Asian-Aust. J. Anim. Sci.
Vol. 24, No. 11 : 1601 - 1606
November 2011

www.ajas.info
http://dx.doi.org/10.5713/ajas.2011.11181

Effects of Varying Creep Feed Duration on Pre-weaning and Post-weaning Performance and Behavior of Piglet and Sow

L. Yan, H. D. Jang and I. H. Kim*

Department of Animal Resource and Science, Dankook University, Cheonan, Choognam 330-714, Korea

ABSTRACT : 32 sows (Landrace×Yorkshire) and their litters were used to evaluate the effects of varying creep feed duration on pre-weaning, post-weaning performance of piglets and sows. Sows were randomly assigned with 1, 2 or 3+ parities into 1 of 4 treatments. Creep feeding was initiated at day 5, 10 and 15 from birth for treatment 1 (TRT1), 2 (TRT2) and (TRT3), respectively, with a control group provided no creep feed. In this study, TRT1 and TRT2 diets had reduced ($p<0.05$) the post-weaning diarrhea scores in piglets and the weaning-to-estrus interval and cortisol concentration in sows at weaning time compared with other treatments. Dietary TRT1 led to a higher ($p<0.05$) epinephrine and norepinephrine concentrations than other treatments. No differences ($p>0.05$) were noted in suckling, sleeping, fighting frequency and mortality in piglet and eating, standing times, backfat and body weight loss in sows. In conclusion, creep feed initiated from day 5 and 10 reduce diarrhea scores in piglets and benefit the estrus interval in sows compared with those initiated from day 15 and no-creep feeding diets, indicating creep feeding could improve the pigs and sows performance, especially those initiated from day 5 and 10. (**Key Words :** Creep Feed, Duration, Piglet, Sow)

INTRODUCTION

Piglets are given creep feed to fill the gap between their increasing nutrients requirement and nutrients supplied by the lactating sow because of the declining milk production, which may be insufficient to meet the steadily increasing demands from growing piglet. Generally, commercial recommendations on when to initiate creep feeding as early as 2 to 3 day of age to induce piglets to consume solid feed and achieve greater total creep feed consumption throughout lactation. Various studies have demonstrated the beneficial effect of creep feed on post-weaning performance, which is highly dependent on the absolute amount of creep feed consumption (Pajor et al., 1991; Carstensen et al., 2005). However, evidence on the effect of creep feeding duration on feed consumption and growth performance has been limited, and only Klindt (2003) showed that creep feeding from 5 day of age resulted in greater pre-weaning daily gains than creep feeding from 2 day prior to weaning. Recently, Sulabo et al. (2010) suggested creep feeding duration for 13 day (lactation period = 21 d) produced 10% unit more eaters than litters fed creep feed for 6 and 2 day. Bruininx et al. (2002) reported that eaters had more visits to the feeder and concomitantly had a greater rate of feed intake than non-eaters. Therefore, the duration of creep feeding could be an important factor in stimulating more pigs to consume more creep feed and subsequently greater daily gains.

The behavior and reproductive performance of sows is known to be influenced by the metabolic state of the sow and the suckling stimulus of the piglets (Foxcroft, 1992). A variety of factors could influence the behavior, including environmental quality, food quality and piglet behavior in some species (Berger, 1979; Hauser and Fairbanks, 1988). Pajor et al. (2002) also demonstrated that creep feeding cause piglets to consume more solid food and hence vocalize less when nursing frequency declines, which weakens the sow's responses to such calls (Weary et al., 1999). They also suggested that creep feeding can reduce the nutritional load, lactation BW loss and the weaning-to-estrus interval. Therefore, the effects of creep feed duration on sows performance was also investigated, in consideration of its potential influence on piglet behavior and nursing-associated vocalization.

Collectively, the objectives of this study were i) to determine the effects of varying duration of creep feeding on the pre-weaning and post-weaning growth performance and behavior of piglets and ii) to determine the effects of

* Corresponding Author : In ho Kim. Tel: +82-41-550-3652, Fax: +82-41-565-2949, E-mail: inhokim@dankook.ac.kr
Received June 15, 2011; Accepted August 15, 2011

varying duration of creep feeding on performance and behavior of sows.

MATERIALS AND METHODS

The experimental protocols employed in this study were approved by the Animal Care and Use Committee of Dankook University.

Animals and housing

A total of 32 sows (Landrace×Yorkshire) and their litters were used in this study. Sows were assigned randomly to 1 of 4 creep feeding groups, with parities of 1, 2 or 3+. At day 107 of gestation, the sows were moved to farrowing crates in an environmentally regulated farrowing house. The mean parity of the sows was 2.6±0.4. Sows were fed on a commercial gestation (2.5 kg) and lactation feed (programmed increased to 7 kg) (Table 1), divided into 2 daily meals. Creep feed (DE: 4,000 kcal/kg; CP: 22%; Lys 1.74%; Met: 0.70%; Ca: 0.81. P: 1.00) was given initiated at day 5, 10 and 15 (weaned at d 21) from birth for treatment 1, 2 and 3, with a control group (TRT 4) provided no creep feed (Table 2). Sows and their offspring were individually housed in farrowing crates (2.4×1.8 m), which were constructed of 1.95 m^2 of solid floor and 2.37 m^2 of slatted floor. This space included a piglet nest equipped with an infrared lamp (500 W), a piglet drinking nipple, and a piglet feeder placed on a dimpled rubber matting to collect any spillage from the feed. The temperature in the farrowing house was maintained at a minimum of 20°C. Drinking nipples provided water *ad libitum* to both sows the piglets. Litter size at birth varied from 7 to 14 piglets, and was standardized to 10 piglets per litter within 2 day after birth by cross-fostering within each treatment. All piglets received injections of 1 ml of iron dextran and the males were castrated 2 day after birth. At weaning, the sows were relocated to a mating room, with the piglets remaining in the pen for 1 week (weanling pigs), the number of weaning

Table 1. Sow diet composition (as-fed basis)

Items	Gestation diet	Lactation diet
Ingredients (%)		
Corn	57.10	51.12
Soybean meal, 46% CP	10.65	24.61
Wheat bran	12.00	4.00
Rapeseed meal	3.70	2.50
Rice bran	6.00	5.00
Tallow	3.59	6.05
Molasses	3.60	3.50
Dicalcium phosphate	1.52	1.64
Limestone	0.99	0.76
Salt	0.60	0.50
L-lysine HCl, 98%	0.05	0.12
Vitamin premix[1]	0.10	0.10
Mineral premix[2]	0.10	0.10
Calculated composition		
ME (MJ/kg)	3.19	3.44
CP (%)	13.10	17.10
Crude fat (%)	6.89	9.10
Lys (%)	0.65	1.00
Ca (%)	0.87	0.85
P (%)	0.76	0.73

[1] Provided per kilogram of complete diet: vitamin A, 10,000 IU; vitamin D_3, 2,000 IU; vitamin E, 48 IU; vitamin K_3, 1.5 mg; riboflavin, 6 mg; niacin, 40 mg; d-pantothenic, 17 mg; biotin, 0.2 mg; folic acid, 2 mg; choline, 166 mg; vitamin B_6, 2 mg; and vitamin B_{12}, 28 μg.

[2] Provided per kilogram of complete diet: Fe (as $FeSO_4 \cdot 7H_2O$), 90 mg; Cu (as $CuSO_4 \cdot 5H_2O$), 15 mg; Zn (as $ZnSO_4$), 50 mg; Mn (as MnO_2), 54 mg; I (as KI), 0.99 mg; and Se (as $Na_2SeO_3 \cdot 5H_2O$), 0.25 mg.

Table 2. Creep feed composition (as-fed basis)

Items	
Ingredients (%)	
Corn	22.40
Soybean meal	8.00
Soy oil	4.50
Whey	24.16
Fish meal	2.50
Fermented soybean meal	10.00
Coconut oil	4.17
Lactose	8.00
Plasma powder	4.00
Sugar	3.05
Isolated soybean protein	6.15
Dicalcium phosphate	1.25
DL-methionine	0.38
L-lysine·HCl	0.41
Threonine, 98%	0.13
Zinc oxide	0.30
Choline Cl, 50%	0.10
Vitamin premix[1]	0.10
Mineral premix[2]	0.18
Probiotics	0.22
Calculated composition (%)	
DE (MJ/kg)	16.74
CP	22.00
Lys	1.74
Met	0.70
Ca	0.81
P	1.00

[1] Provided per kilogram of complete diet: vitamin A, 1,298 IU; vitamin D_3, 260 IU; vitamin E, 2.4 IU; menadione (sodium bisulfate form), 143 μg; vitamin B_{12}, 3.3 μg; riboflavin, 880 μg; d-pantothenic acid, 2.6 mg; niacin, 4.4 mg.

[2] Provided per kilogram of complete diet: Ca, 849 mg; Zn, 150 mg; Fe, 132 mg; Mn, 20 mg; Cu, 12 mg; Se, 0.31 mg; I, 0.79 mg.

piglets were recorded.

Measurements

Individual piglet BW was obtained on day 0, 5, 10, 15, and 21 (weaning), and day 7 after weaning to calculate the average daily gain (ADG). Creep feed residuals and general health was checked daily. Sow body weights were checked within a few hours after farrowing and on the day of weaning (21 day), after which the backfat thickness of the sows (6 cm off the midline at the 10^{th} rib) was measured using a real-time ultrasound instrument (Piglot 105, SFK Technology, Herlev, Denmark). The incidence of diarrhea in piglets was observed and recorded 3 times per day throughout the study. In order to assess the severity of diarrhea, feces from each pig were scored by estimating the moisture content according to the method described by Hart and Dobb (1988). In brief, the scores were as follows: 0, normal, firm feces; 1, possible slight diarrhea; 2, definitely unformed, moderately fluid feces; or 3, very watery and frothy diarrhea. A cumulative diarrhea score per diet and day was then calculated (Montagne et al., 2004).

To assess blood characteristics, the sows were bled via puncture of the vena cava prior to feeding at day 107 of gestation and at weaning (day 21) to determine the concentrations of epinephrine, norepinephrine, and cortisol. Blood samples were collected into non-heparinized tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) to obtain serum, which was separated via 30 min of centrifugation at 4,000×g at 4°C, the aliquot was stored at -4°C. The serum was removed and stored at -20°C until being used in cortisol, Norepinephrine (NE) and epinephrine (EPI) analysis. Serum concentrations of cortisol were determined with a standardized solid phase radioimmunoassay kit (Diagnostic Products Corporation, Los Angeles, CA). The NE and EPI were assayed using an ion-exchange purification procedure followed by liquid chromatography with electrochemical detection, as described previously by Hay and Mormède (1997). In brief, the samples were loaded onto cationic columns, and the catecholamines were eluted with boric acid. The eluates were assayed via HPLC with electrochemical detection with an oxidizing potential of +0.65V. The intra- and inter-assay CV were 7.0% and 7.1% for NE and 6.5% and 11.6% for EPI, respectively.

Detection of estrus was conducted twice per day from weaning onward, at 0830 and 1600 every day. A sow was considered to be in estrus when exhibiting a standing response induced by a back pressure test when in the presence of a boar.

Activity in the farrowing crates was recorded by 24 h time-lapse video recording. The video camera was positioned to provide a view of the entire farrowing crate. Behavior was recorded from the commencement of partition to weaning. All behavior of the litter was continuously recorded to determine the time spent by piglets at the creep feeder, sleeping and fighting during lactation. The time spent by sows on eating, and standing was also determined. Nursing was considered to have begun with the sow lying in the nursing posture with at least 80% of the litter in contact with the udder. Nursing was classified as unsuccessful if it was followed by a second nursing episode within 20 min.

Statistical analysis

All data in this experiment were analyzed in accordance with a completely randomized design using the GLM procedure (SAS Inst. Inc. Cary, NC). The individual sow or litter of piglets was used as the experimental unit. For the blood profile data, the initial data was used as a covariate. Differences among treatment means were determined via Duncan's multiple range test, and a probability level of $p<0.05$ was regarded as statistically significant.

RESULTS AND DISCUSSION

Effect of creep feed duration in piglets

In this study, varying the duration of creep feed had no effect on the pre-weaning and post-weaning piglet growth performance in the current study (Table 3). Pigs fed different creep feeding duration exhibited no differences in suckling, sleeping and fighting frequency and mortality (Table 5). Creep feeding initiated from day 5 and 10 reduced ($p<0.05$) the post-weaning diarrhea scores compared with the other treatments (Table 3). Moreover, increasing creep feed consumption was observed with the increasing creep feeding duration (Table 4), indicating that the longer duration of creep feeding stimulated more pigs to consume more feed. Previously, Alger et al. (1990) observed that small piglets with low milk intake could consume more creep feed as a consequence of compensatory increase in foraging behavior. Pajor et al. (1991) proposed that exploratory investigation and social activity might be key factors in the initiation of creep feeding. Therefore, the duration of creep feeding may stimulate more eaters and subsequently the total feed consumption. Supportably, Sulabo et al. (2008) suggested that litters creep fed for 13 days produced 10% unit more creep feed eaters than litters fed creep diet for both 2 and 6 day. Moreover, ingestion of solid food during lactation can speed up the induction of amylase and protease enzymes (De Passille et al., 1989) and stimulate acid production (Cranwell et al., 1976, Sohn and Maxwell, 1995). Thus, higher creep feed consumption may result in greater growth performance, which is in agreement with Klindt (2003), who showed that creep feeding from 5 day of age resulted in greater pre-weaning daily gains than creep feeding from

Table 3. Effects of varying creep feeding duration on piglet performance and blood characteristics

Items[1]	TRT1	TRT2	TRT3	TRT4	SE[2]
Pigs/litter					
d 0	10	10	10	10	
d 21	9.6	9.4	9.4	9.3	0.31
Mortality (%)	4	6	6	7	1.84
ADG (g)					
0-5 d	181	188	160	175	21
5-10 d	204	213	209	197	31
10-15 d	221	226	213	220	27
15-21 d	230	199	204	200	44
Overall	209	207	197	198	20
21-28 d	225	207	194	193	30
Diarrhea score[3]	4.25^{b}	4.75^{b}	6.20^{ab}	9.80^{a}	2.012

[1] TRT1 = Creep feed from 5-d of age until weaning (16 d); TRT2 = Creep feed from 10 d of age until weaning (11 d); TRT3 = Creep feed from 15 d of age until weaning (6 d); TRT4, no creep feed.
[2] Pooled standard error.
[a,b,c] Within a row, means with different superscripts differ ($p<0.05$).
[3] Diarrhea score: 0, normal, firm feces; 1, possible slight diarrhea; 2, definitely unformed, moderately fluid feces; or 3, very watery and frothy diarrhea; Data were measured by average total diarrhea score during 7 day post-weaning.

2 day prior to weaning. However in the current study, varying creep feeding duration did not affect the growth performance throughout this study in spite of the increased feed consumption. Similarly, Sulabo et al. (2008) found no difference among varying creep feeding duration (2, 6 and 13 day) on pre-weaning gains and weaning weights (day 20). The reason for this lack of significant difference is unknown; it may have occurred due to the small feed intake of piglet may not enough to improve preweaning performance or the large variation among litters or as a result of replication and other systematic experimental errors. Moreover, our results revealed that creep feeding led to a lower diarrhea score than those provided no creep feeding post-weaning, which to some extent suggested that creep feed may have influenced positively gut maturity. Similarly, English (1981) proposed that creep feeding results in gut maturity and minimizes post-weaning scores. It was previously suggested that ingestion of solid food during lactation could modify the gut flora. Liu et al. (2008) indicated that diarrhea is always related to gut health and the intestinal microfloral population. Therefore, our study suggested that the negative effects associated with weaning pressure and the transition from milk to solid food may be impaired with creep feeding, because of the better capacity and maturation of gut health.

Table 4. Effects of varying creep feeding duration on piglet feed intake

Items	TRT1[1]	TRT2[1]	TRT3[1]	SE[3]
FI1[2] (g/d)	7			
FI2[2] (g/d)	12	15		
FI3[2] (g/d)	25	28	25	
TFI[2] (g)	252^{a}	249^{a}	154^{b}	34.1

[1] TRT1 = Creep feed from 5-d of age until weaning (16 d); TRT2 = Creep feed from 10 d of age until weaning (11 d); TRT3 = Creep feed from 15 d of age until weaning (6 d).
[2] FI1, daily creep feed consumption during 5 to 15 d; FI2, daily creep feed consumption during 10 to 15; FI3, daily creep feed consumption during 15 to 21. TFI, total creep feed consumption during lactation.
[3] Pooled standard error.

Effect of creep feeding duration in sows

Creep feeding initiated from day 5 and 10 significantly reduced ($p<0.05$) the weaning-to-estrus interval and cortisol concentration in sows compared with other treatments (Table 6). Creep feeding initiated from day 5 increased ($p<0.05$) the concentrations of epinephrine and norepinephrine in comparison to the piglets subjected to other treatments. No difference was noted in nursing, eating, standing times (Table 7), backfat loss and body weight loss (Table 6) during lactation in this study. Previously, it is well suggested that social stress activate the hypothalamic-pituitary-adrenal axis and the sympathetic-adrenal-medullary axis, and inducing an elevation of catecholamines in the peripheral blood (Axelrod and Reisine, 1984; Ehrhart-Bornstein and Borstein, 2008). Several studies have reported that increased cortisol secretion and higher basal levels of NE and EPI is a valid indicator of stress in pigs (Becker et al., 1985; Smulders et al., 2006). Pajor et al. (2002) have demonstrated that creep feed cause piglets to consume more solid food and hence vocalize less when nursing frequency declines, which weakens the sow's responses to such calls. Tsuma et al. (1995) also noted that suckling and weaning induced increases in the concentrations of peripheral plasma cortisol

Table 5. Effects of varying creep feeding duration on pre-weaning piglet behavior

Items[1] (%)	TRT1	TRT2	TRT3	TRT4	SE[2]
Suckling[3]	42.4	43.8	45.9	42.5	3.00
Sleeping[4]	42.2	43.8	40.4	39.6	3.12
Fighting[5]	15.3	12.4	13.7	17.9	3.03

[1] TRT1 = Creep feed from 5-d of age until weaning (16 d); TRT2 = Creep feed from 10 d of age until weaning (11 d); TRT3 = Creep feed from 15 d of age until weaning (6 d); TRT4, no creep feed.
[2] Pooled standard error. [3] Suckling movements with a teat in the mouth or with the nose in contact with udder.
[4] Lying on the side or belly with closed eyes without performing any other described behavior. [5] Fighting with others.

Table 6. Effect of varying creep feeding duration on lactating sow performance

Items[1]	TRT1	TRT2	TRT3	TRT4	SE[2]
Estrus interval (d)	4.50[b]	4.50[b]	5.00[a]	5.3[a]	0.182
Sow weight (kg)					
Post-farrowing	221	219	217	219	7.4
Weaning	198	198	193	197	8.1
Changes	23	21	24	22	1.9
Back fat (mm)					
Lactation	38.5	38.8	39.2	38.9	0.136
Weaning,	38.3	38.6	38.7	38.5	0.263
Back fat loss	0.23	0.18	0.57	0.38	0.280
Epinephrine (pg/ml)	14.1[b]	22.1[ab]	33.0[a]	34.2[a]	3.195
Norepinephrine (pg/ml)	101[b]	159[ab]	171[ab]	190[a]	24.55
Cortisol (μg/dl)	2.78[b]	2.84[b]	4.16[a]	4.28[a]	0.346

[1] TRT1 = Creep feed from 5-d of age until weaning (16 d); TRT2 = Creep feed from 10 d of age until weaning (11 d); TRT3 = Creep feed from 15 d of age until weaning (6 d); TRT4 = No creep feed.
[2] Pooled standard error. [a,b] Within a row, means with different superscripts differ ($p<0.05$).

and endorphins. Therefore, the decreased EP, NPI and cortisol observed could be considered as a reflection of the reduced stressful effects of the suckling stimulus during lactation, owing to the relationship between the creep feed intake and the suckling time (suckling stimulus). Kuller et al. (2004) may provide support to this hypothesis, wherein they suggested that decreased suckling increased creep feed intake during lactation by an average of 218%. Additionally, Pajor et al. (2002) have suggested that creep feeding can reduce the nutritional load, the lactation BW loss and the weaning-to-estrus interval of sows. Our study revealed that creep feeding initiated from day 5 and 10 reduced the estrus interval compared with the other treatments, indicating the reproductive performance of sow is affected by the different creep feeding duration. It is well accepted that sustained elevations of plasma cortisol concentration impaired the LH surge, estrus and ovulation in female pigs, and also inhibited the secretion of LH in ovariectomized gilts (Turner et al., 1999a, b). Dobson and Smith (2000) and Foxcroft (1992) documented that stress (suckling) stimulates the adrenal axis and, in severe cases, inhibits LH secretion, which ultimately lead to an-ovulation and infertility. Therefore, the reason for the reduced estrus interval and EP, NPI and cortisol levels in blood are likely to be the decreased suckling stimulus. However, to the best of our knowledge, studies concerning the effects of creep feeding on sow performance are somewhat limited. There are no available studies with results that would allow for a clear comparison to the results of this study; therefore, further study will clearly be required to determine with

Table 7. Effect of varying creep feeding duration on lactating sow behavior

Items[1] (%)	TRT1	TRT2	TRT3	TRT4	SE[2]
Eating diet[4]	19.4	18.4	17.7	20.1	2.0
Standing[5]	28.8	28.6	31.6	29.9	2.5

[1] TRT1 = Creep feed from 5-d of age until weaning (16 d); TRT2 = Creep feed from 10 d of age until weaning (11 d); TRT3 = Creep feed from 15 d of age until weaning (6 d); TRT4 = No creep feed.
[2] Pooled standard error. [3] Suckling movements with a teat in the mouth or with the nose in contact with udder.
[4] Eating from the food trough or chewing food. [5] Standing from the floor with 4 feet.

more accuracy the effects of piglet stimulation on sows.

CONCLUSION

In conclusion, creep feed initiated from day 5 and 10 reduce diarrhea scores in piglets and benefit the estrus interval in sows compared with those initiated from day 15 and no-creep feeding diet, indicating creep feeding could improve the pigs and sow performance, especially those initiated from day 5 and 10.

REFERENCES

Alger, B., P. Jensen and L. Steinwall. 1990. Behaviour and weight changes at weaning and regrouping pigs in relation to teat quality. Appl. Anim. Behav. Sci. 26:143-155.

Axelrod, J. and T. D. Reisine. 1984. Stress hormones: Their interaction and regulation. Sci. 224:452-459.

Becker, B. A., J. A. Nienaber, R. K. Christenson, R. C. Manak, J. A. De Shazer and G. L. Hahn. 1985. Peripheral concentrations of cortisol as an indicator of stress in the pig. Am. J. Vet. Res. 46:1034-1038.

Berger. J. 1979. Weaning conflict in desert and mountain bighorn sheep (*Ovis Canadensis*): an ecological interpretation. Zeitschrif for tierpsychologie 50:188-200.

Bruininx, E. M. A. M., G. P. Binnendijk, C. M. C. vander PeetSchwering, J. W. Schrama, L. A. den Hartog, H. Everts and A. C. Beynen. 2002. Effect of feed consumption on individual feed intake characteristics and performance of grouphoused weaned pigs. J. Anim. Sci. 80:1413-1418.

Carstensen, L., A. K. Ersboll, K. H. Jensen and J. P. Nielsen. 2005. *Escherichia coli* post-weaning diarrhea occurrence in piglets with monitored exposure to creep feed. Vet. Microbiol. 110:113-123.

Cranwell, P. D., D. E. Noakes and K. T. Hill. 1976. Gastric secretion and fermentation in the sucking pig. Br. J. Nutr. 36: 71-86.

de Passillé, A. M., B. Pelletier, G. Menard and J. Morisset. 1989. Relationships of weight gain and behavior to digestive organ weight and enzyme activities in piglets. J. Anim. Sci. 67: 2921-2929.

Dobson, H. and R. F. Smith. 2000. What is stress and how does it affect reproduction? Anim. Reprod. Sci. 60-61:743-752.

Ehrhart-Bornstein, M. and S. R. Bornstein. 2008. Cross-talk between adrenal medulla and adrenal cortex in stress. Ann. N.Y. Acad. Sci. 1148:112-117.

English, P. R. 1981. Establishing the early weaned pig. Pig Vet. Soc. Proc. 7:29-37.

Foxcroft, G. R. 1992. Nutritional and lactational regulation of fertility in sows. J. Reprod. Fertil. 45:113-125.

Hay, M. and P. Mormède. 1997. Determination of catecholamines and methoxycatecholamines excretion patterns in pig and rat urine by ion-exchange liquid chromatography with electrochemical detection. J. Chromatogr. B 703:15-23.

Hauser, M. D. and L. A. Fairbanks. 1988. Mother-offspring conflict in vervet monkeys: variation in response to ecological conditions. Anim. Behav. 36:802-813.

Klindt, J. 2003. Influence of litter size and creep feeding on preweaning gain and influence of preweaning growth on growth to slaughter in barrows. J. Anim. Sci. 81:2434-2439.

Kuller, W. I., N. M. Soede, H. M. G. van Beers-Schreurs, P. Langendijk, M. A. M. Taverne, J. H. M. Verheijden and B. Kemp. 2004. Intermittent suckling: Effects on piglet and sow performance before and after weaning. J. Anim. Sci. 82:405-413.

Liu, P., X. S. Piao, S. W. Kim, L. Wang, Y. B. Shen, H. S. Lee and S. Y. Li. 2008. Effects of chito-oligosaccharide supplementation on the growth performance, nutrient digestibility, intestinal morphology, and fecal shedding of Escherichia coli and Lactobacillus in weaning pigs. J. Anim. Sci. 86:2609-2618.

Montagne, L., F. S. Cavaney, D. J. Hampson, J. P. Lalle and J. R. Pluske. 2004. Effect of diet composition on postweaning colibacillosis in piglets. J. Anim. Sci. 82:2364-2374.

Pajor, E. A., D. Fraser and D. L. Kramer. 1991. Consumption of solid food by suckling piglets: Individual variation and relation to weight gain. Appl. Anim. Behav. Sci. 32:139-155.

Pajor, E. A., D. M. Weary, C. Caceres, D. Fraser and D. L. Kramer. 2002. Alternative housing for sows and litters part3. Effects of piglet diet quality and sow-controlled housing on performance and behaviour. Appl. Anim. Behav. Sci. 76:267-277.

Smulders, D., G. Verbeke, P. Mormède and R. Geers. 2006. Validation of a behavioral observation tool to assess pig welfare. Physiol. Behav. 89:438-447.

Sohn, K. S. and C. V. Maxwell. 1995. The effect of creep feeding on postweaning performance in early-weaned pigs. Kor. J. Anim. Sci. 37(1):73-78.

Sulabo, R. C., M. D. Tokach, E. J. Wiedmann, J. Y. Jacela, J. L. Nelssen, S. S. Dritz, J. M. DeRouchey and R. D. Goodband. 2010. Effects of varying creep feeding duration on pre-weaning performance and the proportion of pigs consuming creep feed. J. Anim. Sci. 88:3154-3162.

Tsuma, V. T., S. Einarsson, A. Madej and N. Lundeheim. 1995. Hormone profiles around weaning in cyclic and anoestrous sows. J. Vet. Med. Series A 42:153-163.

Turner, A. I., P. H. Hemsworth, P. J. Canny and A. J. Tilbrook. 1999a. Inhibition of the secretion of LH in ovariectomized pigs by sustained but not repeated acute elevation of cortisol in the absence but not the presence of oestradiol. J. Endocrinol. 163:477-486.

Turner, A. I., P. H. Hemsworth, P. J. Canny and A. J. Tilbrook. 1999b. Sustained but not repeated acute elevation of cortisol impaired the luteinizing hormone surge, estrus and ovulation in gilts. Biol. Reprod. 61:614-620.

Weary, D. M., E. A. Pajor, M. bonnenfant, S. K. Ross, D. Fraser and D. L. Kramer. 1999. Alternative housing for sows and litters. Part 2. Effect of a communal piglet area on pre-and post-weaning behavior and performance. Appl. Anim. Behav. Sci. 65:123-135.