on these days to the treated pigs. These treated pigs remained in the same pen with the non-treated pigs. The non-treated pigs were offered creep feed only during the periods of syringe-dispensed feeding of the treated pigs (3 times/ d). The 5 heaviest pigs selected from each litter were randomly assigned to 1 of 5 feeding regimens. Four of those 5 pigs received either 10, 20, 30, or 40 g of creep feed containing 10 g of Cr_2O_3 kg^{-1} on days 20 and 21; this amount was divided among 3 feedings between 8:00 AM and 09:00 PM. The fifth pig of each litter received 30 g of creep feed containing 10 g of Cr_2O_3 kg^{-1} on day 20 and 30 g of creep feed without chromic oxide on day 21; this was designated as the 30G-Y treatment (so called because feed with Cr_2O_3 is green and feed without Cr_2O_3 is yellow). The order of liquid creep feed administrations among the litters and among the pigs within the litters was similar throughout the experiment, starting with pig 1 and ending with pig 20.

Measurements

Pigs were weighed individually at birth and at weaning. General health variables were assessed daily and no signs of illness were detected. From day 7 to day 21, residual amounts of creep feed were assessed weekly; because no food wastage was observed (the feeder was placed on a solid floor), the feed no longer present was considered eaten. On day 21 (24 to 34 hours after first liquid creep feed administration), day 22 (48 to 58 hours after first liquid creep feed administration), day 23 (72 to 82 hours after first liquid creep feed administration), and day 24 (96 to 106 hours after first liquid creep feed administration), 6 fecal samples were collected by use of fecal loops (Instruvet, Amerongen) from all treated pigs at regular intervals between 08:00 AM and 06:00 PM. At weaning on day 25 (106 hours after first liquid creep feed administration), a single fecal sample was collected. The order in which feces were collected from the litters and the pigs within each litter was similar throughout the experiment and identical to the order of syringe-dispensed feeding.

The color of the fecal samples was determined visually by the same person (WK) and assigned as green or not green. Pigs were considered to not have eaten creep feed (ie, non-eaters) if no green feces were detected in the single sample that was used in the analysis or if no green feces were detected in any of the multiple samples that were used in the analysis. Pigs were considered to have eaten creep feed (ie, eaters) if green feces were detected in the single sample that was used in the analysis or if green feces were detected in at least 1 of multiple samples that were used in the analysis.

Statistical analysis

Differences in the numbers of green fecal samples per day and per feed regimen were assessed by use of a χ^2 test; the sample was the experimental unit. Data are presented as mean ± SE. Means were calculated by use of computer software (Means procedure, SAS version 8.1, SAS Institute, Cary NC). A value of $P < 0.05$ was considered significant.

Results

Patterns of fecal excretion of Cr_2O_3 in individual pigs were assessed (Figure 1). Starting 1 day after initiation of liquid creep feed administrations and during the entire period of sample collection (days 21 to 25), 49.2% (246/500) of the feces samples were classified as green (Figure 1). Green feces were never detected from only 1 pig (pig 4). Additionally, there were pigs that excreted Cr_2O_3 intermittently; thus, alternating green and non-green fecal samples were collected from those pigs on the same day. Eight pigs had a green fecal sample at the first sample collection; thus, excretion of Cr_2O_3 started within 24 hours after the first Cr_2O_3–containing liquid creep feed administration. The proportion of fecal samples collected that were green was significantly ($P < 0.001$) higher at day 22 than at day 24 (83/120 samples vs. 40/120 samples). After day 25, no green feces were evident in the pens (data not shown). On analysis of fecal samples on the basis of only 1 sample/pig, the number of pigs identified as eaters depended on the time point at which each sample was collected, irrespective of the feeding regimen (Figure 2). The highest number of creep feed eaters was detected at day 22. However, depending on the time point at which the fecal sample was collected from each pig on day 22, as many as 40% of the pigs administered liquid creep feed could still be wrongly identified as non-eaters.

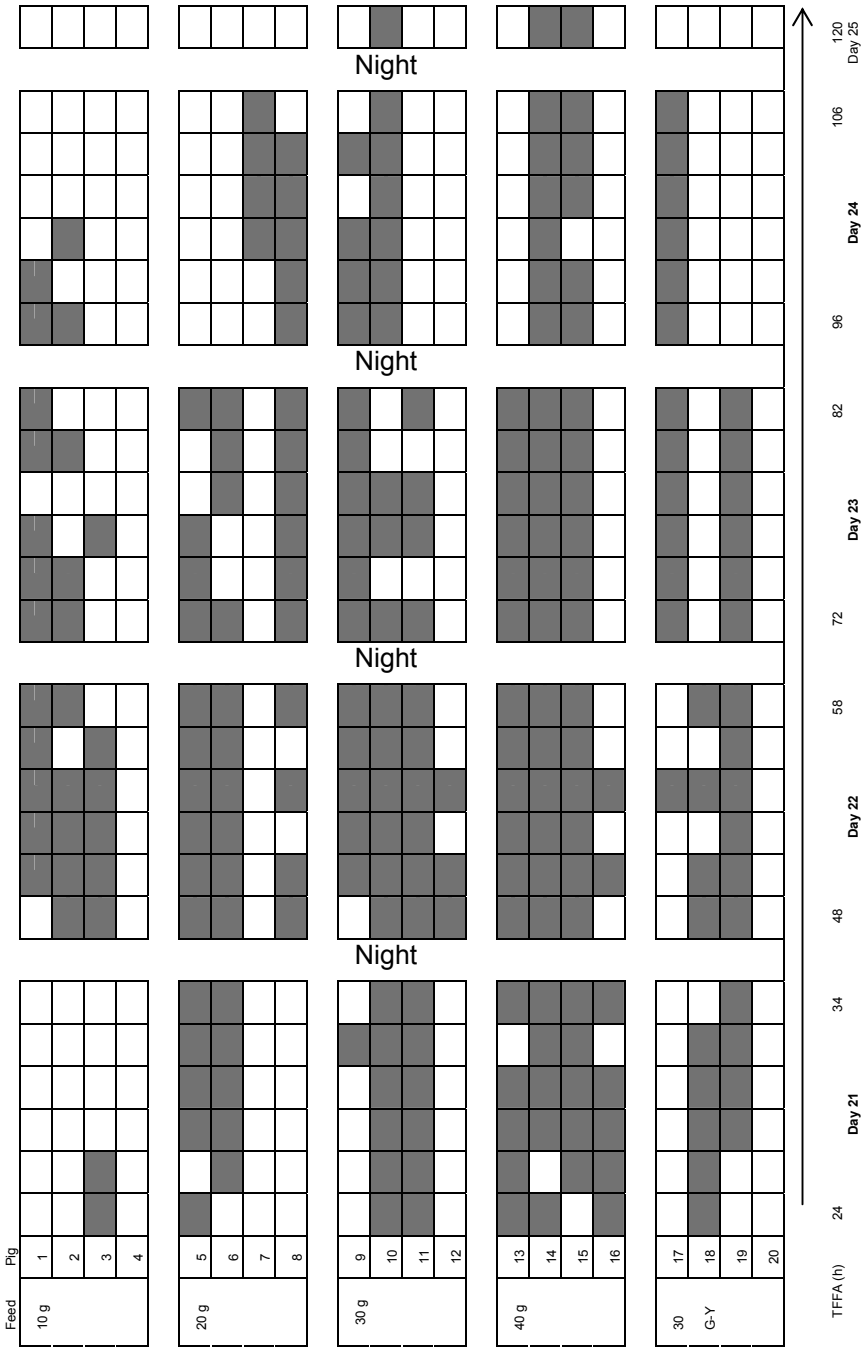

Figure 1—Excretion patterns of chromic oxide (Cr_2O_3) in feces of 20 suckling pigs that were orally administered 10, 20, 30, or 40 g of creep feed containing 10 g of Cr_2O_3•kg^{-1} (divided among 3 daily administrations) on each of 2 consecutive day (days 20 and 21) or 30 g of creep feed containing 10 g of Cr_2O_3• kg^{-1} (divided among 3 daily administrations) on day 20 and 30 g of creep feed without Cr_2O_3 (divided among 3 daily administrations) on day 21 (the 30G-Y treatment). There were 4 pigs in each of the 5 feeding regimen groups; each row represents 1 pig and each block 1 sample. Fecal sample collection (6 times/d) started on day 21 (ie, 24 hours after the start of the feeding regimen). Black shaded areas represent fecal samples in which green Cr_2O_3–associated coloration was detected; white areas represent fecal samples in which green no Cr_2O_3–associated coloration was detected.
TFFA = Time after first feed administration (on day 20).

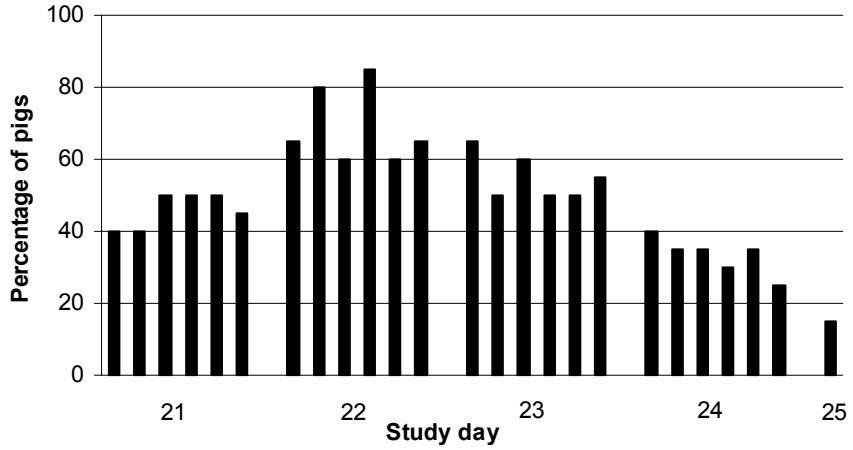

Figure 2— Percentage of the suckling pigs (n=20) in Figure 1, independent of the 5 groups receiving Cr_2O_3–containing creep feed, that were identified as creep feed eaters on the basis of the Cr_2O_3–associated coloration of a fecal sample collected 6 times/d on days 21 through 25. Each bar represents the percentage of suckling pigs (n=20) at one of the sampling moments (n=6) at that particular day. Oral administration of creep feed treatments was performed on days 20 and 21 and each feed treatment was divided among 3 administrations a day. The first fecal samples were collected 24 hours after the start of creep feed administrations. *See* Figure 1 for key.

On analysis of multiple fecal samples (6 sample/pig/d), variation in the percentage of pigs identified as eaters was still high, irrespective of the feeding regimen (Table 1). From multiple fecal samples collected from each pig on day 22, 17 of 20 (85%) pigs were identified as eaters. The pigs that were not identified as eaters when multiple samples from each pig were analyzed were either the pigs that received administrations of low amounts of liquid creep feed containing Cr_2O_3 (10 g or 20 g for 2 consecutive days) or those that received administrations of liquid creep feed containing Cr_2O_3 for only 1 day and were administered liquid creep feed without Cr_2O_3 during the subsequent day (the 30G-Y treatment). At day 22, the proportion of fecal samples collected that were green was higher in pigs that were administered 30 or 40 g of liquid Cr_2O_3-containing creep feed/d than in the pigs that received the 30G-Y treatment (Table 2). The mean numbers of green fecal samples from pigs identified as eaters were calculated (Table 1).

Table 1—Mean number ± SE of green fecal samples per identified creep feed eater* per day† (based on multiple samples) and the number of identified creep feed eaters in 5 groups of 4 suckling pigs that received oral administrations of 10, 20, 30, or 40 g of creep feed containing 10 g of Cr_2O_3•kg^{-1} (divided among 3 daily administrations) on each of 2 consecutive day (days 20 and 21) or 30 g of creep feed containing 10 g of Cr_2O_3• kg^{-1} (divided among 3 daily administrations) on day 20 and 30 g of creep feed without Cr_2O_3 (divided among 3 daily administrations) on day 21 (the G-Y treatment). Fecal samples were collected 6 times/d and the first samples were collected 24 hours after the start of creep feed administrations.

	Study day							
	21		22		23		24	
Feed regime	Mean no. of samples	No. of eaters	Mean no. of samples	No. of eaters	Mean no. of samples	No. of eaters	Mean no. of samples	No. of eaters
10 g	2.0 ± 0	1	5.0 ± 0	3	3.0 ± 1.2	3	2.0 ± 0	2
20 g	5.0 ± 0	2	5.7 ± 0.3	3	4.7 ± 0.7	3	4.5 ± 0.5	2
30 g	4.3 ± 1.7	3	5.0 ± 0.7	4	4.3 ± 0.9	3	5.0 ± 1	2
40 g	5.3 ± 0.3	4	5.0 ± 1	4	6.0 ± 0	3	5.5 ± 0.5	2
30G-Y	4.5 ± 0.5	2	3.7 ± 1.5	3	6.0 ± 0	2	6.0 ± 0	1
Total		12		17		14		9

*Eaters were defined as pigs with ≥ 1 green fecal sample. Each group consists of 4 pigs
†Collection days 21 through 25 represent 24 to 34 hours, 48 to 58 hours, 72 to 82 hours, and 96 to 106 hours after start of creep feeding treatments, respectively.

Discussion

The objective of the present study was to determine whether ingestion of Cr_2O_3 in creep feed could be used as a visual marker in fecal samples to select creep-feed–eating suckling pigs for further research. In the experiment, pigs were administered liquid creep feed on 2 consecutive days (days 20 and 21; feed contained Cr_2O_3 on 1 or both days), after which no further feed treatments were administered and the excretion of Cr_2O_3 in feces was visually determined. Syringe administration of liquid creep feed preparations was used to standardize creep feed intake, because ad libitum creep feed intake is highly variable among pigs and within litters and can only be described on a litter level. When individual feed intake is unknown, the relation to the excretion pattern of Cr_2O_3 cannot be determined.

With the regimens of liquid creep feed administration used in the present study, the most suitable period for fecal sample collection was from 48 to 58 hours after treatment, because high numbers of green fecal samples were evident at day 22. Therefore, in our experiments, a comparison of data from single fecal samples with data from multiple fecal samples was made at day 22. In pigs that are not fed Cr_2O_3–containing creep feed during specific treatments but ingest marked creep feed more continuously, it can be expected that these high numbers of green fecal samples would continue to be detected for a longer period of time, because it is known that litters that eat creep feed on 1 day will continue eating during the following days.[3-5] Fecal excretion of Cr_2O_3 would then reach a plateau, comparable to or possibly even higher than the values detected at day 22 in the study of this report.

When identification of pigs as eaters or non-eaters was made on the basis of the color of 1 fecal sample at day 22, the number of pigs administered liquid Cr_2O_3 –containing creep feed that were identified as eaters depended on the time point at which the fecal sample was collected, and as many as 40% of the pigs were wrongly identified as non-eaters. Thus, the evaluation of only 1 fecal sample collected during lactation to identify pigs as eaters or non-eaters would not be accurate enough to select individual pigs for use in further research. When identification of pigs as eaters or non-eaters was made on the basis of the color of multiple fecal samples (6 samples/pig) at day 22, the proportion of pigs administered liquid Cr_2O_3 –containing creep feed that were identified as eaters was 85% and thus, only 15% of those pigs were wrongly identified as non-eaters. Therefore, if eaters are to be selected for further experiments, at least evaluation of multiple fecal samples collected within 1 day is necessary.

The mean probability (based on the means of samples at each time point, not the probability after repeated measurements) of accurately identifying a pig as an eater at day 22, if only 1 fecal sample/d was evaluated, was 0.69. The probability that during several consecutive days a pig has at least 1 green fecal sample is calculated as 1 minus the probability (P) of only negative samples during those days (ie, $1 - P\ [\text{only negative samples}]^{\ n\ days}$). When fecal samples are collected once daily for 4 consecutive days and the assumption is made that excretion of Cr_2O_3 has reached a plateau, then the probability of identifying an eating pig accurately as an eater will be 99% ($1 - 0.31^4$). Thus, if pigs are indeed consistent in their creep feed intake, fecal sample collection once daily for 4 days will decrease the probability of wrongly identifying an animal as non-eater to 1%.

In the present study, errors in identification of pigs occurred when pigs had been administered only low amounts of liquid creep feed containing Cr_2O_3 (10 g or 20 g) or when pigs had been administered liquid creep feed containing Cr_2O_3 for only 1 day (the 30G-Y

treatment). Compared with findings in those pigs, the proportion of fecal samples that were green was higher in pigs that received 30 or 40 $g.d^{-1}$ of Cr_2O_3–containing creep feed and when multiple fecal samples were evaluated, the chance of detecting these marked feed–eating animals was 100%. Possibly, a higher amount of Cr_2O_3 added to the creep feed could increase the number of green fecal samples for all feeding regimens. In our study, the addition of 10 g of Cr_2O_3 to each kilogram of creep feed was based on data from other investigations[1,2] in suckling pigs. Another group of animals that were not easily detected as eaters were pigs that were administered liquid creep feed containing Cr_2O_3 on 1 day and liquid creep feed without Cr_2O_3 on the following day (the 30G-Y treatment). When creep feed is provided ad libitum, this group would be represented by pigs with irregular feed intake. It is known that litters that eat creep feed on a particular day will continue eating that feed during the following days[3-5] and it appears likely that this also the case for individual pigs. However, it is possible that young pigs do not eat creep feed for several consecutive days, especially during the early stages of lactation. Therefore, the use of Cr_2O_3 to identify creep-feed–eaters is less reliable when pigs have a low or inconsistent feed intake, because these animals have a higher risk of being misclassified as non-eaters. This problem is less important when only creep-feed–eating pigs have to be selected for further research (eg, for studies on the effect of creep feed intake on gastrointestinal physiologic processes in swine).

With the use of Cr_2O_3, the exact amount of creep feed eaten by an individual pig cannot be determined. It is, however, still not possible to assess creep feed intake of individual pigs within a litter by any other means, and so the use of Cr_2O_3 is a good method at present. Moreover, in an earlier experiment in suckling pigs by our group, creep feed intake was not affected by the addition of Cr_2O_3; thus, Cr_2O_3 can be used to select creep-feed–eating pigs without interfering with creep feed intake. Overall, our data suggest that Cr_2O_3 is a suitable marker for selection of creep-feed–eating pigs within a litter during lactation (for purposes of further research) by determination of fecal color, provided that repeated fecal samples are collected. However, it is important to note that pigs with low or irregular creep feed intake can erroneously be identified as non-eaters and thus, selection of non-eaters by this method is rather difficult.

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Chapter 5

Intermittent suckling and level of feed intake during lactation influence feeder visiting behaviour of piglets

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ABSTRACT

Intermittent suckling (IS) has proven to stimulate creep feed intake in suckling piglets. This paper describes the development of eating behaviour in three litters with high (H) and three litters with low (L) feed intake in both a control (C) and IS treatment. IS litters were separated from the sow for a period of 12 h/d (0930 to 2130) from T14 to weaning (T25). Feeder visits of individual piglets and nursing behaviour were analysed from continuous video recordings at 5 treatment days: T13, T16, T24, T25 and T26. Non-feeding related activity of piglets was scored at 10 minute intervals.

A high number of CL piglets never visited the feeder during lactation; at T24, 56 % of the CL piglets but only 9 % of the ISL and CH piglets did not visit the feeder. On the other hand, at T24 100% of the ISH piglets visited the feeder at least once. Visiting frequency did not change in CL piglets during lactation, but increased in ISH piglets between T13 and T16 and in CH and ISL piglets between T16 and T24. At T16, T24 and T25, visiting frequency and total feeder time were higher in H than in L piglets and were higher in ISL than in CL piglets at T24. Total feeder time increased in all piglets between T16 and T24, except in CL piglets. At T26, average feeder time and total feeder time were lower in CL piglets than in the other piglets. Latency to first visit to the feeder after weaning did not differ between groups, but variation was greater in L than in H piglets.

Nursing frequency decreased in IS litters once treatment started. Average nursing time decreased in CH, remained unchanged in L and increased in ISH litters during lactation.

At the end of lactation (T24), H litters were more active than L litters. After weaning, no difference was found between the litters but at T26 ISH litters were least active.

It is concluded that IS treatment did not affect feeder visiting behaviour of piglets from litters with an anyhow high level of feed intake during lactation. IS piglets from litters with a low level of creep intake were stimulated to visit the feeder during lactation, which probably made them familiar with the feeder and the feed. Part of the variation in feed intake between litters might be explained by differences in suckling behaviour and activity.

Keywords: pig; creep feed; nursing; weaning; behaviour

Introduction

In pigs, creep feed intake during lactation stimulates feed intake after weaning (Bruininx et al., 2002) and average daily gain after weaning (Appleby et al., 1991; Bruininx et al., 2002; Pajor et al., 1991). Also net absorption in the small intestine (the net result of secretion and absorption) immediately after weaning is significantly higher in piglets consuming creep feed during lactation than in non- eating piglets (Kuller et al., 2004b), thereby probably decreasing the risk of post- weaning diarrhoea. So, stimulating creep feed intake in suckling piglets could be important to optimize pig performance after weaning.

Creep feed intake in suckling piglets is usually low during lactation but can be stimulated by intermittent suckling (IS; (Berkeveld et al., 2007; Kuller et al., 2004a; Kuller et al., 2007), a management technique in which piglets are separated from the sow for a number of hours every day during the second half of lactation. IS increases average creep feed intake per piglet and also increases the number of litters with high feed intake during lactation (Kuller et al., 2004a). However, also during IS treatments, litters have been identified with little or no creep feed intake during lactation. Apparently, some litters start eating creep feed during lactation, or can be stimulated to do so by the use of IS, while others are not. Moreover, IS does not seem to increase the number of piglets that were eating within a litter, as judged by green coloured faeces after addition of chromic oxide to the creep feed (Kuller et al., 2007).

At the moment, little is known regarding the development of creep feed intake during lactation by individual piglets, because creep feed intake is usually determined at the litter level and assessment of creep feed intake of individual piglets is still not possible. So presently, one way to investigate the development of creep feed intake by individual piglets during lactation and shortly after weaning is to investigate feeder visiting behaviour by quantifying the number and duration of visits to the feeder over time. Because IS stimulates creep feed intake, it is of interest to study the development of feeder visiting behaviour in IS litters. Study of these litters also helps in understanding the relevance of suckling (and deprivation of suckling) in the development of feeder visiting behaviour.

Thus, this paper describes the development of feeder visiting behaviour in intermittently and continuously suckled pigs during lactation and shortly after weaning and aims to give insight in the motivation for creep feed intake in piglets. To investigate a possible link between feed intake level of the litter and eating behaviour of piglets, litters consuming high and low levels of creep feed were compared from IS and control treatments.

Material and methods

Treatments, animals and housing

The experimental design was approved by the Ethical Committee of the Veterinary Faculty of Utrecht University (The Netherlands).

There were two treatments, control (C) and intermittent suckling (IS). In the control treatment, piglets had access to the sow for 24 h/d until weaning. In the IS treatment, the piglets were separated from the sow for 12 h each day (0930 until 2130; separation period: SP) and allowed access to the sow for the other 12 h (2130 until 0930; non separation period: NSP). In order to synchronize the start of intermittent suckling within a farrowing batch, treatment day 0 (T0) was designated as the start of data collection. Piglets were born from 1 d before to 2 d after T0. Intermittent suckling always started at T14 and piglets were weaned at T25 at 0800 a.m. During SP, piglets and sow remained in the pen and were separated by a removable wooden partition (height 65 cm) that was attached on both sides to the farrowing crate of the sow not allowing any physical contact. The sows were housed individually in farrowing crates (2.40 x 1.80 m). The farrowing pen consisted of a partly solid floor and a partly slatted floor. During the SP, IS piglets were allowed extra space (solid floor) at the back of the pen to create comparable floor space with that of the control piglets (IS: 3.75 m^2 vs. C: 4.32 m^2 (including sow)). Lights were on between 0730 and 2330. To facilitate video recordings, a low level of light (12 lux) was maintained during the night. At weaning sows were moved to a mating room and the piglets remained in the pen.

Fourteen weekly farrowing batches were alternately allocated to each treatment: 7 control batches (in total 31 sows) and 7 IS- batches (in total 31 sows). Each batch consisted of 4 to 5 sows (Dutch Landrace x York). Batches were housed in separate rooms during lactation. Only one treatment was applied per batch to avoid an influence by suckling of control sows on IS sows, since suckling is highly synchronized between animals in a room. Video recordings were made of 28 sows (14 IS and 14 control). From each treatment, six sows were selected. Within each treatment, selection was based on feed intake level of the litter during the complete lactation period (T7 to T24; high: H, or low: L), because feed intake during the first week of feed intake (T7 to T13) was too low to assign treatments. This resulted in 3 CH litters (n = 32 piglets; control, high feed intake level) and 3 CL litters (n = 27 piglets; control, low feed intake level), 3 ISH litters(n = 28 piglets; intermittent suckling, high feed intake level) and 3 ISL litters (n = 32 piglets; intermittent suckling, low feed intake level. Litter size, weight and feed intake of each of the twelve litters are shown in Table 1. The

sows used in the current experiment and the other sows in the room were also part of another study investigating the effects of intermittent suckling on weight gain and feed intake until slaughter (Kuller et. al 2007).

Piglet feeding

Water was available ad libitum and distributed by use of a drinking nipple at the rear end of the pen. Creep feed residuals were weighed per litter at 7 d intervals. Because no food wastage was observed (feeder was placed on a solid floor), disappeared feed was considered eaten. Creep feed based on milk products (34%), soybeans, corn, sugar, vegetable oil and a premix (12.8 MJ NE.kg^{-1}, 21.7% CP, 14.7% crude fat, 2.0% crude fiber, 5.2% ash, 1.46% lysine, 0.86% calcium, 0.58% phosphorus, 160 mg. kg^{-1} copper, 500 units. kg^{-1} phytase; as- fed basis) was offered to the piglets ad libitum from T7 onwards and given in a round piglet trough (diameter 25 cm). From T14 onwards a pig feeder with 4 feeding spaces was used (11 cm feeder space/ piglet). From T21 to T23 a gradual change (respectively 40%, 60% and 100% replacement) to a weaner diet based on milk products (18.5%), barley, soy beans, corn, sugar, vegetable oil and a premix (11.4 MJ NE.kg^{-1}, 17.9% CP, 10.7% crude fat, 2.9% crude fiber, 5.8% ash, 1.25 % lysine, 0.77% calcium, 0.59% phosphorus, 160 mg. kg^{-1} copper, 500 units. kg^{-1} phytase; as-fed basis) was made, which was given until T31 (7 d after weaning) of the experiment.

Measurements

Video recordings were made continuously for 24 h at five treatment days; T13 (day before start of IS), T16 (3 days after onset IS), T24 (day before weaning), T25 (day of weaning) and T26 (day after weaning). All piglets had been marked on their back to allow individual identification. When a piglet stayed for at least 2 s with its head in the feeder, this was recorded as a visit and beginning and end of the visit were recorded. The following parameters of feeder visiting behaviour were calculated for each piglet: total time spent at the feeder per piglet per day (total feeder time, s.), visiting frequency per day and average time per visit per day (average feeder time, s.). Nursing was defined as more than 50 % of the litter being active (massaging or sucking) at the udder. Nursing characteristics of the litter are: total time spent nursing per day, nursing frequency and average duration of each nursing. It was also recorded whether the nursing was ended by the sow or by the piglets. The nursing was considered to be ended by the sow, when she turned to sternal recumbence or, in case of a nursing while standing, she started moving forwards and backwards in her farrowing crate or lied down. The nursing was considered to be ended by

Table 1. Littersize (n), weight and feed intake level of the individual litters in high and low eating litters in the control (C) and intermittent suckling treatment (IS), means ± SE. In the intermittent suckling treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). Piglets were weaned at 0800 h at T25.

				Feed intake (g/piglet)			Piglet weight (g/piglet)			Piglet weight gain
Trt	Sow	Level	n	T7 to T13	T14 to T24	T25 to T32 (after weaning)	Birth	Start IS	Weaning	T25 to T32 (after weaning)
C	1	High	10	64	171	1857	1650 ± 40	5571 ± 169	8377 ± 243	184 ±18
C	2	High	12	42	471	2833	1458 ± 21	4366 ± 124	6465 ±196	178 ± 42
C	3	High	10	25	186	1380	1389 ± 24	3798 ± 176	6700 ± 84	166 ± 12
C	4	Low	11	16	10	727	1198 ± 20	4504 ± 89	7479 ± 116	65 ± 17
C	5	Low	8	21	64	1250	1585 ± 32	5191 ± 146	7367 ± 239	129 ± 26
C	6	Low	8	17	67	888	1513 ± 40	5531 ± 137	8296 ± 217	42 ± 36
IS	7	High	9	28	451	2429	1609 ± 46	5949 ± 174	8531 ± 187	266 ± 28
IS	8	High	7	23	219	1571	1651 ± 36	5751 ± 211	7037 ± 298	71 ± 35
IS	9	High	12	19	170	1500	1145 ± 20	4801 ± 131	6634 ± 151	186 ± 23
IS	10	Low	10	10	41	1643	1509 ± 27	4657 ± 98	6819 ± 124	211 ± 21
IS	11	Low	12	24	4	583	1281 ± 32	3941 ± 93	5439 ± 110	104 ± 19
IS	12	Low	10	10	14	750	1500 ± 36	5052 ± 138	7000 ± 187	140 ± 28

the piglets when, after a nursing less than 50 % of the litter was active at the udder.
Various behavioural elements (moving, fighting, exploring, eating, and suckling) of piglets within litters were scored at 10 minute intervals (6 times/ h). So, the total number of behavioural observations per litter (24 h) was: 144 x n piglets. All behavioural elements, except resting and feeder visiting behaviour (feeder visits, drinking water, massaging or sucking at the udder) was summed and designated as 'non feeding related active behaviour'. The proportion of total observations spent on active behaviour was calculated by dividing the number of observations scored as active (= all behavioural elements except lying) divided by the total number of observations per day.

Statistical analysis
All statistical analyses were performed using the SAS 8.2 statistical software program (SAS Institute, Inc., Cary, NC).
Time of the visits to the feeder were summed per piglet and averaged for each day. Because data on feeder visits (total feeder time, average feeder time and visiting frequency) were not normally distributed, square root transformations were performed. Data on creep feeder visiting behaviour were analysed using a linear mixed model (West et al., 2006), allowing for repeated measurements per subject (piglet, nested within sow and treatment and feed intake level) and random effects of sow (nested within treatment and feed intake level) and piglet (nested within sow and treatment and feed intake level) with unstructured covariance structure. The model included effects of feed intake level (H vs. L), treatment (IS vs. control) and day of treatment (T13, T16, T24, T25, T26) and their two way and three way interactions. Effects of gender, weight at birth or at start of treatment, and weight gain between T0 and T6 or between T7 and T13 were not significant and therefore omitted from the model. Data were analysed for the whole day but also for the SP and the NSP periods separately. Period (SP vs. NSP) was significant in the analysis of visiting frequency and therefore added to the model of visiting frequency.
Nursing characteristics were analysed using a linear mixed model (West et al., 2006) allowing for repeated measurements per subject (sow, nested within treatment and feed intake level) and random effects of sow (nested within treatment and feed intake level).
Data on litter activity were analysed using a linear mixed model allowing for repeated measurements per subject (sow, nested within treatment and feed intake level) and random effects of sow (nested within treatment and feed intake level) with compound symmetry covariance structure. The model included the effects of feed intake level, treatment and day of treatment and period of the day and their interactions.

Table 2. Percentage of piglets with either 0, 1 to 15, 16 to 30 or more then 31 visits per 24 h to the feeder in high and low eating control and intermittent suckling piglets (IS) litters. In the IS treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). Piglets were weaned at 0800 h at T25.

	Control								IS							
	High (n=32)				Low (n=27)				High (n=28)				Low (n=32)			
Day	Number of visits				Number of visits				Number of visits				Number of visits			
	0	1-15	16-30	>31	0	1-15	16-30	>31	0	1-15	16-30	>31	0	1-15	16-30	>31
T13	0	75	25	0	30	56	15	0	32	54	14	0	19	75	6	0
T16	22	63	16	0	56	44	0	0	7	43	21	29	44	56	0	0
T24	9	59	16	16	56	44	0	0	0	32	50	18	9	78	9	3
T25	0	9	41	50	0	67	33	0	0	7	39	54	0	63	25	13
T26	0	0	41	59	0	37	22	41	0	0	61	39	0	19	34	47

Bonferroni corrections were applied to all models to correct for multiple comparisons. Data are presented per treatment day and, if period was significant in the analyses, also per SP or NSP period. Data are presented as means ± SE.

Results

Feeder visiting behaviour

-Lactation period (T13 to T24) -

Visiting frequency to the feeder ranged from 0 to 28 per piglet at T13, from 0 to 70 at T16 and from 0 to 71 at T24. Average feeder time per visit varied between 6.5 and 300 s per piglet at T13, from 3 to 207 s per piglet at T16 and from 3 to 204 s per piglet at T24. As a result, variation between piglets in total feeder time was high, ranging from 0 to 1704 s, from 0 to 2274 s and from 0 to 5207 s per piglet at T13, T16 and T24, respectively.

A high number of CL piglets never visited the feeder during lactation; at T24, 56 % of the CL piglets but only 9 % of the ISL and CH piglets did not visit the feeder (Table 2). On the other hand, at T24 100% of the ISH piglets visited the feeder at least once.

Visiting frequency (Figure 1) increased during lactation between T13 and T16 (ISH piglets; $P<0.05$) or between T16 and T24 (CH and ISL piglets; $P<0.05$). However, in CL piglets visiting frequency never increased during lactation ($P>0.10$). At T24, visiting frequency was higher in ISL than in CL piglets. Visiting frequency at T16 and T24 was higher in H than in L litters. So, IS stimulated piglets from low feed intake litters to visit the feeder.

An increase in average feeder time (Figure 1) was found between T16 and T24 in IS piglets ($P<0.05$), but not in control piglets. Between the four groups, average feeder time did not differ, except at T16 where CH piglets had a greater average feeder time than piglets in L litters. Between T16 and T24, total feeder time increased in all piglets ($P<0.05$) except in CL piglets where no change was found ($P>0.10$). Within L litters, IS piglets had a greater total feeder time than control piglets at T24. At T16 and T24, total feeder time was higher in H litters than in L litters. At T13 and T24, differences in total feeder time were the result of differences in visiting frequency, and not of differences in average feeder time.

Period of the day (SP vs. NSP) affected visiting frequency (Figure 2), but not average or total feeder time. In H piglets, but not in L piglets, visiting frequency was generally higher during SP than during NSP. During NSP, visiting frequency was low in all piglets. Visiting frequency during NSP was higher in H than in L piglets at T13 in C piglets, at T16 in IS piglets and at T24 in both C and IS piglets.

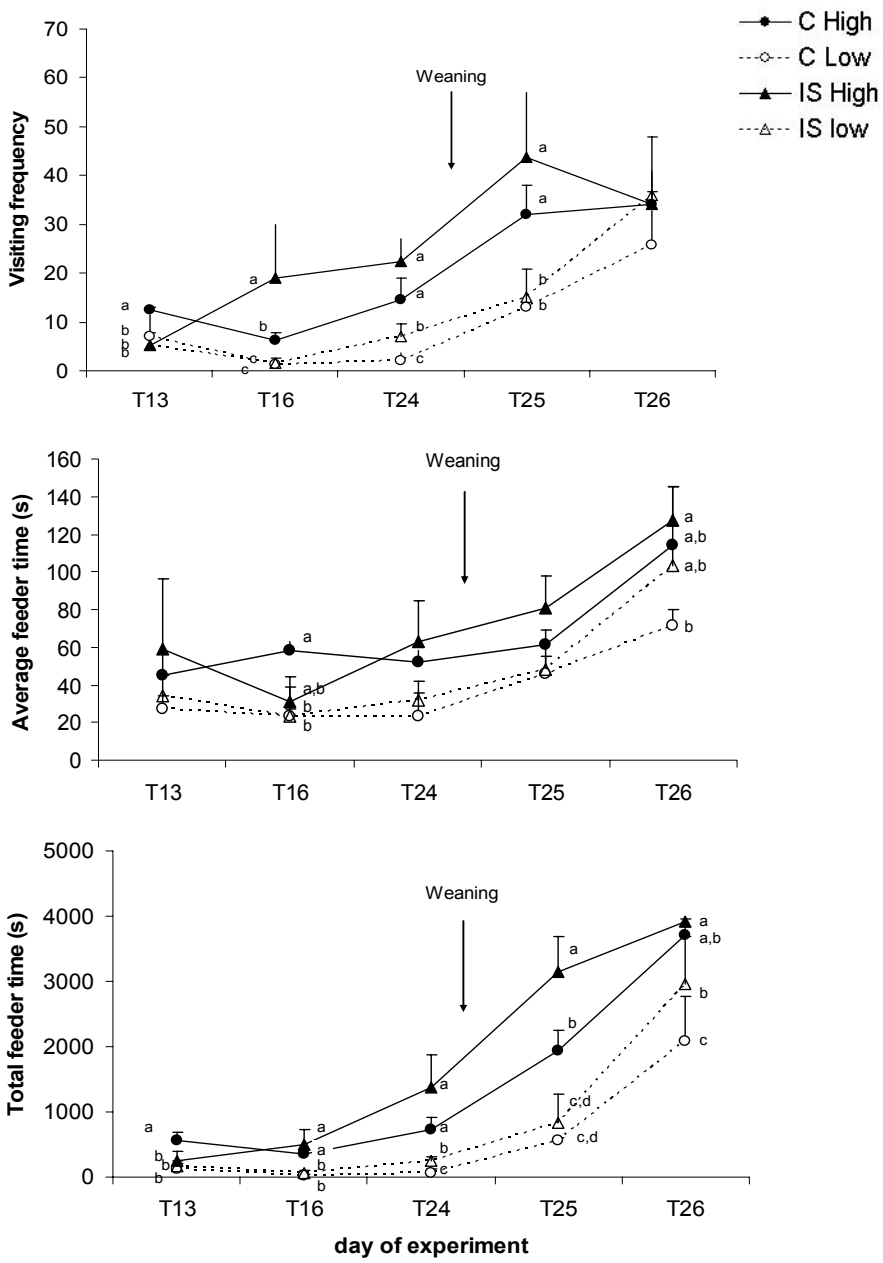

Figure 1. Visiting frequency, average feeder time and total feeder time in high (solid line, closed symbols) and low (dotted line, open symbols) eating litters in the control (circles) and intermittent suckling (triangles) treatment at different treatment days (24 h). In the control treatment piglets were continuously with the sow. In the intermittent suckling treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d (T 14) before weaning. Piglets were weaned at 0800 h at T25. Data are presented as means ± SE. Within a treatment day, different letters indicate significant differences between groups.

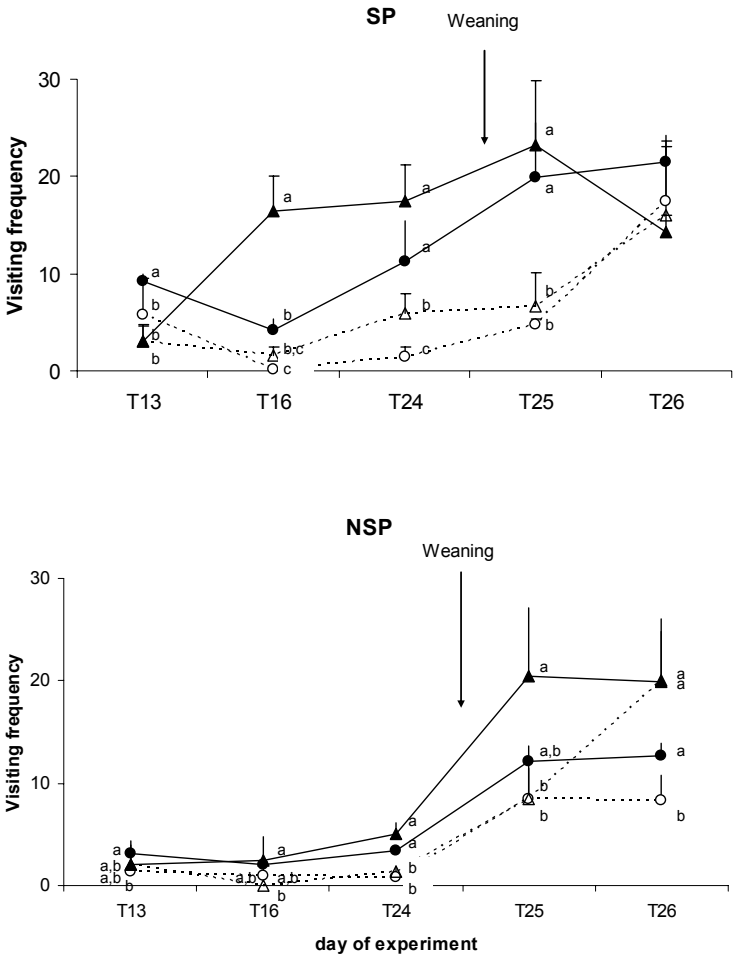

Figure 2. Visiting frequency during the separation (SP; 0930 to 2130) and non separation (NSP) period in high (solid line, closed symbols) and low (dotted line, open symbols) eating piglets in the control (circles) and intermittent suckling (triangles) treatment. In the control treatment piglets were continuously with the sow. In the intermittent suckling treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). Piglets were weaned at 0800 h at T25. Data are presented as means ± SE. Within a treatment day, different letters indicate significant differences between groups.

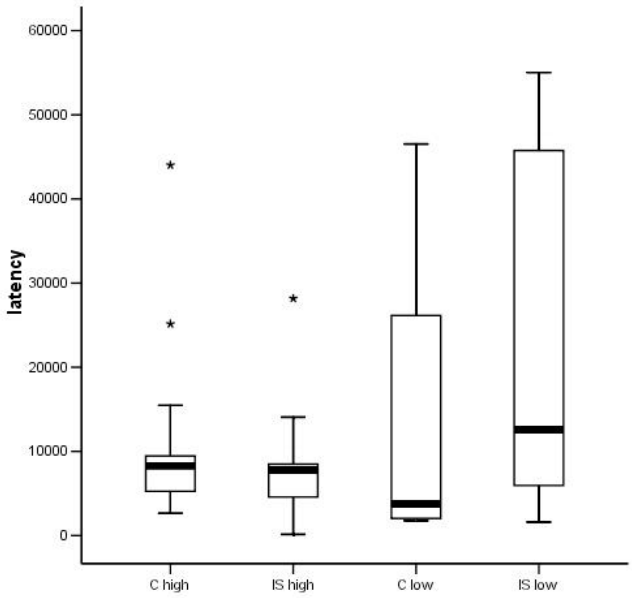

Figure 3. Boxplot of the latency (s) to first visit to the feeder after weaning in low and high eating litters of the control (C) and intermittent suckling (IS) treatment. In the C treatment, piglets were continuously with the sow. In the IS treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). Piglets were weaned at 0800 h at T25. * = outliers

-After weaning (T25 and T26) -

No differences were found between the treatments or between the feed intake levels in latency to first visit to the feeder after weaning (Figure 3). Variation was greater in L piglets than in H piglets. Variation in visiting frequency and average feeder time was high, also after weaning. Visiting frequency ranged from 1 to 93 at T25 and from 3 to 97 at T26. Average feeder time ranged from 13 to 151 s at T25 and from 21 to 362 s at T26. As a result, also variation in total feeder time was high and ranged from 24 to 5574 s and from 132 to 7549 at T25 and T26, respectively.

All piglets visited the feeder at T25 and T26 (Table 2). Also the percentage of piglets visiting the feeder with a high frequency (> 31 visits per day) increased after weaning, although it took until T26 before this increase was seen in CL litters.

Visiting frequency was higher in H than in L piglets at T 25 (Figure 1), but did not differ between piglets at T26 figure 1. Average feeder time increased in L piglets between T24 and T25 ($p<0.05$) and in all piglets between T25 and T26 ($p<0.05$). At T26, average feeder time was lower in CL piglets, but not in ISL piglets, than in H piglets. Total feeder time (Figure 1) increased over time from T24 to T25 ($p<0.05$) and from T25 to T26 for all groups ($p < 0.05$). At T25, total feeder time was greater in the H piglets than in L piglets. At T26, CL piglets had a lower total feeder time than piglets from the other treatments. The greater total feeder time in the H piglets at T25 was mainly the result of a higher feeder visiting frequency by these piglets.

Also after weaning, period of the day (SP vs. NSP) affected only visiting frequency (Figure 2). In H piglets, visiting frequency did not differ between SP and NSP at T25 but was higher during SP than during NSP at T26. In CL piglets, visiting frequency did not differ between SP and NSP at both days. Strikingly, in ISL piglets visiting frequency was lower during SP than during NSP after weaning.

Nursing characteristics

Nursing frequency ranged from 23 to 34 at T13, from 17 to 31 at T16 and from 16 to 32 at T24. Average time per nursing varied between 44 s and 15.2 min at T13, between 42 s and 13.8 min and 1.5 min and 20 min at T24. As a result, total nursing time per day ranged from 136 to 212 min at T13, from 96 min to 176 min at T16 and 78 min to 190 min at T24.

Within the control treatment, nursing frequency did not differ between the days, but within the IS treatment nursing frequency decreased once IS treatment had started (table 3). Average nursing time did not change in L litters, but decreased in CH litters and increased in ISH litters towards the end of lactation. In all litters, total nursing time was lower at the end of lactation (T24) than at T13.

No differences were found in nursing frequency before start of IS, but once IS treatment has started nursing frequency was lower in IS litters than in control litters. At T16, average nursing time was lower in H than in L litters in both treatments, but at T24 this difference was only found in the control treatment. At T16 and T24, total nursing time was lower in H than in L litters in the control treatment, but no difference was found between H and L litters in the IS treatment.

Table 3. Nursing characteristics of high and low eating litters in the control and intermittent suckling (IS) treatment.

		Control[1]				IS[1]			
Nursing	Day[2]	High		Low		High		Low	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Frequency	T13	28	2	27	2	32^{x}	1	30^{x}	0
	T16	30^{a}	1	25^{a}	1	$19^{b,y}$	2	$20^{b,y}$	1
	T24	26^{a}	1	27^{a}	3	$19^{b,y}$	0	$20^{b,y}$	2
Average time	T13	$5.4^{a,x}$	0.5	6.7^{a}	0.1	$4.9^{b,x}$	0.3	5.3^{a}	0.3
(min)	T16	$4.4^{a,x}$	0.2	6.5^{b}	0.2	$4.8^{a,x}$	0.4	5.7^{b}	0.5
	T24	$3.5^{a,y}$	0.3	5.2^{b}	0.4	$5.5^{b,y}$	1	5.8^{b}	0.6
Total time	T13	153^{x}	9	181^{x}	17	155^{x}	4	156^{x}	8
(min/day)	T16	$129^{a,x}$	5	$163^{b,x}$	6	$89^{c,y}$	11	$113^{ac,y}$	12
	T24	$90^{a,y}$	3.6	$144^{b,y}$	26	$103^{a,y}$	17	$114^{a,y}$	7
Nursings ended	T13	$58^{ac,x}$	5	$35^{b,x}$	4	$37^{ab,x}$	14	$65^{c,x}$	7
by sow (%)	T16	$27^{a,y}$	6	$61^{b,y}$	2	$56^{b,xy}$	6	$39^{a,y}$	6
	T24	$29^{a,y}$	3	$24^{a,x}$	4	$61^{b,y}$	11	$40^{ab,y}$	8

[1] In the control treatment, piglets were continuously with the sow. Piglets in the IS treatment were separated from the sow for 12 h/d (0930 to 2130) beginning at treatment day 14 (T14)
[2] T13 = day before start of IS; T16= 3rd day of IS; T24 = day before weaning
[a,b] Within a row, means with a different superscript differ ($p<0.05$)
[x,y] Within a column, means with a different superscript differ ($p<0.05$)

The percentage of nursings ended by the sow (table 3) decreased between T13 and T24 in CH and ISL litters, varied greatly but did not change in CL litters and increased in ISH litters. At T13, the percentage of nursings ended by the sow (Table 3) was higher in H than in L litters in the control treatment, but in the IS treatment it was lower in H than in L litters. At T16, in both treatments the opposite was true; the percentage of nursings ended by the sow (Table 3) was lower in H than in L litters in the control treatment, but in the IS treatment it was higher in H than in L litters. At T24, no differences between H and L litters were found within treatments.

Activity (Non feeding related)

-Lactation period (T13 to T24) -

Within the 4 groups, no significant differences in non feeding related activity were found between the treatment days, except an increase between T13 and T16 in CH litters (Figure 4). Non feeding related activity was affected by period of the day. In the CH, CL and ISH group, litters were more active during SP (light period) than during NSP at all days of lactation ($p<0.05$). Activity of ISL litters was higher during SP than during NSP at T13 ($P<0.05$) and T16 ($P<0.05$), but at T24 no difference was found between SP and NSP ($P>0.10$). Within treatment H litters were more active than L litters during SP at the end of lactation (T24; $P<0.10$), but no difference was found during NSP ($P>0.10$).

-After weaning (T25 and T26) -

Between the groups, non feeding related activity (Figure 4) did not differ at T25 ($P>0.10$). At T26, ISH litters were less active than the other groups.

Also after weaning, non feeding related activity was affected by period of the day. In the control treatment, litters were more active during the SP period than during the NSP period at T25 and T26 ($P<0.05$). In the IS treatment, however, activity in ISH litters was similar during SP and NSP at T25 and T26 ($P>0.10$). Activity of ISL litters did not differ at T25 between SP and NSP ($P>0.10$) but at T26 ISL litters were more active during NSP ($P<0.05$). So after weaning, the diurnal rhythm seems to be changed or changing in IS litters, especially in ISL litters.

Discussion

It is known that IS increases feed intake before and after weaning (Kuller et al., 2004a; Berkeveld et al., 2007). In these studies some 60% of the IS litters, against 20% of the control litters, had an average feed intake per piglet of more than 600 g before weaning, a level which was suggested to be needed for better performance after early weaning (28 d) (English, 1980). So, the number of litters with low creep feed intake during lactation decreased by IS. Some litters, however, could not be stimulated by IS to consume a considerable amount of creep feed and IS did not seem to increase the number of piglets that were eating within a litter (Kuller 2007). This raised the question how creep feed intake develops in time, to what extend this differs between IS and control litters and whether this is affected by level of creep feed intake. Because it is not (yet) possible to measure individual

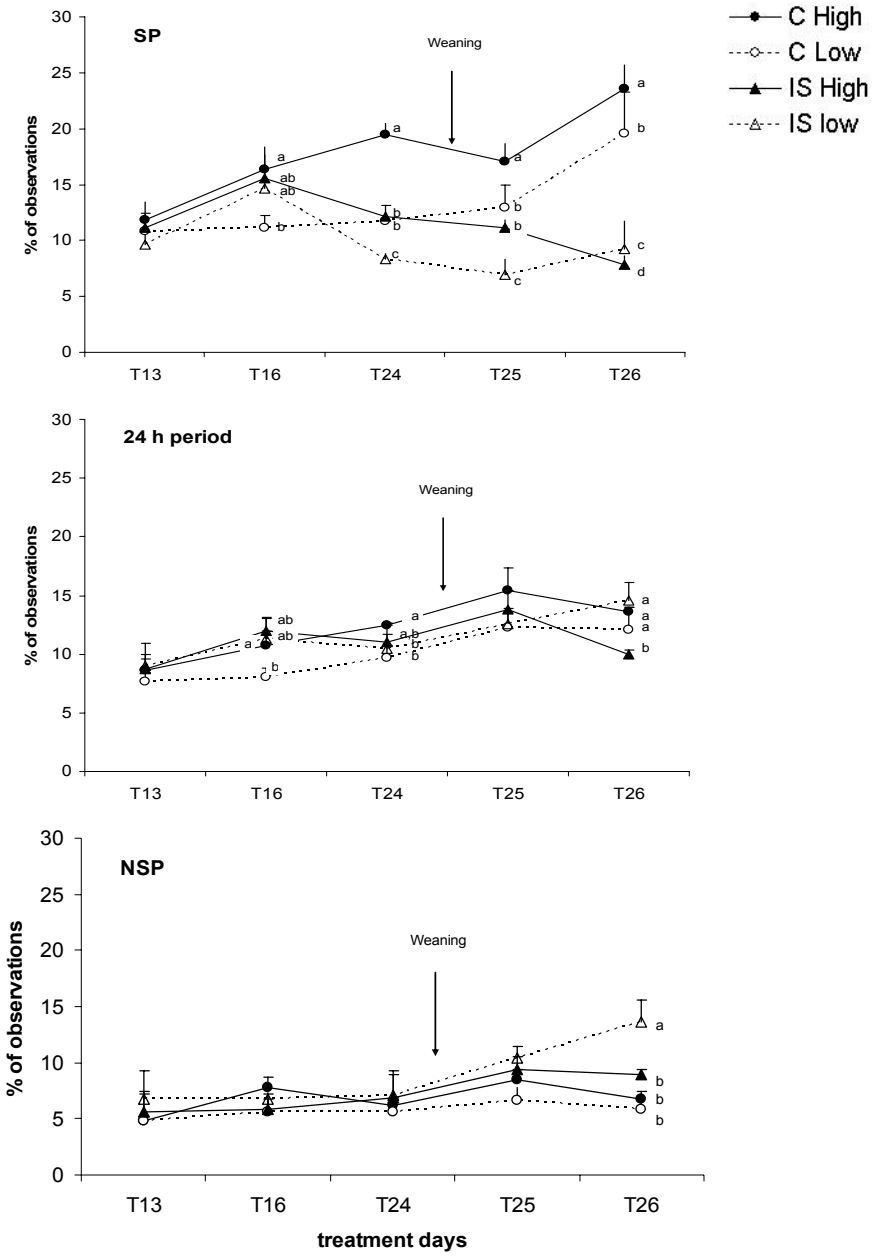

Figure 4. Non feeding related activity (all behaviour except resting/lying, eating creep, drinking water, manipulating the udder and suckling) during the complete 24 h period, the separation (SP; 0930 to 2130) and non separation (NSP) period in high (solid line, closed symbols) and low (dotted line, open symbols) eating litters in the control (circles) and intermittent suckling (triangles) treatment. In the control treatment piglets were continuously with the sow. In the intermittent suckling treatment, piglets were separated from the sow for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). Piglets were weaned at 0800 h at T25. Data are presented as means ± SE. Within a treatment day, different letters indicate significant differences between groups.

creep feed intake in suckling piglets, feeder visiting behaviour was studied, assuming that the time spent at or number of visits made to the feeder will mirror creep feed intake. Although high correlations between time spent at the feeder or number of feeding acts and actual (litter) creep feed consumption have been reported (Appleby et al., 1992; Delumeau and Meunier-Salaun, 1995; Fraser et al., 1994), creep feed intake based on feeder visiting behaviour can be overestimated, especially in piglets that just started eating creep feed (Appleby et al., 1991; De Rensis et al., 1993; Delumeau and Meunier-Salaun, 1995). So, when feeder visiting behaviour is used to give insight creep feed intake of piglets within a litter, some caution should be taken in account especially when creep feed intake is still low.

In the present study, visiting frequency, average feeder time and as a result total feeder time varied greatly between piglets during and after lactation, which was also reported for one or more of the variables by other authors (de Passillé et al., 1989; Delumeau and Meunier-Salaun, 1995; Dybkjaer et al., 2006). This probably is in line with the huge variation in creep feed intake between litters that is seen during and after lactation (Aherne et al., 1982; Appleby et al., 1992; Delumeau and Meunier-Salaun, 1995; Pajor et al., 1991).

Piglets in litters with a high feed intake had similar eating behaviour in the IS treatment and the control treatment, and differed from L piglets both during and after lactation. Visiting frequency increased in H litters, which is in agreement with others (Delumeau and Meunier-Salaun, 1995; Wattanakul et al., 2005) who found that the number of creep feeding acts increased over time in the 3rd and 4th week of lactation. Like in previous studies, total feeder time increased by the end of lactation (de Passillé et al., 1989; Mason et al., 2003) and after weaning (Algers et al., 1990; Dybkjaer et al., 2006; Mason et al., 2003; Morgan et al., 2001) in H piglets. It is known that piglets that start eating during one day will continue to do so on the next day (Appleby et al., 1991; Pajor et al., 1991), implying that piglets in high eating litters will probably not stop visiting the feeder and will continue eating after weaning. Therefore, it is less likely that they will encounter problems that are associated with low feed intakes after weaning, like a growth check or diarrhoea.

In piglets of litters with low feed intake during lactation, patterns feeder visiting behaviour were similar at T13 and T16, but started to differ by the end of lactation. Visiting frequency and total feeder time increased in ISL piglets between T16 and T24, while in CL piglets no increase was ever seen during lactation. As a result, piglets from low feed intake litters in the IS treatment had a higher visiting frequency and a higher total feeder time than piglets from low feed intake litters in the control treatment one day before weaning. Also on the second day after weaning, total feeder time was higher in ISL than in CL piglets. This difference in feeder visiting behaviour might explain why in a previous study (Kuller et al., 2004a) we

found that IS litters with a low creep feed intake during lactation had a higher feed intake and a higher average daily gain after weaning than control litters with a comparable feed intake during lactation. It has been reported that piglets, placed in an unfamiliar environment and offered an unfamiliar source of feed at weaning, do not consume enough feed to meet energy requirements (Bark et al., 1986). Also other authors (Pluske and Williams, 1996) suggested that low feed intake levels by newly weaned piglets may be related to unfamiliar feeders. Visiting frequency decreased between T13 and T16 in all piglets except ISH piglets, which might also be due to a change of the type of feeder. Wattanakul (Wattanakul et al., 2005) proved that piglets visited an open tray feeder (comparable to our feeder used until T13) more frequently and for a longer time then they did visit a feeder with a hopper (comparable to our feeder used from T14 onwards). Although in the present study piglets were not moved to another pen at weaning, their familiar source of feed (sow's milk) was removed from the pen. The same piglet feed and feeder were used after weaning as before weaning, but still some 56% of the CL piglets had never found this feed or the feeder because they never visited the feeder, while this was the case in only 9% of the ISL piglets. Pre-exposure to the smell or presence of novel food can reduce neophobia to the food (Nicol and Pope, 1994), which in our experiment probably facilitated feed intake and thus weight gain in ISL piglets after weaning.

After weaning, average latency to first visit to the feeder did not differ between the groups in our experiment. Bruininx (Bruininx et al., 2002) found that the number of piglets that did not eat after weaning declined faster in piglets with known creep feed intake before weaning than in non eaters. However, he also found that the number of visits to the feeder after weaning did not differ between so called 'eaters' and 'non eaters', but that the number of visits during which feed was consumed was higher in eaters. Therefore, it was suggested that piglets that are familiar with food at the moment of weaning (eaters) are more efficient in their food intake than piglets that are unfamiliar with the food (non eaters). Thus, latency to first visit to the feeder may not be a good parameter to distinguish eaters from non eaters.

Feeder visiting behaviour was highly variable between piglets and litters and this has been related to differences in milk production by the sow (Delumeau and Meunier-Salaun, 1995). In our experiment, a difference in milk availability was imposed by denying access to the udder for 12 h/ day in the IS treatment and this resulted in a significant decrease in suckling frequency. Manipulation of nursing frequency is crucial in adjusting the volume of milk output during an individual nursing (Auldist et al., 2000; Spinka et al., 1997), because piglets will receive a similar amount of milk when nursing interval is above 35 minutes (Spinka et al.,

1997). So, piglets with a lower suckling frequency will probably receive the same amount of milk per suckling but less frequently and thus daily milk intake will be lower. Although suckling frequency was lower in the IS treatment, suckling interval was decreased by the piglets during the non separation period to 35 minutes on average (20 nursings in 12 h) thus making optimal use of the sow as a source of milk. Besides the decreasing nursing interval, also average nursing time increased in IS litters. Increasing the time of post massaging the udder by the piglets, will increase milk output according to the so- called restaurant hypothesis (Algers and Jensen, 1985). This hypothesis states that piglets can order their meal size, since more massaging resulted in a higher milk yield during the following nursing. Piglets in the IS treatment and CL litters spent similar long time at the udder per nursing. In CH litters, however, average nursing time decreased during lactation and was shorter at T24 than in the other treatments. Apparently CH litters voluntarily decreased their average nursing time, because in these litters the number of nursings ended by the sow decreased during lactation. The number of nursings ended by the sow at the end of lactation was higher in IS litters than in control litters, possibly because the high frequency of nursing and massaging during the non separation period irritated the sow to a higher extent (Algers and Jensen, 1985). So, we hypothesize that daily milk intake was lower in IS litters and they were trying to optimize milk production by decreasing the interval between the nursings and by stimulating milk production by investing in post massaging the udder. Compensation for the missed nursings failed, however, as weaning weights were lower in the IS litters than in the control litters in the current experiment (control: 7447 vs. IS: 6910 g on average) and in earlier experiments (Kuller et al. 2004a, 2007). The result of the decrease of the number of sucklings and thus the decreased milk intake was that piglets became motivated to increase solid food intake (Puppe and Tuchscherer, 2000). Such an increase has been shown in our earlier experiments using IS (Berkeveld et al., 2007; Kuller et al., 2004a; Kuller et al., 2007).
Some IS litters, were not stimulated to consume high amounts of creep feed during lactation. We expected a high level of restlessness in these ISL litters, but this was not confirmed by our data on non feeding related activity. Actually, litters with a low feed intake did not differ in activity during the complete 24 hour period and within treatments, L litters were even less active during SP than the H litters at the end of lactation and during the first day after weaning. This might partly explain their low feed intakes, as several authors suggest a positive relationship between social and exploratory behaviour (which is most probably a large part of the non feeding related activity behaviour, as quantified in our study) and the development of creep feed behaviour (Delumeau and Meunier-Salaun, 1995; Pajor et al., 1991). Activity and feeder visiting behaviour usually show a diurnal pattern with high levels

during the day and low levels during the night (de Passillé et al., 1989; Petrie and Gonyou, 1988; Schouten, 1986; Wattanakul et al., 2005), which is in agreement with our results. After weaning, ISL litters became more active and had a higher visiting frequency during the second night (former NSP) after weaning than during the second day after weaning (former SP). So, diurnal rhythm seems to be affected by IS in low eating litters. Probably these litters were waiting for the sow to come back to suckle and when the sow did not return and the piglets got hungry, they visited the feeder instead, possibly because creep feed intake is usually performed after a nursing (Schouten, 1986). This would also explain why visiting frequency was higher in ISL than in CL piglets.

Conclusions

The IS treatment did not affect feeder visiting behaviour of piglets with an anyhow high level of feed intake during lactation, but stimulated IS piglets from litters with a low level of creep intake to visit the feeder during lactation, which probably made them familiar with the feeder en the feed during lactation. This might explain why in earlier studies such litters had higher creep feed intake and ADG after lactation than the low feed intake control litters. Part of the variation in feed intake between litters might be explained by difference in suckling behaviour and activity.

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Chapter 6

Creep feed intake during lactation enhances net absorption in the small intestine after weaning

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ABSTRACT

The aim of the study was to measure the effect of creep feeding during lactation on net absorption in the small intestine at 4 days after weaning. Intermittent suckling was used to increase creep feed intake during lactation. Creep feed containing chromic oxide was provided. Based on the colour of the faeces, piglets were classified as 'eaters' or 'non-eaters', respectively. At day 4 after weaning, an *in vivo* small intestine segment perfusion test was performed at 5 sites along the small intestine in 24 piglets (12 eaters and 12 non-eaters). At both sides of each intestinal segment a tube was fitted to perfuse and drain fluid in order to assess net absorption. Net absorption was higher in eaters than in non-eaters ($P<0.001$). Net absorption varied greatly between and within piglets and was highest in the caudal segments of the small intestine ($P<0.001$). These data suggest that creep feeding could be a useful tool in the prevention of post weaning diarrhoea.

Keywords: Absorption, Creep feed, Pig, Small intestine

Introduction

Creep feed is provided during lactation, in order to facilitate the nutritional transition from milk to solid feed at weaning. Creep feed intake during lactation has proven to stimulate early post- weaning feed intake and growth after weaning (Bruininx et al., 2002; Kuller et al. 2002). We postulated that these beneficial effects could be attributed to stimulation of the small intestine function.

The functioning of the small intestine can probably be best assessed on basis of net absorption. Net absorption is the net result of secretion and absorption – the main functions of the small intestine - and can be tested at different sites along the small intestine in the *living* animal by the small intestine segment perfusion test developed by Nabuurs et al. (1993). When net absorption decreases after weaning the risk of developing diarrhoea may be increased, because diarrhoea can be a result decreased absorption from the gastrointestinal tract (Blikslager et al., 2004) Whether an increased feed intake during lactation improves small intestinal absorption after weaning is not known, but might be expected because of the positive relation between feed intake and gut architecture.

The aim of the present experiment was to measure the effect of creep feed intake during lactation on net absorption in the small intestine at 4 days after weaning, using the small

intestine segment perfusion test developed by Nabuurs et al. (1993). Intermittent suckling was used as a tool to increase creep feed intake (Kuller et al, 2002).

Material and methods

Animals and treatments

Net absorption was assessed *in vivo* in 24 piglets at 4 d after weaning (d 27 of lactation). During lactation, creep feed was provided from d 7 onwards and supplemented with 1% chromic oxide, in order to color piglet faeces. Faeces sampling took place 4 times before weaning at day 17, 21 23 and 24. Piglets that never showed colored faeces were considered non-eaters. Piglets that showed colored faeces in at least 2 of 4 samples were considered eaters. In order to stimulate creep feed intake, intermittent suckling was used (IS; Kuller et al,2002) a management system in which sow and piglets are separated for 12 h/ day from day 16 to weaning at day 27 (creep feed intake IS: 237 ± 44 vs. C: 54 ± 50; $P<0.05$). After weaning, the piglets stayed in the same pen. To exclude an effect of IS on the small intestine, a control group was kept continuously with the sow (C). From each group (IS and control) 6 eaters and 6 non-eaters were randomly selected from 3 different sows (two eaters and two non-eaters per sow).

Anesthesia and surgery

The small intestine segment perfusion test was performed at day 4 after weaning, in general as described by Nabuurs et al. (1993). Briefly, piglets were tranquilized with 2 $mg.kg^{-1}$ bodyweight azaperone (Stressnil®, Jansen-Cilag BV, Tilburg, The Netherlands) and subsequently anesthesia was induced and maintained with cefoflurane and nitrous oxide during the whole experiment. After opening the abdominal cavity, segments (of ± 20 cm in length) were prepared at 5 sites (10%, 25%, 50%, 75% and 95%) along the small intestine. At both sides of each segment a tube was fitted through which fluid was perfused and drained. Directly caudal to this first segment, a second segment was prepared in order to make a pair at the same site along the small intestine. Between two segments of a pair, a piece of the small intestine was taken and opened to measure the width of the segment. After the surgery, the abdominal wall was closed again.

Perfusion

Fifteen minutes before start of perfusion, one segment of a pair was injected with 5 ml phosphate-buffered saline (PBS). The other segment was infected with enterotoxic *Escherichia coli* suspended in 5 ml PBS (O149:K91:K88ac; $1x10^9$ cfu/ml). Each segment was perfused for 8 hours with a volume of 8 ml per hour (9 g/l NaCl ,1 g/l glucose and 1 g/l amino acids). Non- absorbed fluid was collected in separate bottles that were placed at the same height as the piglet's abdomen. At the end of the perfusion, the remaining fluid was blown out of each segment into the bottles.

Net absorption

Piglets were killed using 200 mg/kg bodyweight sodiumpentobarbital (Dolethal ®, Vétoquinol, Den Bosch, The Netherlands). After the piglets were killed, each segment was taken out, opened and length and width were measured. Net absorption (electrolytes + water) was determined as the volume of the inflow minus the volume of the outflow, divided by the surface of a segment (length * width).

Statistical analysis

Data were analysed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) using eater/non-eater and infected/non-infected and their interaction as fixed effects and sow nested within treatment (IS or control), piglet nested within sow and site along the small intestine nested within piglet as random effects.

Results

No difference in net absorption was found between IS and control piglets therefore data were pooled. In non- infected segments net absorption was higher in eaters than in non-eaters ($P<0.05$; Figure 1). In infected segments no difference was found. Net absorption was lower in *E.coli* infected segments ($P<0.001$; Figure 1) than in non-infected segments. Net absorption was highest in the caudal segments of the small intestine ($P<0.001$; Figure 1). Net absorption varied greatly between and within piglets (e.g. segment 10%: -413 to 199 microliter/cm^2). Length (748±78 cm on average) and width after opening the segment (2.6±0.3 cm on average) of the small intestine did not differ between eaters and non- eaters.

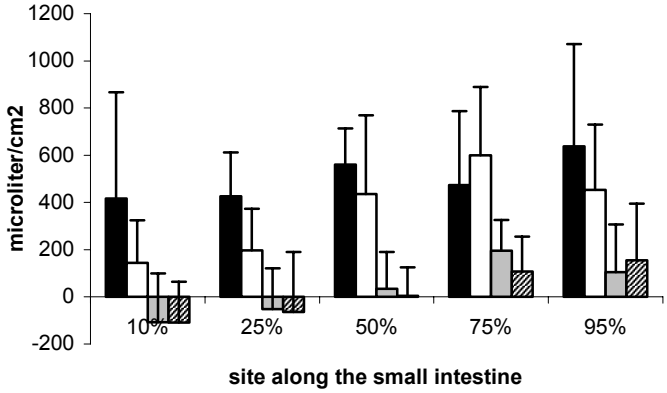

Figure 1. Net absorption ± SE in 5 paired segments of the small intestine of eating and non-eating piglets; one segment of each pair was infected with *Escherichia coli*.
Black = Non-infected eater, White = non- infected non-eater, Grey = infected eater, striped = infected non- eater

Discussion

Net absorption in uninfected segments at day 4 after weaning was significantly higher in piglets eating creep feed during lactation than in non- eating piglets. Generally, diarrhoea is a result of increased secretion or decreased absorption from the gastrointestinal tract (Blikslager et al., 2004). Most probably, the increased net absorption in the small intestine as a result of creep feed intake during lactation will therefore decrease the risk of post-weaning diarrhoea. Along with the improved net absorption, pre-weaning creep feed intake improved post- weaning feed intake and prevented the post-weaning growth check (Bruininx et al., 2002; Kuller et al., 2002). So, stimulation of creep feed intake during lactation is beneficial for the newly weaned piglet. Surprisingly, we did not find an effect of creep feed intake on net absorption in *E. coli* infected segments. Further research is needed to find out whether this can be accounted to the small number of piglets used in the present study and the high variation in net absorption between segments and between piglets.

Conclusion

We concluded that it is important to stimulate feed intake of piglets before weaning. This will, besides increasing feed intake after weaning and reducing the growth check after weaning, improve net absorption in the small intestine. As result the risk of post-weaning diarrhoea may be reduced.

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Chapter 7

General discussion

Introduction

In this thesis it was hypothesized that early adaptation to a solid diet for young piglets by intermittent suckling (IS) during the lactation period results in piglets with a better performance after weaning. On most pig farms, the intake of solid feed by piglets before weaning is very low and after weaning it is far below the amount necessary for maintenance. This 'lack of energy' results in morphological and functional changes in the small intestine. These changes are the major predisposing factors for the frequently occurring post weaning diarrhoea.

In the strategy of intermittent suckling used in this thesis, sow and piglets were separated for 12 h/day (0930 to 2130 h) during the last 11 days of a 25 day lactational period. As was hypothesised, IS resulted in higher (157- 218 %) average creep feed intake during lactation and in a lower number of litters with low feed intake during lactation. IS was especially efficient in piglets from low feed intake litters. Piglets were stimulated to investigate the feeder during lactation, which facilitated the consumption of creep feed after weaning. After weaning, feed intake was higher in IS litters until 2 weeks after weaning (and weight gain until one week after weaning). Moreover, piglets that were designated as eaters during lactation had higher body weights after weaning and had a higher net absorption in the small intestine than their non eating litter mates.

So, I conclude that intermittent suckling improves both creep feed intake during lactation and feed intake and weight gain after weaning, and that independent of feeding regimen piglets consuming creep feed during lactation had higher weights and net absorption in the small intestine after weaning.

This study primarily focussed on studying if IS improves feed intake during lactation and what consequences it has for weight gain and feed intake after weaning. In this chapter we will integrate and discuss the main results of this thesis. The first issue addressed below is another strategy to increase creep feed intake during lactation known as sow controlled housing (Pajor et al., 2002; Pajor et al., 1999; Pitts et al., 2002; Weary et al., 2002; Weary et al., 1999). I will compare the strategy of sow controlled housing with our strategy of intermittent suckling. Moreover, I will provide new data on three behavioural elements (explorative behaviour, redirected oral behaviour and fighting behaviour) in IS and control litters.

Intermittent suckling not only significantly increased average creep feed intake during lactation, but also reduced the number of low feed intake litters and stimulated piglets within

these low feed intake litters to become familiar with the feeder and the feed already during lactation. So, the second issue of this chapter is to discuss the effects of IS and feed intake during lactation on feed intake and performance after weaning.

Since it is not yet possible to quantitatively assess individual creep feed intake in suckling piglets, two indicators of individual creep feed intake were used in our experiments: chromic oxide that was added to the creep feed and used to distinguish eaters and non eaters, and continuous video recordings to analyse feeder visiting behaviour of individual piglets. Because in some of the piglets data of both indicators were available, a comparison of results will be made in the third issue.

The strategy of IS is only acceptable if sow reproductive performance is not compromised. It was shown that IS reduced weight and back fat loss during lactation, and reduced the weaning to oestrus interval in sows. So, consequences of the effects of IS on sow reproductive performance will be discussed in the fourth issue of this chapter, not only during conventional lactational periods but also during extended lactation.

This thesis was performed to check if it is possible to prevent a period of 'lack of energy' just after weaning by using IS. As already mentioned above, the lack of energy results in morphological and functional changes in the (small) intestine. Nabuurs (1993, 1996) showed that creep feed intake during lactation could partially prevent the occurrence of reduction in villus height and net absorption from the small intestine. He used piglets with an unknown history of feed intake; although the piglets were offered creep feed, the intake of each piglet was not quantified. In our experiment, eaters and non-eaters selected and their net absorption in the small intestine was tested. It was proved that eaters have a higher net absorption than non eaters. However, our study was only a pilot experiment. Therefore I will conclude this chapter with some proposals for future research on morphology and functionality of the small intestine around weaning, but also for future research on the strategy of IS and for research on individual feed intake in suckling piglets.

1. Intermittent suckling, sow controlled housing and piglet behaviour

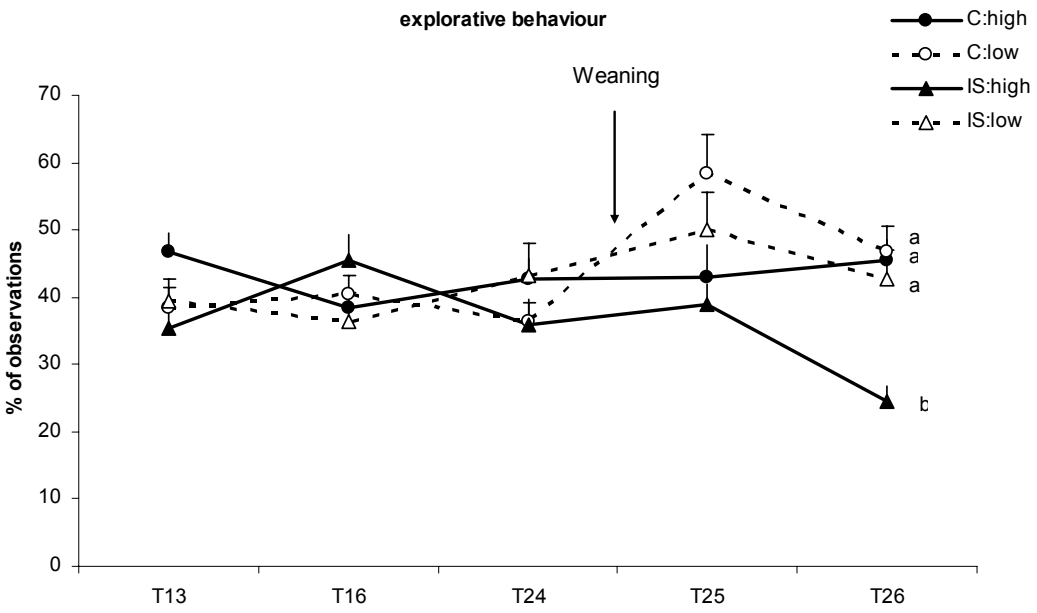
In (semi) natural conditions, piglets are weaned between 12 and 17 weeks of age. During lactation the sow spends an increasing amount of time away from her litter (Boe, 1991; Jensen and Recen, 1989), and around 4 weeks of age (weaning age in Europe) she only spends some 9 hours per day with her litter (Boe, 1991). In this way the piglets gradually become used to separation from the sow and become independent of the sow's milk by

increasing their solid feed intake. In modern intensive housing systems, however, sow and piglets are continuously housed together and then piglets are abruptly weaned around 4 weeks of age. This has consequences for both sow and piglets. During lactation, the sow cannot leave her piglets in order to control access to the udder and thereby regulate milk production and her loss of weight (Pitts et al., 2002). On the other hand, at weaning the piglets are abruptly separated from the sow, leading amongst others to social (separation from the sow) and nutritional stress (abrupt transition to solid food).

Sow controlled housing has been developed to address these problems of close confinement of sow and litter by permitting the sow to leave her litter at will (Pajor et al., 2002, 1999; Pitts et al., 2002; Weary et al., 2002). In these systems sows were housed in so-called get away pens, with a nest area and a piglet free area which were separated by a piglet-proof partition that could only be crossed by the sow. Piglets were weaned between 27 and 35 d of age. At the end of lactation, between 35 and 40 % of the sows voluntarily spent more than 12 h per day away from her litter (Pajor et al., 2002; Pitts et al., 2002), which corresponds to the number of hours that we separated sow and piglets in our IS regime. The percentage of time that a sow spent away from her litter and the nursing frequency were negatively correlated, although coefficients were relatively low (Pitts et al., 2002). Nursing frequency decreased with only 10% from 26 to 23 times per day on average (Pajor et al., 2002). So, sow controlled housing considerably decreased the time the sows spent with their litters but only slightly decreased the number of nursings. Weight loss of the sow only decreased with 1.7 kg during lactation (28 d) and no effect of housing was found on the weaning to oestrus interval (Pajor 2002). On the other hand, solid feed intake of the piglets before weaning was increased with 65% (Pajor et al., 2002). Piglets under this sow controlled housing system consumed 31% more feed in the first two weeks after weaning (499 ± 29 vs. 655 ± 31 g/day per pig) and gained 27 % more weight (471 ± 20 vs. 371 ± 18 g/day per pig) (Pajor et al., 1999).This probably reflected a better adaptation to weaning (Pajor et al., 1999). However, the positive effects of sow controlled housing depended on the frequency of the voluntary use of the get away area and unfortunately this varied greatly between sows. Some sows used the get away area too often (>90% of the time spent in the get away area), resulting in inadequate maternal care, whilst others almost never left their litters thereby taking no advantage of the system (Pitts et al., 2002). Moreover, use of the get away area was not consistent between one litter and another of the same sow, so sows can not be selected for this system (Pitts et al., 2002). It was therefore suggested by the authors (Pajor et al., 2002) that housing systems should be developed that lead to a more frequent or more consistent use of the get away area.

In our experiments using intermittent suckling, the sow was separated from her litter for 12 h/day and like in sow controlled housing this resulted in a decreased weight loss of the sow (control -17 ± 2 vs. -9 ± 2 kg) (Kuller et al., 2004b), an increase in feed intake of the piglets during lactation with 157 and 218 % and an increase in feed intake and weight gain of the piglets after weaning (Kuller et al., 2004b; 2007). The main difference with sow controlled housing was that separation of sow and piglets was not voluntarily but imposed, which standardised the time a sow was away from her litter. This latter parameter was the main source of variation and thus caused the main problem in sow controlled housing systems (Pajor et al., 1999; Pitts et al., 2002). Pitts et al. (2002) suggested that in terms of welfare, the sow benefits in several ways from a sow controlled housing system; her condition is improved, she is allowed to spend time away from her litter and thus udder stimulation is reduced and she is also able to spend time in a more complex social environment. These advantages are also present in our system of IS, except for the fact that the sow was not removed from the pen and she was thus not allowed to act in a different social environment. However, recently Berkeveld et al.(2007a; 2007b) conducted experiments with IS, in which the sow was removed but piglets were left in the pen. Although these authors moved the sows to an individual crate, moving the sow to a group could be a possibility in future research. Also in their system of IS during extended lactation feed intake during lactation was improved. Such a system would, in fact, resemble more or less older Dutch husbandry systems in which the sow was removed from the litter and brought to the pasture for a few hours every day.

No evidence has been reported that sow controlled housing affects behaviour of piglets or sows during lactation (Pajor et al., 1999), but it has been found that after weaning piglets from get away pens were more active and bit their pen mates more often than piglets from control litters. As described in Chapter 5, after weaning no effect of IS was found on overall activity of the piglets during the whole 24 h period. More detailed behavioural data of the same litters as described in Chapter 5 are presented in Figure 1. On average 40% of non feeding related activity existed of exploratory behaviour (Figure 1). There was no difference in exploratory behaviour between the 4 groups of litters during lactation, but at the first day after weaning explorative behaviour tended ($p = 0.09$) to be higher in litters with a low feed intake during lactation. At the same time level of activity did not differ between the groups (Chapter 5). So, at the first day after weaning, piglets in low eating litters spent a higher proportion of their active time on exploration which might be spent on searching for food; several authors have suggested that a positive relationship exists between social and exploratory behaviour and the development of creep feed behaviour (Delumeau and



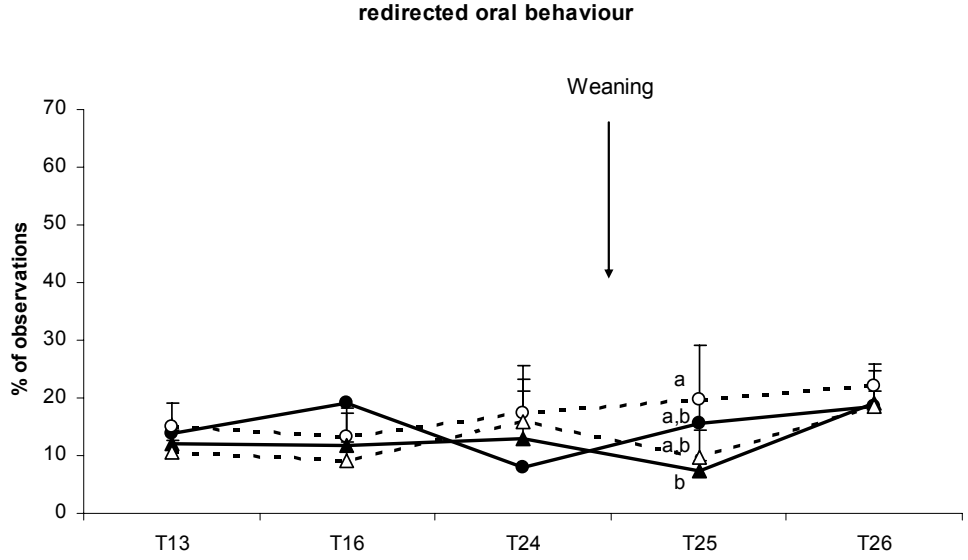


Figure 1. (*For caption see page 101*)

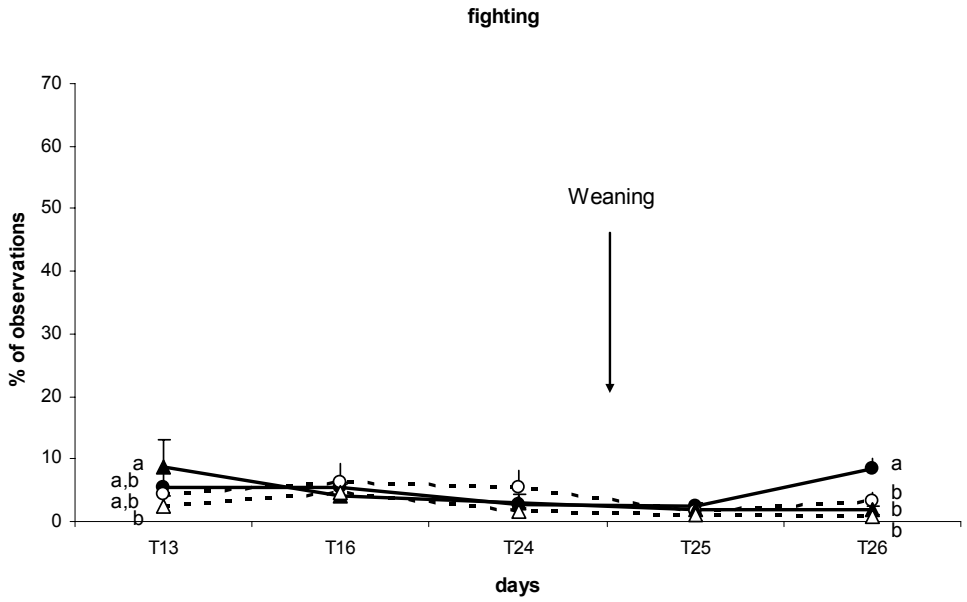


Figure 1. exploratory, redirected oral behaviour and fighting behaviour as a % of non feed intake related behaviou in high and low feed intake litters from the control and intermittent suckling treatment. The experiment started on T0, IS on T14 and weaning took place on T25. Behaviour of all the piglets within litters was scored at 10 minute intervals (6 times/ h). So, the total number of behavioural observations per litter per day (24 h) was: 144 x n piglets. Averages are given from three sows in each group (ISH, ISL, CH and CL). All behaviour, except resting and feed intake behaviour (creep feed eating, drinking water, massaging or sucking at the udder) was summed per litter and designated as 'non feeding related active behaviour'. For each litter, exploring (at any place in the pen), redirected oral behaviour (manipulating or biting another piglet) and fighting were presented as a percentage of non feeding related active behaviour, because it is known from Chapter 5 that feed intake behaviour varied between the groups. Within a treatment day, different letters indicate significant differences ($p < 0.05$) between groups.

Meunier-Salaun, 1995; Pajor et al., 1991). No explanation could be found for the sudden decrease in exploratory behaviour in IS high litters at the day after weaning (T26).

Redirected oral behaviour did not seem to increase over time in any of the groups. Redirected oral behaviour, also described as manipulating pen mates (Dybkjær, 1992), can be explained by the high motivation for exploring the environment and for suckling (Van Putten and Dammers, 1976) and it was suggested to be an indicator of stress by Dybkjaer (Dybkjær, 1992). So, the fact that this behaviour did not differ between IS and control litters during lactation suggests that although piglets are deprived from milk and thus deprived of the possibility to suckle during the 12 hours of IS, these piglets do not redirect their oral behaviour to pen mates. After weaning, redirected oral behaviour only differed at the first day after weaning between control litters with low feed intake and IS litters with high feed intake during lactation. However, redirected oral behaviour was only measured during the first 2 days after weaning and it is known that this behaviour can increase until 2-3 weeks after weaning (Colson et al., 2006).

Aggressive behaviour of litters was low (Figure 1) during lactation and did not differ between the groups during IS (T14 to T25), so IS did not induce extra aggressive behaviour. Aggressive behaviour was also low after weaning and was higher in high eating control litters on the second day after weaning than in the other groups. As far as we know, no other studies have been performed to check if temporary weaning has an effect on aggressive behaviour.

In summary, our data suggest that IS does not significantly affect exploratory, redirected oral behaviour or aggressive behaviour during lactation or after weaning. However, our data should be interpreted with care because data were collected at a litter level in a small number of litters (n = 3 per group). The presented parameters are considered as indicators of piglet distress (Dybkjær, 1992). I conclude that IS does not evoke distress in piglets. IS also improved feed intake during lactation and feed intake and weight gain after weaning. I therefore suggest that well being of the piglet is not negatively affected by IS. These conclusions are in line with a recent behavioural study on IS during extended lactation (Berkeveld et al., 2007a), in which piglets were separated for 12 h per day from day 14 onwards until weaning between days 41 and 47. In that study no behavioural patterns indicative of piglet distress were found.

2. Intermittent suckling and feed intake after weaning

In Chapter 5, feeder visiting behaviour of individual piglets from low or high feed intake litters in the IS and control treatment was described. Strikingly, no statistical difference was found in time to first visit to the feeder between piglets from the IS or control treatment or between piglets of low or high feed intake litters, nor in average time to first visit (Chapter 5) nor in latency to first visit (survival analysis). However, it should be taken into account that the number of observations was small in this experiment. In Figure 2, two groups of piglets from the low feed intake litters were very late in visiting the feeder and such groups were not found in high eating litters. Bruininx (2002) found that the number of piglets that did not eat after weaning declined faster in piglets that ate creep feed before weaning than in non eaters. However, he also found that the number of visits to the feeder after weaning did not differ between eaters and non eaters, but that the number of visits during which feed was consumed was higher in eaters. It is possible, therefore, that in our experiment there was no difference in latency between the groups, but that the low feed intake piglets visited the feeder shortly after weaning without consuming any feed while high feed intake piglets did consume feed at their first visit.

Most of the piglets from high feed intake litters visited the feeder within 5 h after weaning which is in agreement with other data (Brooks et al., 2001). Strikingly, 9 C and 7 IS piglets from these high feed intake litters who were the last ones to visit the feeder were designated as non eaters by use of chromic oxide in the creep feed. So, it seemed that they were not familiar with feed intake by the time they were weaned.

One thing that stands out when looking at the latency data is that low feed intake piglets went to the feeder as a litter (ovals in the Figure 2). Most probably this is the result of the synchronization of behaviour and nursings of litters during lactation. Behaviour of suckling piglets is highly synchronized around nursings, which is mainly controlled by the sow's milk let down (Fraser, 1980). Milk is only available during the few seconds of milk let down, because there is no mammary cistern in pigs. As a result, piglets that are not present at the right time will miss a nursing. So, piglets are driven to synchronize their suckling behaviour with a concomitant synchronization of activity and inactivity patterns as a result (Docking et al., 2007). This also programs litters to feed as a group (Brooks and Burke, 1998). It is likely that this synchrony in activity continues shortly after weaning, although it is known that synchrony of activity and inactivity decreased with age (Docking et al., 2007).

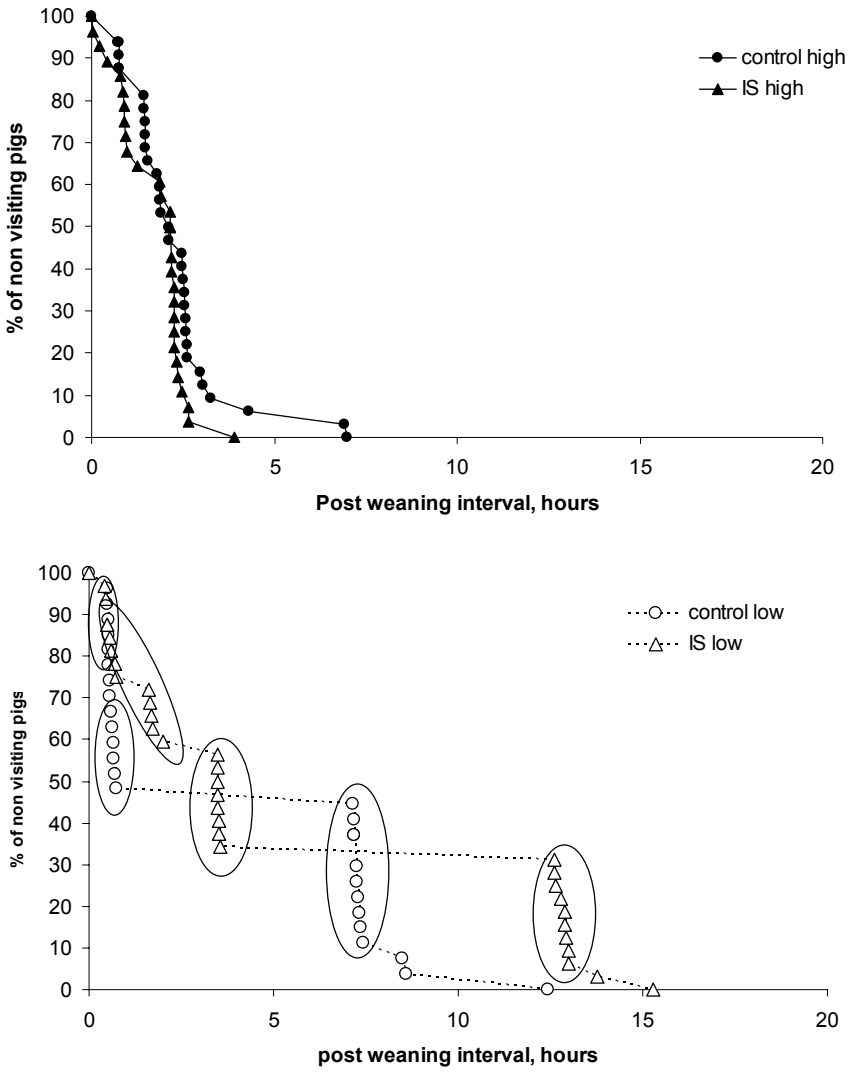


Figure 2. Percentage of piglets that had not eaten after weaning as a function of post weaning interval. Ovals indicate/ show piglets of the same litter. In the control treatment piglets were continuously with the sow. In the intermittent suckling treatment, piglets were separated from the sow from for 12 h/d (0930 to 2130) starting 11 d before weaning (T 14). The experiment started at treatment day 0 (T0). Piglets were weaned at 0800 h at T25. Lights were turned of, at 15 h after weaning.

In our experiment all piglets visited the feeder within approximately 15 h after weaning (Figure 2). This also meant that all piglets visited the feeder during the light period, as the dark period started at 2300 p.m., which is 15 hours after weaning (0800 a.m). It is possible that visiting patterns in our experiments would have been different when applying the same light regimen as Bruininx (2001b; 2002) where the dark period started 4 to 7 h after weaning. In such a situation, time to first visit might have been significantly longer because only few piglets visit the feeder for the first time during the dark period (Bruininx et al., 2002). It is, however, also possible that synchronization would have been affected in that case because some piglets within litters might visit the feeder individually because they became hungry.
It was shown in the first and in the second experiment that there was a positive correlation between feed intake before and after weaning (r = 0.67) and between creep feed intake before weaning and, so, ADG after weaning (r = 0.63). We concluded that increasing creep feed intake during lactation will improve feed intake and (thus?) weight gain after weaning. We found that not only average creep feed intake was improved by IS during lactation but also that the number of low eating litters was decreased. We assumed that these litters with a low feed intake during lactation could take advantage of the strategy of IS, based on our findings in Chapter 5 that low feed intake litters were stimulated to visit the feeder during lactation. Although these litters visited the feeder without consuming any creep feed, this probably familiarised the piglets with the feeder and the feed, which resulted in a higher creep feed intake after weaning than the feed intakes seen in the litters with comparable (low) feed intakes in the control litters. So, IS reduced the number of low feed intake litters and familiarised the piglets with the feeder and the feed during lactation in the low feed intake litters left, which benefited these litters after weaning.

3. Assessment of individual creep feed intake

Currently, there are no methods to quantitatively assess the daily individual creep feed intake in suckling piglets. Therefore, only indicators of individual creep feed intake were used during our experiments. In Chapter 3 and 4, eaters and non eaters were discriminated based on examination of faeces colour, after addition of chromic oxide to the creep feed. In the experiment described in Chapter 3, four faecal samples were taken on 4 different days (T17, T21, T23 and T24) during lactation and 1 point was given when faeces were coloured green, no point when no green colouring was seen and 0.5 when findings were inconclusive. Classification was made into three groups based on the number of points (maximum 4): non

eater (0 points), eater (sum of 1.5 points or higher) and non classified (0.5 or 1 point). This classification was made in order to guarantee selection of eaters that consumed considerable amounts of creep feed and selection of non eaters with no or very low creep feed intake. In Chapter 4, the use of chromic oxide as a marker for selection of creep feed eating piglets was evaluated. It was shown that chromic oxide can be used to select eating piglets and the probability of accurately identifying a pig as an eater was 99% when 1 sample was taken per day on 4 consecutive days. Thus, chromic oxide was an excellent method to select eating piglets. Since that study focussed on selection of eating piglets only, inconclusive faeces samples were considered not green. Therefore, classification in Chapter 4 (eater = at least 1 green sample) differed from classification in Chapter 3 (eater = 1 green and 1 inconclusive sample or three inconclusive samples).

Another complication in the classification of eaters and non eaters is that excretion of chromic oxide differed between the two feeding regimens (unpublished data). Excretion was shorter in the intermittent suckling regime and the total number of positive feces samples during the 120 h after first forced feeding was lower at every feeding level. This difference could be due to the difference of pattern in milk- and creep feed intake between the two treatments. Piglets in the C- treatment had free access to milk and creep feed for 24 h. d^{-1}, assuming a more regular pattern of milk- and creep feed intake than piglets in the IS treatment that could only drink milk during the night. The intake of a large amount of milk during the night in IS- piglets possibly increased the transit time by increasing the intestinal volume, resulting in the accelerated excretion of chromic oxide that was consumed with the creep feed during daytime. Especially the difference in number of positive samples between the two feeding regimes could complicate classification because threshold levels could be different in both regimes. So, adding chromic oxide to creep feed enables selection of eating piglets, but caution should be taken in to account when comparing different feeding regimes and selection criteria could be varied.

In Chapter 5, creep feed intake behaviour (frequency, average time per visit and total time per day of each feeder visit) of individual piglets was studied during continuous video recordings under the assumption that creep feed intake and creep feed intake behaviour are correlated (Appleby et al., 1992; Delumeau and Meunier-Salaun, 1995; Fraser et al., 1994). However, some caution is warranted especially when creep feed intake is still low because creep feed intake based on creep feed behaviour could be overestimated in piglets that just started eating creep feed (Appleby et al., 1991; Delumeau and Meunier-Salaun, 1995; Gardner et al., 2001): if those piglets spend time at the feeder this does not always mean that they are also actually consuming creep feed.

So, in this thesis two different ways of acquiring information on individual feeding traits of suckling piglets were used. Data used in Chapter 3 and Chapter 5 were acquired from the same experiment, so in a limited number of pigs both data on excretion of chromic oxide and on creep feed behaviour were available. Total feeder time seemed to be lower in piglets classified as non eaters than in piglets classified as eaters by use of chromic oxide (Figure 3). So, the two different parameters of creep feed intake seemed to support each other with their outcomes, but still further research is needed to make it possible to quantitatively assess individual creep feed intake in piglets during lactation.

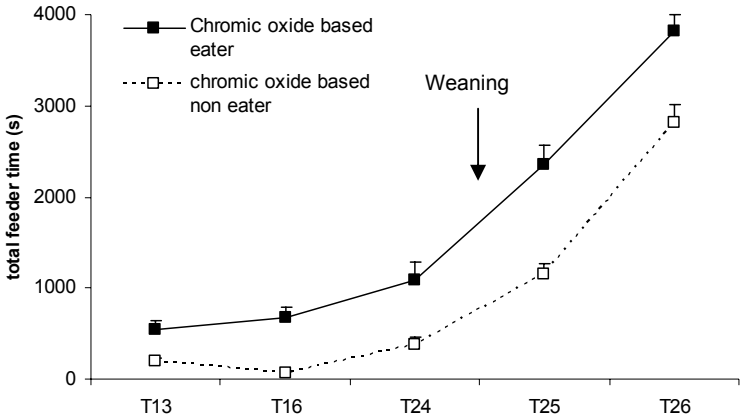


Figure 3. Total feeder time in chromic oxide based eaters (solid line, closed symbols), and chromic oxide based non eaters during lactation (dotted line, open symbols) at different treatment days (24 h). The experiment started on T0, IS on T14 and weaning took place on T25. During lactation, creep feed was supplemented with 1% chromic oxide, which colored piglet feces green if creep feed was eaten. At T17, T21, T23 and T24 fecal samples were taken and color of the samples was determined visually. One point was given to piglets that had green feces at time of sampling and zero points when no green color was seen. When color of feces was inconclusive, 0.5 point was given. Piglets that had zero points were non-eaters and piglets with a sum of 1.5 points or higher for the four samples during lactation were designated as eaters. Piglets with 0.5 or 1 point were designated as inconclusive and not used in the experiment. In total, 119 animals were used; 24.4 % (29 of 119) piglets were designated as eater, 66.4 % (79 of 119) as non eater and 9.2 % (11 of 119) as non classified based on excretion of chromic oxide.

4. Effects of intermittent suckling on sow performance

So far, only effects of IS on piglet performance were discussed. The method of IS is, however, only acceptable if sow performance will not be compromised. In the first experiment (Chapter 2), it was shown that 22% of the sows had lactational ovulation and that ovulation was advanced in the other IS animals. Most probably this was the result of the decreased suckling stimulus, which is normally known to suppress follicular development during lactation by blocking GnRH secretion (Armstrong et al., 1988; Britt et al., 1985). Sows also lost less weight in the IS treatment than in the control treatment (IS: -9 ± 2 vs. control: -17 ± 2 kg.sow^{-1}), but we found no correlation between weight loss of the sow and weaning to ovulation interval. In experiment two (Chapter 3), data on sow performance were also available (Kuller et al., 2004a). IS sows had larger, nearly pre-ovulatory sized follicles at the end of lactation, which surprisingly did not result in a higher percentage of lactational ovulation (IS: 14.8 % (4 of 27 sows) vs. control: 0%; $p > 0.10$) or shortened weaning to ovulation interval (IS: 108 ± 3 h vs. control: 108 ± 3 h; $p > 0.10$). Again, weaning to ovulation interval and also follicle size were not affected by weight loss of the sow (IS: -12 ± 2 vs. control: -19 ± 2 kg.sow^{-1}), number of piglets weaned or weaning weight of the piglets and thus we hypothesised that the larger follicles at weaning were again a result of the decreased suckling stimulus. So, IS had the advantage of decreasing weight loss of the sow during lactation but had the risk of inducing lactational ovulation in pigs. In other studies with IS, lactational ovulation even reached 100% (Langendijk et al., 2007).

Lactational ovulation is not desirable in intensive farming systems since sows are not regularly checked for oestrus symptoms in their farrowing pen and thus lactational ovulation will result in an increased weaning to oestrus interval. As stated, the larger follicles and shorter weaning to ovulation interval were most probably the result of the decrease in suckling stimulus. So, it might be an option to decrease the period of intermittent suckling from 11 to e.g. 9 days of a 25 day lactational period to increase the suckling stimulus and decrease the risk of lactational ovulation. Others found that when IS started at 21 days, creep feed intake was higher during the first week of IS than when IS started on day 14 and hypothesised that a shorter period of IS would be just as effective in stimulating creep feed intake as longer period of IS (Langendijk et al, 2007). Another possibility would be to extend the lactation period in order to facilitate adaptation to weaning for the piglets and meanwhile establish gestation in sows by inseminating sows showing oestrus during lactation. The first results of intermittent suckling during extended lactation (weaning at 41 to 47 days) are

promising as reviewed by Langendijk et al (2007). Of the sows used, 34% to 100 % showed oestrus and 28 to 93% ovulated during lactation, both depending largely on the sow breed used. When Topigs 40 instead of Topigs 20 was used, these values were 85 to 100 % and 63 to 93 respectively. When sows were mated during lactation, pregnancy rate varied between 71 and 88% and embryo survival varied between 46 and 78% at 23 to 30 days of gestation. Unfortunately, no data on subsequent farrowing rate or litter size at farrowing are available yet. So, extending lactation could benefit the piglets, but effects on reproduction in the sow are still not clear.

5. Future research

At present, the strategy of intermittent suckling is still under investigation. In our experiments, sow and piglets were separated by a wooden fence that was attached to the farrowing crate. Separating the piglets from the sow, took approximately 10 to 15 minutes for 10 sows within one unit. For a farmer, this will probably be too time-consuming. Undoubtedly, automation is a realistic possibility and could require only a simple adaptation to already existing systems in which the piglet nest will move down when the sow stands up and raises again when the sow lies down. This system is developed to prevent piglets from crushing by the sow and claims to decrease piglet mortality shortly after weaning, but could also be used to separate the sow from her piglets. Further research is needed to study the possibilities of such a system and to make a cost-benefit analysis on costs of these farrowing crates.

Another major topic that needs attention is the fact that sows showed a high number of lactational ovulations in studies with IS. Oestrus control in farrowing pens is not standard operation procedure in commercial swine operations. Thus, oestrus might not be easily detected during lactation. As a result, lactational ovulation will result in animals that return to oestrus at an irregular interval after weaning. Usually, herd owners have strict breeding schedules on their farms and sows with irregular intervals will disturb these schedules. As already suggested above, it could be a possibility to decrease the length of the IS period during a 27 day lactation period from 11 to for example 9 days in order to manipulate the suckling stimulus in such a way that a balance will exist between the number of sows showing lactational ovulation and a sufficiently high level of creep feed intake by the piglets. Another possibility could be to increase lactation length to 6 weeks in combination with IS. This is a strategy which was shown to improve performance of the piglets during lactation

(Berkeveld et al., 2007b). When sows are mated during this extended lactation period, and thus will conceive during ongoing lactation, piglet welfare and performance would be improved without compromising sow reproductive performance. Preliminary data on reproductive performance are promising, but still at its experimental stage (Langendijk et al., 2007). Further research is needed on preventing lactational oestrus during a lactation of approximately 4 weeks or on using lactational oestrus during an extended lactation.

As a result of the low feed intakes usually seen after weaning, weaning is often associated with a growth check and with major morphological changes in the small intestine such as decreased villus height and increased crypt depth (Pluske et al., 1997). This decrease in villous height could lead to a decrease in absorption but also to a decrease in digestive capacity (Pluske et al., 1997), which could lead to problems of maldigestion. So, the growth check often seen after weaning could, besides low energy intake per se, result from this combination of maldigestion and malabsorption. Malabsorption can be attributed to the shortage of villi and the subsequent loss of absorptive capacity. In order to find out if IS affected absorptive capacity of the small intestine at day four after weaning, an in vivo small intestine segment perfusion (SISP-) test according to Nabuurs (1993) was performed in a pilot study in 24 newly weaned piglets (6 eaters and 6 non- eaters from the control and IS treatment; Chapter 6*)*. It was found that net absorption was significantly higher in eaters than in non- eaters, in the non- infected segments of the small intestine. It is known that high intake of cows (Pluske et al., 1996b) or sows milk (van Beers-Schreurs et al., 1998) or liquid milk replacer (Verdonk et al., 2001), and thus maintenance of nutrient supply (Pluske et al., 1996a) can prevent the usual villous atrophy seen after weaning (Pluske et al., 1997). Moreover, Nabuurs (1996) showed that piglets that were provided with creep feed (although creep feed intake was not assessed) during temporarily weaning from the sow were partly prevented from the usual decrease in net absorption and villous height. So, if eaters in our experiment continued to consume feed after weaning as is most likely (Bruininx et al., 2002), then this continuous nutrient supply probably diminished villous atrophy, thereby diminishing the usual decrease in absorptive surface, which probably accounted for the higher net absorption.. Digestive capacity was not studied in this thesis. The small number of animals used in this pilot study might explain why no difference was found between the IS and control treatment in net absorption. So, further research might focus on development of digestive and absorptive capacity of the small intestine and its relation with creep feed intake and IS. Also the effect of IS and creep feed intake on gut integrity could be of interest especially with respect to post weaning diseases like oedema disease and streptococcal

meningitis. The value of these kind of investigations would be significantly increased if creep feed intake during lactation could be measured in the individual piglet, instead of the use of extrapolated data from litter feed intake.

In all research in unweaned piglets, creep feed intake is measured on a litter level and then data are presented as intake.piglet^{-1}. For example, English showed that the piglets used in his experiment consumed on average 610 g.piglet^{-1} and had better performance after weaning than the control piglets that were not offered creep feed. However, the 600 g was based on a single experiment that used litter averages and nothing was known about the distribution of feed intake of piglets within the litters. Subsequently these data were used by others to create a cut off point for creep feed intake. This way of extrapolating data from litters to individuals has the risk of overestimating creep feed intake of some piglets and underestimating the intake of others, since it is known that creep feed intake not only varied between but also within litters (Aherne et al., 1982; Appleby et al., 1992; Delumeau and Meunier-Salaun, 1995; Pajor et al., 1991). At this moment, the best way to get an impression of the number of eating and non eating piglets or to get an estimation of creep feed intake of individual piglets during lactation is to add a marker like chromic oxide (Barnett et al., 1989; Bruininx et al., 2002) or use behavioural data of creep feed intake (Appleby et al., 1991; Delumeau and Meunier-Salaun, 1995; Fraser et al., 1994; Pajor et al., 1991; Wattanakul et al., 2005). Although both methods have been validated and proven to be valuable parameters to gain information on the number of eaters and non eaters and to some degree on the level of creep feed intake (behaviour), exact creep feed intake cannot be assessed.

Summarizing, there is need for a way to quantitatively assess individual creep feed intake comparable to the IVOG station used in weanling (Bruininx et al., 2001a) and growing pigs (de Haer and de Vries, 1993), where a dry feeder placed on a load cell is combined with electronic identification. Some difficulties could arise in development of this kind of feeder for suckling piglets, because creep feed intake is low during lactation and young piglets may get frightened of impressive feeders. The opportunities for further research will be almost infinite if such feeder for individual feed intake could be developed.

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Summary

In Europe, piglets are generally weaned at three to four weeks of age, thus changing abruptly from a diet of highly digestible milk to a relatively poorly digestible starter diet. As a result of this change and other stressors related to weaning, feed intake and growth are markedly reduced shortly after weaning and piglets are more vulnerable to develop diarrhea and edema disease. Intake of a sufficient amount of creep feed during lactation creates a more gradual transition at weaning and can reduce post weaning disorders. However, creep feed consumption during lactation is usually low and is also highly variable between piglets and litters. This thesis describes the effect of intermittent suckling (IS) during lactation on performance of pigs before and after weaning. IS is a management technique in which piglets are separated from the sow during a number of hours every day in the second part of lactation. In the studies of this thesis piglets were separated for 12 h/ day (0930 to 2130 h) from d 14 to weaning (d 25). Creep feed was provided from d 7 onwards.

In the first experiment (Chapter 2), we studied the effect of intermittent suckling on creep feed intake and weight gain of litters during lactation and during the first week after weaning. Loss of weight and back fat of the sow during lactation, as well as reproductive performance, were also measured. Creep feed intake of the litters during lactation was higher in IS litters than in control litters (686 ± 57 vs. 314 ± 42 g.piglet^{-1}, $P < 0.01$). The distribution of creep feed intake shifted from a skewed one, with a majority of litters consuming less than 250 g.piglet^{-1} in control litters, to a normal distribution with an average creep feed intake of 500 to 750 g.piglet^{-1} in IS litters. Sixty percent of the IS litters had an average creep feed intake per piglet during lactation of more than 600 g, in contrast to the control litters where only 20 % consumed more than 600 g.piglet^{-1} during lactation and 66 % of the litters consumed less than 250 g.piglet^{-1}. So, IS resulted in a shift in the distribution of creep feed intake and apparently improved creep feed intake especially in litters with an otherwise low creep feed consumption. The higher creep feed intake caused by IS resulted in better performance after weaning: compared to the control litters the IS litters had higher feed intake (281 ± 15 vs. 204 ± 9 g.piglet^{-1}.d^{-1}, $P < 0.01$) and higher ADG (255 ± 10 vs. 177 ± 8 g.piglet.d^{-1}, $P < 0.01$) after weaning. Although creep feed intake was not stimulated in all IS litters, IS litters with little or no creep feed intake during lactation still tended to have a weight gain after weaning that was 68 g.d^{-1} higher than control litters with comparable creep feed intake during lactation. Also feed intake after weaning seemed to be higher in IS litters than control litters with comparable creep feed intake during lactation, although this was not significant ($P = 0.12$). Apparently, positive effects of IS on growth and feed intake of the litters after weaning

were also mediated by some other mechanism than by increased creep feed intake during lactation.

Also the effects on reproductive performance of the sow were studied in this experiment. Ovulation was advanced by IS, resulting in lactational ovulation in a number of sows (IS: 22 vs. control: 3 %, $P < 0.01$) and shortened weaning to ovulation interval (IS: 4.7 ± 0.2 vs. control: 5.3 ± 0.2 d, $P < 0.05$). Weight loss of the sows was significantly reduced during the 11 days of IS. This probably resulted from lower milk production in IS sows because piglet weight gain, which is highly correlated with milk nutrient production, was lower in IS sows.

The second experiment (Chapter 3, 5 and 6) was conducted to study if the improved creep feed intake found in regimes of intermittent suckling is of major importance for post-weaning growth performance. Performance of piglets was studied until they reached commercial slaughter weights (107 ± 0.3 kg). Creep feed intake of litters has been assessed and within litters eaters and non-eaters were distinguished using chromic oxide (Chapter 3). Moreover, the development of eating behaviour was investigated (Chapter 5) and the effect of creep feeding during lactation on net absorption in the small intestine at 4 days after weaning was measured (Chapter 6).

In Chapter 3 it was confirmed that intermittent suckling improves feed intake during lactation (IS: 231 ± 38 vs. C: 147 ± 38 g.piglet^{-1}; $P < 0.001$), but also in the first (IS: 201 ± 24 vs. C: 157 ± 25 g.piglet^{-1}.d^{-1}; $P < 0.05$) and second (IS: 667 ± 33 vs. C: 570 ± 35 g.piglet^{-1}.d^{-1}; $P < 0.05$) week after weaning. Thereafter, no differences in feed intake were found to slaughter. Weaning weight was lower in IS litters (IS: 7.1 ± 0.01 vs. C: 8.1 ± 0.01 kg/piglet; $P < 0.05$), but 7 d after weaning BW was similar (IS: 8.5 ± 0.2 vs. C: 8.7 ± 0.2 kg/piglet; $P = 0.18$), and no differences were found to slaughter.

IS did not increase the percentage of eaters within a litter during lactation (IS: 23 ± 4.5 % vs. C: 19.0 ± 4.1 %; $P = 0.15$) and weaning weights did not differ between eaters and non-eaters (eater: 7683 ± 99 vs. non-eater: 7523 ± 79 g.piglet^{-1}; $P = 0.63$). From one until four weeks after weaning, however, piglets that were eaters during lactation had higher weights than non-eaters (eater: 20.3 ± 0.3 kg vs. non-eater: 18.2 ± 0.2 kg; $P < 0.05$). So, stimulation of creep feed intake during lactation may improve performance of newly weaned piglets. We concluded that IS increases average creep feed intake and that creep feed intake improves performance after weaning. In this experiment, in which creep feed intake was low in comparison to the experiment of chapter 2, the percentage of eaters within a litter was not increased, suggesting that IS stimulated creep feed intake of piglets that were already eating.

A third experiment (Chapter 4) was designed to further evaluate the use of chromic oxide as a marker to select eaters and non eaters during lactation. Five piglets from each of four litters received oral administrations of 10, 20, 30, or 40 g of creep feed containing 10 g of Cr_2O_3 .kg^{-1} on each of 2 consecutive days (days 20 and 21), or 30 g of creep feed containing 10 g of Cr_2O_3 .kg^{-1} on day 20 and 30 g of Cr_2O_3–free creep feed on day 21. On days 21 through 24, 6 fecal samples were collected from each piglet at regular intervals. Green-colored feces were considered indicative of creep feed consumption (eaters). Data analyses were based on single and multiple fecal samples. On day 22, evaluation of 1 fecal sample/piglet and multiple fecal samples/piglet resulted in identification of as many as 40% and only 15% of the feed-treated piglets wrongly as non-eaters, respectively. Repeated sampling over multiple days would identify 99% of eaters accurately. Piglets erroneously identified as non-eaters were those administered either low amounts of Cr_2O_3–supplemented creep feed for 2 days or Cr_2O_3–supplemented creep feed on only 1 day. We concluded that addition of Cr_2O_3 to creep feed enables selection of individual creep-feed–eating suckling piglets via examination of feces, provided that repeated fecal samples are evaluated.

In Chapter 2 and 3 it was shown that IS increased average creep feed intake per piglet and also increased the number of litters with high feed intake during lactation. However, also during IS treatments, litters have been identified with little or no creep feed intake during lactation. Apparently, some litters start eating creep feed during lactation, or can be stimulated to do so by the use of IS, while others are not. Moreover, IS did not seem to increase the number of piglets that were eating within a litter, as judged by green coloured faeces after addition of chromic oxide to the creep feed. Because IS stimulates creep feed intake, we asked ourselves the question how feeder visiting behaviour develops in IS litters.. Study of the behaviour of IS litters might also improve our understanding of the relevance of suckling (and deprivation of suckling) in the development of feeder visiting behaviour.
Therefore, development of feeder visiting behaviour in intermittently and continuously suckled piglets during lactation and shortly after weaning was investigated in Chapter 5. To study a possible link between feed intake level of the litter and eating behaviour of piglets, both from IS and control (C) treatments three litters consuming high (H) and low (L) levels of creep feed were compared with each other. Feeder visits of individual piglets and nursing behaviour were analysed from continuous video recordings at 5 treatment days (treatment

started at T0): T13, T16, T24, T25 (first day after weaning) and T26 (second day after weaning). Non-feeding related activity of piglets was scored at 10 minute intervals.
A majority of the CL piglets never visited the feeder during lactation (at T24, 56 % of the CL piglets), while only 9 % of the ISL and CH piglets did not visit the feeder. On the other hand, at T24 100% of the ISH piglets visited the feeder at least once. Visiting frequency did not change in CL piglets during lactation, but increased in ISH piglets between T13 and T16 and in CH and ISL piglets between T16 and T24. At T16, T24 and T25, visiting frequency and total feeder time (total time spent at the feeder per piglet per day) were higher in H than in L piglets and were higher in ISL than in CL piglets at T24. Total feeder time increased in all piglets between T16 and T24, except in CL piglets. At T26, average feeder time (time spent at the feeder per visit) and total feeder time were lower in CL piglets than in the other piglets. Latency to first visit to the feeder after weaning did not differ between groups, but variation was greater in L than in H piglets. Nursing frequency decreased in IS litters once treatment started. Average nursing time decreased in CH, remained unchanged in CL and ISL and increased in ISH litters during lactation. At the end of lactation (T24), H litters were more active than L litters. After weaning, no difference was found between the litters but at T26 ISH litters were least active. It was concluded that IS treatment did not affect feeder visiting behaviour of piglets from litters with an anyhow high level of feed intake during lactation. IS piglets from litters with a low level of creep intake were stimulated to visit the feeder during lactation, which probably made them familiar with the feeder and the feed. Part of the variation in feed intake between litters might be explained by differences in suckling behaviour and activity.

As a result of the low feed intakes usually seen during the first days after weaning, weaning is often associated with a growth check and with major morphological changes in the small intestine such as decreased villus height and increased crypt depth. This decrease in villous height could lead to a decrease into absorption but also to a decrease in digestive capacity, which could lead to problems of maldigestion. So, a growth check after weaning could, besides low energy intake per se, result from a combination of maldigestion and malabsorption. Malabsorption can be attributed to shortage of villi and the subsequent loss of absorptive capacity. In order to find out if IS and/or creep feed intake affects absorptive capacity of the small intestine (with and without E.coli infection present) at day four days after weaning, an in vivo small intestine segment perfusion (SISP-) test was performed (Chapter 6) in a pilot study in 24 newly weaned piglets (6 eaters and 6 non- eaters from the control and IS treatment*)*. Net absorption in non- infected segments of the small intestine

was significantly higher in eaters than in non- eaters. No difference was found between IS and control piglets. Generally, diarrhoea is a result of increased secretion or decreased absorption from the gastrointestinal tract. Our preliminary data therefore suggested that, because creep feed intake during lactation increased net absorption after weaning, creep feeding could be a useful tool in the prevention of post weaning diarrhoea.

Finally, in the General Discussion (Chapter 7), results from the different experiments are integrated and discussed. Not only effects on piglet performance and behaviour but also the effects of IS on the reproductive performance of the sow are discussed and suggestions for further research are given. Also some additional data of the non feeding related behaviour such as exploring (at any place in the pen), redirected oral behaviour (manipulating or biting another piglet) and fighting, are presented and discussed in this final chapter, because they were beyond the main scope of Chapter 5.

Results described in this thesis have demonstrated that intermittent suckling improves both creep feed intake during lactation and feed intake and weight gain after weaning, and that independent of feeding regimen piglets consuming creep feed during lactation had higher weights and net absorption in the small intestine after weaning. IS resulted in higher (157-218 %) average creep feed intake during lactation and in a lower number of litters with low feed intake during lactation. IS was especially efficient in piglets from low feed intake litters. Piglets were stimulated to investigate the feeder during lactation, which facilitated the consumption of creep feed after weaning.

Samenvatting

Het effect van tijdelijk spenen op de voeropname en groei van biggen

In de Europese varkenshouderij worden biggen gespeend op een leeftijd van drie tot vier weken, waardoor een abrupte overgang plaats vindt van goed verteerbare zeugenmelk naar een relatief slecht verteerbaar dieet voor gespeende biggen. Tengevolge van deze verandering en andere stressoren rondom het spenen zijn groei en voeropname kort na het spenen zeer laag en zijn de biggen gevoeliger voor het ontwikkelen van speendiarree en oedeemziekte. De opname van een voldoende hoeveelheid bijvoer tijdens de zoogperiode zorgt voor een geleidelijker overgang bij het spenen en kan zo de problemen rond het spenen verminderen. Helaas is de bijvoeropname van biggen tijdens de lactatie meestal laag en erg variabel tussen biggen in een toom, en ook tussen tomen. Dit proefschrift beschrijft het effect van het tijdelijk spenen van biggen tijdens de lactatie op de voeropname en groei van biggen voor en na het spenen. Tijdelijk spenen is een management techniek waarbij zeug en de biggen tijdens de tweede helft van de lactatie van elkaar gescheiden worden gedurende een aantal uren per dag. In de deelonderzoeken van dit proefschrift werden de biggen 12 uur per dag (0930 tot 2130 uur) gescheiden van dag 14 tot de dag van spenen (dag 25). De biggen werden vanaf dag 7 bijgevoerd.

In het eerste experiment (Hoofdstuk 2), is er gekeken naar het effect van tijdelijk spenen (TS) op bijvoeropname en groei van tomen tijdens de lactatie en gedurende de eerste week na spenen. Bovendien is er bij de zeugen gekeken naar gewicht- en spekdikte verlies en het interval van spenen tot ovulatie. De bijvoeropname was hoger in TS tomen dan in controle tomen (686 ± 57 vs. 314 ± 42 g.big^{-1}, P < 0.01). De verdeling van de bijvoeropname verschoof van een scheve verdeling, waarbij de meerderheid van de tomen minder dan 250 g. big^{-1} op nam in de controle groep, naar een normale verdeling met een gemiddelde voeropname van 500 tot 750 g. big^{-1} in de TS tomen. Tijdens de lactatie had 60% van de TS tomen een gemiddelde voeropname van meer dan 600 g. big^{-1}, in tegenstelling tot de controle groep waar slechts 20 % van de tomen een gemiddelde voeropname van meer dan 600 g. big^{-1} had en 66% van de tomen minder dan 250 g.big^{-1} bijvoer consumeerde. Dus TS resulteerde in een verschuiving in de bijvoeropname verdeling en verbeterde blijkbaar de voeropname in tomen die anders een lage voeropname zouden hebben. De hogere bijvoeropname ten gevolge van tijdelijk spenen zorgde voor een betere voeropname en groei na het spenen: in vergelijking met de controle tomen hadden TS tomen een hogere voeropname (281 ± 15 vs. 204 ± 9 g.big^{-1}.d^{-1}, P < 0.01) en een hogere groei (255 ± 10 vs. 177 ± 8 g.big.d^{-1}, P < 0.01). Hoewel TS niet in alle tomen de bijvoeropname tijdens lactatie stimuleerde was er een tendens dat TS tomen met weinig of geen bijvoeropname tijdens de lactatie een hogere groei hadden dan controle tomen met vergelijkbare voeropname tijdens

de lactatie. Ook de voeropname na het spenen leek hoger in deze TS tomen, maar dit verschil was niet significant (P=0.12). Blijkbaar worden de positieve effecten van TS na het spenen ook nog door iets anders veroorzaakt dan een verhoogde bijvoeropname tijdens lactatie. In hetzelfde experiment werd ook onderzoek gedaan naar de effecten van TS op de reproductieve functie van de zeug. Het moment van ovulatie werd door TS vervroegd, wat resulteerde in ovulaties tijdens de lactatie (TS: 22% vs. controle: 3 %, $P < 0.01$) en een verkort interval tussen spenen en ovulatie (4.7 ± 0.2d vs. 5.3 ± 0.2 d, $P < 0.05$). Het gewichtsverlies van de zeug werd aanzienlijk verminderd door TS. Dit is waarschijnlijk het gevolg van een lagere melkproductie, aangezien de groei van de biggen, welke sterk is gecorreleerd aan melkproductie van de zeug, lager was in TS zeugen.

Het tweede experiment (hoofdstuk 3, 5 en 6) is uitgevoerd om te onderzoeken of de verhoogde voeropname tijdens de lactatie ten gevolge van TS belangrijk is voor de voeropname en groei van biggen na het spenen tot de slachtleeftijd (107 ± 0.3 kg). Bijvoeropname van de tomen werd gemeten en binnen tomen werd onderscheid gemaakt tussen eters en niet-eters door toevoeging van chroomoxide aan het voer (Hoofdstuk 3). Bovendien werd de ontwikkeling van voeropname gedrag bestudeerd (Hoofdstuk 5) en werd het effect onderzocht van bijvoeropname tijdens de lactatie op netto absorptie in de dunne darm op 4 dagen na het spenen (Hoofdstuk 6).
In hoofdstuk 3 werd bevestigd dat TS de bijvoeropname tijdens lactatie verbetert (TS: 231 ± 38 vs. controle: 147 ± 38 $g.big^{-1}$; $P < 0.001$), evenals tijdens de eerste (TS: 201 ± 24 vs. controle: 157 ± 25 $g.big^{-1}.d^{-1}$; $P < 0.05$) en tweede (IS: 667 ± 33 vs. controle: 570 ± 35 $g.big^{-1}.d^{-1}$; $P < 0.05$) week na spenen. Daarna werden er tot aan het slachten geen verschillen in voeropname gevonden. Het speengewicht was lager in TS tomen (TS: 7.1 ± 0.01 vs. controle: 8.1 ± 0.01 kg/big; $P < 0.05$), maar dit verschil was zeven dagen na het spenen verdwenen (TS: 8.5 ± 0.2 vs. controle: 8.7 ± 0.2 kg/big; $P = 0.18$) en tot aan slacht werden er vervolgens geen verschillen meer gevonden.
TS verhoogde het aantal etende biggen binnen een toom niet (TS: 23 ± 4.5 % vs. controle: 19.0 ± 4.1 %; $P = 0.15$) en ook het speengewicht van eters en niet-eters verschilde niet (eter: 7683 ± 99 vs. niet-eter: 7523 ± 79 $g.big^{-1}$; $P = 0.63$). Echter, vanaf de eerste tot de vierde week na het spenen waren biggen die aten tijdens de lactatie zwaarder dan niet-eters (eter: 20.3 ± 0.3 kg vs. niet-eter: 18.2 ± 0.2 kg; $P < 0.05$). Dus het stimuleren van bijvoeropname tijdens de lactatie zou de prestaties van biggen direct na het spenen kunnen verbeteren. Onze conclusie was dat TS de gemiddelde voeropname verbetert en dat bijvoeropname tijdens de lactatie de voeropname en groei van biggen na het spenen

verbetert. In dit tweede experiment, waar de voeropname laag was in vergelijking tot het eerste experiment (Hoofdstuk 2), werd het percentage eters binnen een toom niet verhoogd. Het lijkt er dus op dat TS met name de voeropname stimuleerde van biggen die toch al aten.

Een derde experiment (Chapter 4) werd uitgevoerd om het gebruik van chroomoxide, als een marker om eters en niet eters tijdens de lactatie te kunnen selecteren verder te evalueren. Uit vier tomen werden per toom vijf biggen geselecteerd en deze dieren kregen oraal op 2 opeenvolgende dagen (dag 20 en dag 21) 10, 20, 30, of 40 g. bijvoer toegediend waaraan 10 g Cr_2O_3. kg^{-1} was toegevoegd, of zij kregen oraal 30 g bijvoer met Cr_2O_3 op dag 20 en 30 g bijvoer zonder Cr_2O_3 op dag 21. Tussen dag 21 en 24 werden zes keer per dag mestmonsters genomen. Wanneer bij een big groene mest werd aangetroffen dan werd aangenomen dat er bijvoer was opgenomen (eters). De data analyse werd gebaseerd op enkele en op herhaalde afname van mestmonsters. Op dag 22 werden bij enkele, versus herhaalde afname respectievelijk 40 en 15% van de gevoerde dieren foutief als niet–eters ingedeeld. Herhaalde waarnemingen gedurende meerdere dagen bleek 99% van de eters juist in te delen. Biggen die ten onrechte als niet-eters werden ingedeeld waren dieren die een kleine hoeveelheid voer met Cr_2O_3 toegediend hadden gekregen of dieren die slechts 1 dag voer met Cr_2O_3 hadden gekregen. Wij trokken de conclusie dat toevoeging van Cr_2O_3 aan bijvoer het mogelijk maakt om individueel bijvoer etende biggen middels afname van mestmonsters te selecteren, vermits de monsters herhaald worden genomen.

In Hoofdstuk 2 en 3 werd aangetoond dat TS de gemiddelde voeropname per big en ook het aantal tomen met hoge voeropname verhoogt. Echter, ook als TS wordt toegepast komen er tomen met lage of geen voeropname tijdens de lactatie voor. Blijkbaar zijn er tomen die tijdens de lactatie gaan eten, of in ieder geval gestimuleerd kunnen worden om te gaan eten, terwijl andere tomen niet gaan eten. Omdat TS de voeropname stimuleert, stelden wij ons de vraag hoe voeropname gedrag zich bij biggen van TS tomen ontwikkelt. Onderzoek naar het gedrag van deze tomen zal ook nader inzicht verschaffen met betrekking tot de relevantie van het zuigen (en het niet kunnen zuigen) bij de moeder voor de ontwikkeling van het aantal en duur van de bezoeken aan de voerbak. Daarom werd dit laatste gedrag beschreven voor tijdelijk gespeende biggen en voor controle biggen, zowel tijdens de lactatie als kort na het spenen (Hoofdstuk 5). Om een mogelijke relatie te kunnen onderzoeken tussen het niveau van voeropname van de toom en het voeropname gedrag van biggen, werden zowel voor de TS als de controle (C) behandeling van 3 tomen biggen onderzocht met respectievelijk een laag (L) en een hoog (H) voerniveau. Op 5 verschillende

behandelingsdagen (de behandeling startte op T0) werden bezoeken aan de voerbak van individuele biggen en hun zooggedrag geanalyseerd door gebruik te maken van continue video opnames: T13, T16, T24, T25 (eerste dag na spenen) en T26 (tweede dag na spenen). Activiteit van biggen die niet met voeropname was gerelateerd werd met 10 minuten intervallen gescoord.
Een groot aantal CL biggen werd nooit bij de bak gezien tijdens de lactatieperiode: op T24, bezocht 56% van de CL biggen de bak niet, tegenover slechts 9% van de TSL en CH biggen. Daarentegen bezocht 100% van de TSH biggen de voerbak tenminste 1 keer op T24. De frequentie van voerbakbezoek van CL biggen veranderde niet tijdens lactatie, maar nam toe bij ISH biggen tussen T13 en T16 en bij CH en TSL biggen tussen T16 en T24. Op T16, T24 en T25 waren zowel de frequentie als de totale duur van het voerbakbezoek (= totale duur per dag per big) groter bij H dan bij L biggen en beide waren op T24 groter bij TSL dan bij CL biggen. De totale duur van het voerbakbezoek nam toe bij alle biggen tussen T16 en T24, behalve bij CL biggen. Op T26 was de gemiddelde duur van een voerbakbezoek en de totale duur van het voerbakbezoek kleiner bij CL biggen dan bij alle andere biggen. De latentietijd tot eerste bezoek aan de voerbak na spenen verschilde niet tussen de groepen, maar de variatie was groter bij L dan bij H biggen. De zoogfrequentie nam af in TS tomen zodra de TS behandeling begon. De gemiddelde zoogduur nam af bij CH tomen, veranderde niet bij CL en ISL tomen en nam toe bij TSH tomen. Aan het einde van de lactatie (T24) waren H tomen meer actief dan L tomen. Direct na het spenen (T25) was er geen verschil in activiteit tussen de tomen, maar op T26 waren ISH tomen het minst actief. De conclusie was dat de TS behandeling geen effect heeft op het gedrag bij de voerbak bij biggen van tomen die toch al een hoge voeropname hadden. TS biggen uit tomen met een laag voeropname niveau werden echter gestimuleerd om de bak te bezoeken tijdens de lactatie, waardoor ze mogelijk bekend raakten met de voerbak en het voer. Een deel van de variatie in voeropname tussen tomen zou verklaard kunnen worden door verschillen in zooggedrag en activiteit.

Als gevolg van de lage voeropnames die kort na het spenen worden gemeten gaat het spenen vaak gepaard met een tijdelijke afname van de groei en met grote morfologische veranderingen in de dunne darm, zoals een afname in villushoogte en een vergroting van de diepte van de crypten. Deze afname van de villushoogte zou kunnen leiden tot een afname in absorptie maar ook tot een afname in verteringscapaciteit, wat zou kunnen leiden tot maldigestie. De tijdelijke afname in de groei die zo vaak na het spenen wordt waargenomen zou dus, afgezien van een lage energie opname, ook het gevolg kunnen zijn van deze

combinatie van maldigestie en malabsorptie. Malabsorptie kan worden toegeschreven aan de verkorting van de villi en het daarop volgende verlies van absorberende capaciteit. Om te onderzoeken of TS en/of bijvoeropname van invloed zijn op de absorptiecapaciteit van de dunne darm op 4 dagen na het spenen (in aan- en afwezigheid van een E.coli infectie), werd in een pilot studie (Hoofdstuk 6) een in vivo small intestine segment perfusion test (SISP) uitgevoerd met 24 biggen direct na het spenen (6 eters en 6 niet-eters in zowel de TS als de controle groep). De netto absorptie was significant groter bij eters dan bij niet-eters in de niet-geinfecteerde segmenten. In het algemeen kan worden gesteld dat diarree een resultante is van verhoogde secretie of verminderde absorptie van het maagdarmkanaal. Op grond daarvan doen onze resultaten vermoeden dat het bijvoeren een goede manier zou kunnen zijn om speendiarree te voorkomen omdat de netto absorptie na het spenen verhoogd is door de opname van bijvoer tijdens de lactatie.

Tenslotte worden in de algemene discussie (Hoofdstuk 7) resultaten van verschillende experimenten geïntegreerd en bediscussieerd. Naast een bespreking van de effecten van TS op de prestaties en het gedrag van biggen, worden ook de effecten op de reproductie van de zeug bediscussieerd en worden suggesties gedaan voor nieuw onderzoek. Ook worden nieuwe aanvullende data gepresenteerd van gedrag dat niet met voeropname is verbonden, zoals exploratief en vecht gedrag.

De resultaten van dit proefschrift tonen aan dat TS zowel de bijvoeropname tijdens lactatie als de voeropname en groei na het spenen bevordert en dat, onafhankelijk van behandeling, biggen die bijvoer opnemen tijdens de lactatie zwaarder zijn na het spenen en een hogere netto absorptie in de dunne darm hebben na het spenen. TS resulteerde in een grotere gemiddelde voeropname (157- 218%) tijdens de lactatie en in een kleiner aantal tomen met lage voeropname tijdens lactatie. TS was in het bijzonder efficiënt in biggen uit tomen met een geringe voeropname. Deze biggen werden gestimuleerd om na het spenen de voerbak te onderzoeken, waardoor de voeropname na het spenen vergemakkelijkt werd.
penen, waardoor de voeropname na het spenen vergemakkelijkt werd.

Dankwoord

“Een mooie herinnering,
Iets waarvan je houdt,
Neem je overal mee naar toe”

-Tekst: H. van Veen –

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Nunc est bibendum!

Curriculum vitae

Wikke Kuller werd op 28 februari 1977 geboren te Naarden en groeide op in de provincie Noord Holland. In 1995 haalde zij haar Gymnasium diploma aan het Murmellius Gymnasium in Alkmaar. In hetzelfde jaar begon zij aan de studie diergeneeskunde in Utrecht. In 1999 werd het doctoraal gedeelte van deze studie afgerond en heeft zij bij de afdeling varkensgezondheidszorg een excellent tracé jaar gelopen, waarin de basis voor dit proefschrift is gelegd. Na het doorlopen van de differentiatie varken werd de studie diergeneeskunde in 2002 afgerond. In 2002 is Wikke als junior docent dierenarts onderzoeker begonnen als medewerker bij de afdeling Gezondheidszorg Landbouwhuisdieren, met dit proefschrift als resultaat.
Wikke heeft samen met Barend van den Enden twee zonen, Guus (21- 07- 2005) en Teun (06- 10- 2006).

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-quod erat demonstrandum -