INFLUENCE OF CREEP FEEDING ON INDIVIDUAL CONSUMPTION CHARACTERISTICS AND GROWTH PERFORMANCE OF NEONATAL AND WEANLING PIGS

by

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B.S., University of the Philippines at Los Baños, Philippines, 1997
M.S., South Dakota State University, 2003

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Animal Sciences and Industry
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Abstract

Five experiments were performed to determine the influence of creep feeding on individual consumption characteristics and growth performance of neonatal and weanling pigs. These evaluated the effects of lactation feed intake and creep feeding (n = 84 litters; Exp. 1), creep feeding duration (n = 54 litters; Exp. 2), creep feeder design and feed accessibility (n = 54 litters; Exp. 3), organoleptic properties of the creep feed (n = 50 litters; Exp. 4) and creep diet complexity (n = 96 litters; Exp. 5). In summary, creep feeding did not affect preweaning gains and weaning weights of pigs weaned at 3 weeks of age. Creep feeding for 18 d did not influence sow performance. However, creep feeding tended to improve litter weaning weights due to improved survivability. Creep feed consumption was related to piglet maturity rather than the induction of creep feeding. In both experimental and field conditions, pigs that consumed creep feed (eaters) had greater post-weaning feed intake and daily gains compared to non-eaters (pigs that did not consume creep feed) and non-creep fed pigs. This led to improvements in pig weight uniformity and reduction of the severity of post-weaning lag. These benefits were achieved regardless of weaning weight, the complexity of the creep diet, and the duration of creep feeding. The proportion of eaters of creep feed in whole litters can be manipulated. Longer duration of creep feeding increased the proportion of eaters. A rotary creep feeder with a hopper created the most eaters with the lowest creep feed disappearance. Creep diet complexity had the greatest effect in increasing the proportion of pigs consuming creep feed. On the other hand, low feed intake of lactating sows and adding feed flavors to the creep feed did not affect creep feed consumption and the proportion of pigs consuming creep feed. Therefore, creep feeding that focuses in encouraging more suckling piglets to eat is beneficial in producing weanling pigs that are better adapted to weaning, which improves post-weaning performance.

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Dedication

This work is dedicated to my family, Papa, Mama, Eric, Sherwin, Ryan, Riza, Kyle, Cody, and my wonderful wife Shayne. I love you all. And to the **Filipino Farmers**, *kayo ang aking lakas at inspirasyon.* I offer my life and being to serve all of you.

CHAPTER 1 - Creep feeding neonatal pigs: a review

Introduction

The main premise of providing supplemental nutrient sources to neonatal pigs lies in the relationship of pre-weaning growth and post-weaning pig performance. In commercial production, suckling pigs of modern genotypes typically achieve growth rates between 240-270 g/day from birth to 18-22 d of age (Le Dividich and Sève, 2001; Sulabo et al., 2008a). In comparison, artificially-reared piglets of similar ages provided ad libitum access to liquid milk based diets have preweaning growth rates of 400 to 550 g/day (Hodge, 1974; Harrell et al., 1993). This substantial difference in growth rates represents a greater potential for postnatal growth that remains unachieved in commercial production. It also presents opportunities for improving weaning weights that may positively impact postweaning and lifetime pig performance (Mahan, 1993; Mahan et al., 1998; Cabrera et al., 2002).

Nutrient availability is considered a major limiting factor for determining preweaning growth rates (Klindt, 2003). Though sow milk consumption remains as the main source of nutrients for neonatal pigs, providing alternative food sources may offer numerous benefits. Liquid-diet feeding during lactation provides the most potential for improving dry matter intake and growth rates of suckling pigs (Odle and Harrell, 1998); however, the cost and management problems associated with the delivery of liquid diets remains a major constraint for widespread application in commercial production systems. Providing dry diets to piglets during lactation or 'creep feeding' continues to be one the most popular methods. This is especially true in pig producing countries where weaning is performed at older ages (4 weeks or older). Despite wide commercial acceptance, research assessing the value of creep feeding is limited and equivocal especially for weaning ages less than 4 weeks of age (Pluske et al., 1995). In addition, the current trend of increasing weaning ages in North America has generated more interest in creep feeding, which further substantiates the need to determine the relevance of this practice in modern pig production.

Creep feeding and lactating sow performance

One of the major reasons for providing creep feed is to augment sow milk production, which often becomes limiting during early- to mid-lactation (Le Dividich and Sève, 2001). Boyd et al. (1995) estimated that lactating sows need to produce at least 18 kg of milk per day to meet the energy requirements of a 10-pig litter at 21 d, which is greater than the typical production of 10 to 12 kg of milk produced in modern sows. Thus, milk production may limit piglet growth as lactation advances, especially in large litters. In addition, Pluske et al. (1995) and Le Dividich and Sève (2001) contend that the protein content of sow milk may also be a limiting factor. Noblet and Etienne (1987) suggested that the protein to energy ratio in sow milk is lower than the level that is needed to maximize neonatal pig growth. Therefore, creep feeding may help supplement the deficiencies in sow milk supply and composition to positively impact preweaning growth.

Creep feeding was also thought to reduce the nutritional load in lactating sows especially those with large litters, which may have corollary effects in reducing lactation weight loss and weaning-to-estrus interval. Recently, Sulabo et al. (2008a) investigated the interactive effects of lactation feed intake and creep feeding on sow and litter performance. Litters were provided a high complexity creep diet from d 3 of age until weaning (d 21). Overall, creep feeding for 18 d did not have any effect on sow performance. Average litter creep feed intake provided about 3.65 Mcal ME to the litter, which is only 1.26% of the total energy intake of the sows. Therefore, the variation associated with creep feed intake and the magnitude of its contribution is simply too small to generate any appreciable, nutritional savings to lactating sows that may merit a reduction in mobilized body reserves or improve their metabolic state. Though the impact of creep feeding in reducing nutritional requirements of the sow may potentially be greater with older weaning ages, it does not appear to have any effects in a 21-d lactation period.

Creep feeding and preweaning pig performance

In earlier studies where litters were weaned at least 35 d of age, the positive effect of creep feeding on weaning weights was generally consistent (Aumaître and Salmon-Legagneur, 1961; Friend et al., 1970; Aherne et al., 1982). However, results were more equivocal when pigs were weaned at a younger age, with some studies showing positive effects on preweaning weight gains or weaning weights (English et al. 1980; Pajor et al., 1991; Appleby et al., 1992; Fraser et al., 1994; Lawlor et al., 2002; Wattanakul et al., 2005) while others showing no effects (Bruininx et al., 2002; Kim et al., 2005; Callesen et al., 2007a; Sulabo et al., 2008a,b,c,d). These differences in preweaning response to creep feeding may be related to a number of factors such as the type of creep diet used and the duration of creep feeding; however, preweaning feed intake may largely explain this variation in responses. In a review, Pluske et al. (1995) calculated that the contribution of creep feed to daily energy intake prior to weaning at 21 to 35 d of age ranged from 1.2 to 17.4%. Pajor et al. (1991) suggested that creep feed intake is influenced by digestive maturity and nutritional demand, which are both related to weaning age. Callesen et al. (2007a) observed that pigs weaned later (33 d of age) consumed between 137 to 266% more creep feed than early-weaned pigs (27 d). Therefore, the response to creep feeding prior to weaning may be dependent on the level of creep feed consumption or weaning age.

Creep feeding and postweaning pig performance

One of the major justifications of creep feeding is its potential effects in improving adaptation to weaning and postweaning performance. Highly digestible and palatable creep diets are offered during lactation not only to improve weaning weights, but to ease the transition from milk during the suckling period to solid feed after weaning. Creep feed consumption is also thought to help initiate and promote gut and digestive enzyme development that may help pigs to utilize alternative food sources once milk is removed (Aumaître, 1972; de Passille et al., 1989; Nabuurs et al., 1993). These physiological factors including familiarity with solid food is speculated to stimulate postweaning feed intake, which may help maintain villus integrity and digestive function (Kelly, 1990; Pluske and Williams, 1996) and reduce occurrence of postweaning disorders (Carstensen et al., 2005). Eventually, these benefits may lead to a reduction in postweaning growth check and potential improvements in overall nursery performance.

However, evidences of the postweaning effects of creep feeding were inconsistent across studies; with most showing no effects on postweaning performance (Okai et al., 1976; Aherne et al.,1982; Barnett et al.,1989; Aherne, 1982; Pajor et al., 1991; Appleby et al., 1992; Fraser et al., 1994; Kavanagh et al., 2002; Lawlor et al., 2002) while others observed positive effects on postweaning gains (English, 1980; Fraser et al., 1994; Bruininx et al., 2002; Kuller et al., 2004; Berkeveld et al., 2007). Pajor et al. (1991) suggested that the lack of any clear relationship between creep feed intake and postweaning weight gain could be attributed to differences in the absolute amount of creep feed consumed before weaning. Carstensen et al. (2005) showed that piglets with a low creep feed contact during the suckling period ate less feed the two first days after weaning, compared to piglets with a high creep feed contact and non-creep fed piglets, respectively. Kuller et al. (2007b) also found a strong relationship between creep feed intake during lactation ($ADFI_{lact}$) and feed intake in the first week after weaning ($ADFI_{aw}$), where: $ADFI_{aw} = 136 + 0.26 \times ADFI_{lact}$ ($R^2 = 0.69$). Likewise, there was a positive relationship between litter creep feed intake during lactation ($ADFI_{lact}$) and litter ADG during the first week after weaning, which is described in the following formula: $ADG_{aw} = 95 + 0.24 \times ADFI_{lact}$ ($R^2 = 0.59$). Therefore, any postweaning benefits from creep feeding may be highly dependent on creep feed consumption.

Factors affecting creep feed consumption

The effectiveness of creep feeding is dependent on a number of factors, but creep feed consumption clearly has an important role. Neonatal pigs have the ability to convert a highly digestible creep feed with high efficiency (Renaudeau and Noblet, 2001; Kavanagh et al., 2002). A 1 gram of increase in daily litter creep feed intake resulted in a 2-g increase in litter weight gain (Renaudeau and Noblet, 2001) in one study and obtained a lower estimate (1 g of creep feed: 1.14 g of weight gain; Kavanagh et al., 2002) in another. It is then hypothesized that if litter creep feed intake can be stimulated; greater differences in preweaning weight gains and weaning weights can be achieved.

However, creep feed intake during lactation is variable between and within litters (Okai et al., 1976; Barnett et al., 1989; Pajor et al., 1991; Bruininx et al., 2002). Factors that influence the large variation in voluntary creep feed intake between and within litters during lactation are largely unknown. However, some factors have been identified that may influence creep feed consumption of whole litters.

1. Creep feeding duration

Commercial recommendations on when to initiate creep feeding vary widely from as early as 2 to 3 d of age to induce piglets early to solid feed and achieve greater total creep feed consumption throughout lactation, to as late as 2 to 3 d prior to weaning when milk production of the sow subsides. Klindt (2003) showed that creep feeding from 5 d of age resulted in greater preweaning daily gains and d 17 weaning weights in large litters (> 8 pigs per litter) than creep feeding from 2 d prior to weaning. Though creep feed consumption was not recorded in this study, the authors speculated that pigs in larger litters consumed sufficient creep feed after 5 d of age to affect preweaning growth rates. In contrast, Sulabo et al. (2008b) did not observe any effects of varying creep feeding duration (13, 6, and 2 d) on preweaning gains and weaning weights (d 20). This study also demonstrated that initiating creep feeding at a later age did not detrimentally affect creep feed intake; instead, older piglets readily accepted creep feed and consumed the same or more feed than piglets started on creep feed at an earlier age. This is plausible since 60 to 80% of the total creep feed intake is usually consumed in the last week prior to weaning regardless if pigs are weaned at 3 weeks (Sulabo et al., 2008a) or 4 weeks of age (Fraser et al., 1994; Bruininx et al., 2002; Pluske et al., 2007). Thus, creep feed consumption seems to be more related to piglet maturity rather than the period of induction of creep feeding.

2. Creep feed presentation and accessibility

The physical presentation and method of creep feeding litters influence creep feed consumption. Neophobia, or the reluctance to accept a new food source, may be a limiting factor in initiating and stimulating creep feed consumption; thus, familiarizing pigs early to the creep feeder may help condition pigs to accept creep feed associated with it (Chapple et al., 1987). Delumeau and Meunier-Salaün (1995) evaluated the effect of early trough familiarity on creep feeding behavior. Introducing the trough early did not affect creep feeding activity, which suggests that familiarity with the trough did not enhance the acceptance of creep feed placed in the feeder.

Increasing access to the creep feed has the most consistent effect in increasing creep feed consumption. Appleby et al. (1991) observed that increasing piglet access to creep feed from 2 to 6 feeding spaces resulted in greater creep feed consumption and longer feeding time, especially in piglets that consumed very little during the last week prior to weaning. In a follow-up study, increasing access from 2 to 8 feeding spaces improved creep feed intake in the last 3 d prior to weaning and reduced the number of pigs that consume very little in the last 24 h from 4.1 to 0.6 pigs per litter (Appleby et al., 1992).

Creep feeder design also influences creep feed consumption. Wattanakul et al. (2005) compared litters provided creep feed using a conventional creep hopper (2 to 3 feeding spaces) and a shallow tray. The use of the tray, which increased feeding space and accessibility, improved both feeder visiting time and litter creep feed intake. Recently, Sulabo et al. (2008c) found that litters using a rotary feeder with an ad lib hopper had 2.7 times lower total creep feed disappearance than litters using a conventional rotary feeder without a hopper and a pan feeder. However, preweaning gains and weaning weights of litters were unaffected by increased access or creep feeder design (Appleby et al., 1992; Wattanakul et al., 2005; Sulabo et al., 2008c). The lack of differences in pig and litter growth rates observed in these studies may be related to the nutritional contribution of the amount of creep feed consumed, the complexity of the creep diet, or feed wastage. Sulabo et al. (2008c) suggested that even though open designs or increased accessibility may provide greater opportunities for feeder-directed behavior, this may also allow some piglets to root, lie, and push feed out of the feeder contributing largely to wastage. Creep feed disappearance with the rotary feeder with a hopper may be closer to the actual intake of the litters, which would suggest that certain aspects of the design can help reduce feed wastage and improve the efficiency of delivery of the feed. Therefore, choosing the right creep feeder is vital in maximizing creep feed consumption and controlling feed wastage. Typically, since creep diets are expensive minimizing feed wastage will be an important consideration for implementation of creep feeding.

3. Creep diet composition

Fraser et al. (1994) compared a low-complexity creep diet based on corn, barley and soybean meal with a high-complexity commercial creep diet without soybean meal. In this study, the average creep feed intake of pigs fed a high and low complexity creep diet were correlated with their mean creep feeding scores (number of video frames of feeding behavior/pig/day) and the slopes of the regression line were compared. The slope of the line for the high complexity creep diet was double the slope of the low complexity creep diet, which suggests that feeding piglets with the high complexity creep diet will consume about twice the amount of the low complexity diet per unit of feeding time.

Pajor et al. (2002) also compared a complex creep diet high in protein and fat with a standard diet, and found a 52% greater consumption in pigs fed the high complexity diet, which persisted even after weaning. Sulabo et al. (2008d) compared a simple creep diet based on milo and soybean meal with a highly complex creep diet, and observed that litters fed the complex creep diet consumed twice the total (1.24 vs. 0.62 kg) and daily (412 vs. 205 g) creep feed intake of litters fed the simple creep diet. As a result, pigs fed the complex creep diet had 13% higher daily gains and 11% higher total gain than pigs fed the simple creep diet, with no creep pigs being intermediate.

Callesen et al. (2007a,b) observed differences in creep feed consumption and preweaning weight gains in neonatal pigs when the composition of the creep diet was manipulated. Four creep diets were compared: (1) wheat-soy based diet with animal and vegetable (mixed) protein sources, (2) heat-processed rice (HPR) with barley hulls and potato starch and mixed protein sources, (3) HPR with sugarbeet pulp and mixed protein sources, and (4) HPR with mixed protein sources. Pigs fed the HPR diet with mixed protein sources consumed 40% and 17% greater than those fed the wheat-soybean meal based creep diet for early- (27 d) and late-weaned (33 d) piglets, respectively. Pigs offered the wheat-soy based creep diet grew slower than pigs offered all HPR-based diets.

4. Organoleptic properties of the feed

Organoleptic properties of the feed may be a dietary factor that can reduce feed neophobia and influence creep feed consumption. Feed flavors are commonly used in nursery diets to improve diet acceptance and stimulate intake (McLaughlin et al., 1983; van Heugten et al., 2002). However, there are limited studies that have evaluated the effect of feed flavors on stimulating creep feed consumption. King (1979) observed no differences in preweaning feed intake or litter growth rate when feed flavors were added to the creep feed, despite observing improvements in feed consumption after incorporating the same feed flavor in both the sow and the starter diets. In contrast, Gatel and Guion (1990) added monosodium L-glutamate to the creep feed and found a significant increase in creep feed intake from day 18 postfarrowing; however, no differences in weaning weights were observed despite the increase in intake. Monosodium L-glutamate is the principal source of the umami taste, which increases the intensity and acceptability of inherent flavors of food. In a follow-up study, addition of monosodium L-glutamate to an associated commercial flavor in the creep feed did not elicit any effect on creep feed intake or preweaning performance. More recently, Millet et al. (2008) and Sulabo et al. (2008c) did not observe any improvements in creep feed consumption and preweaning performance with the addition of feed flavors to the creep feed. The lack of effect in suckling pigs may suggest age-related differences or greater individual variation in palatability perception. This also suggests that changing the flavor properties of the creep feed may not be sufficient to positively affect preweaning feed intakes.

5. Ambient temperature

Renaudeau and Noblet (2001) investigated the effects of ambient temperature on piglet creep feed consumption. Daily creep feed intake of litters kept at 29°C were 67% higher (388 vs. 232 g/d) than litters kept at 20°C, which resulted in a greater increase in weight gain between week 1 to 3 and week 4 of lactation at the higher temperature. These results were similar to Azain et al. (1996), where litters had 2.4 times greater daily milk replacer intake and piglet weight gains during the warm season compared to the cool season. This demonstrates the importance of creep feed intake; where creep feeding can help reduce the negative effects of heat exposure in sows on preweaning performance of the litter.

Methods used to determine individual creep feed consumption

Majority of the early studies that evaluated creep feeding used whole-litter values in determining creep feed consumption; where average intake was estimated by dividing the total creep feed disappearance by the number of piglets in the litter (Pajor et al., 1991; Fraser et., 1994; Pluske et al., 2007). This relies on the assumption that all piglets in a litter consume exactly the same amount of feed. However, recent studies have demonstrated that there is a wide variation in creep feed consumption within litters and certain proportion of pigs do not consume creep feed even when it is highly accessible or offered for longer durations (Barnett et al., 1989; Bruininx et al., 2002; Sulabo et al., 2008a). To further investigate postweaning effects of creep feed intake, it is also necessary to know whether individual pigs actually consumed creep feed during lactation. Therefore, determining individual consumption characteristics of creep fed pigs is important to obtain the true response attributable to creep feed consumption.

Different methodologies have been used to estimate creep feed consumption. Some studies have used a combination of video and electronic recordings to estimate creep feed consumption of individual piglets (Appleby et al., 1991; Pajor et al., 1991; Fraser et al., 1994). Time-lapse video recordings monitored the use of the feeder by each piglet, which is then combined with electronic monitoring of the amount of food in the dispenser before and after each feeding episode (Pajor et al., 1991). From the analysis of the video records, a creep feeding score is derived for each piglet, which corresponds to the number of video frames per 24 h (maximum of 1440) in which the pig had its head in the feeder. Creep feed consumption is then estimated by correlating the average weight loss from the feeder per pig per day with their mean creep feeding scores (video frames of feeding behavior per pig per day).

A number of studies used direct visual observations to estimate creep feed intake or ‘contact with feed’ (Delumeau and Meunier-Salaün 1995; Carstensen et al., 2005; Wattanakul et al., 2005; Hedemann et al., 2007). ‘Contact with feed’ was defined as ‘taking bites of creep feed and chewing on the feed’ (Carstensen et al., 2005). This method involves an observer with good eyesight who records the activity at the feeder by 5 min scan sampling (Delumeau and Meunier-Salaün 1995). Creep feeding behavior is recorded in each scan, which includes any behavioral act with a physical contact with feed (snout in the feeder, sniffing, rooting, ingesting). Exploratory activities towards the trough such as sniffing, rooting, or chewing acts were distinguished from those focused on the floor. Daily feed intake of individual piglets is estimated by allocating the litter’s total consumption to individual piglets according to the time frequency they were observed with their snouts in the feeder. This method is often used as an acceptable method of estimating individual feed intake in piglets with ad libitum access to feed (Dybkjær et al., 2006); however, it may not completely reflect the actual feed intake (Appleby et al., 1991). Wattanakul et al. (2005) suggested that this estimation has many potential inaccuracies because it involves extrapolation of information from the direct observation period to the 24 h day and takes no account of the possible differences in ingestion rate of individual piglets when feeding.

In recent studies, inert colored markers have been used to identify individual pigs within a litter that consumed creep feed. Chromic oxide is the most commonly used visual marker in these studies, typically added at 1% of the diet (Barnett et al., 1989; Bruininx et al., 2002; Kuller et al., 2007b; Sulabo et al., 2008a). Recently, a dye such as indigo carmine (cyan color) added at 0.5% of the diet was also used in a number of studies (Kim et al., 2005; Callesen et al., 2007a,b; Pluske et al., 2007). Fecal samples from each pig in a litter are collected once or twice daily using fecal loops (Bruininx et al., 2002) or cotton-tipped swabs (Sulabo et al., 2008a). The color of the collected samples are assessed, where it is assumed that green feces indicated that the pig had consumed creep feed and that the absence of green color in the feces was indicative of no creep feed consumption. Kuller et al. (2007a) validated this procedure and indicated that the chromic oxide is a suitable marker for identifying pigs that actually consumed creep feed within the litter, given that fecal collection is repeated a number of times. This method then provides a qualitative classification whether the pig is an eater (consumed creep) or non-eater (no evidence of consuming creep feed). It is still not possible to assess the quantity of creep feed intake for individual pigs within a litter. The chromic oxide marker method is simple, direct, and practical for use in investigating the effects of creep feeding pre- and post-weaning.

Individual consumption and growth characteristics according to creep consumption category

Preweaning effects

Prior to weaning, there are some contrasting findings in the characteristics and growth performance of eaters and non-eaters of creep feed. Bruininx et al. (2004) showed that pigs categorized as good eaters (pigs that showed green feces in all three sampling times) grew 5.8% faster than both moderate eaters (pigs that showed green feces once or twice) and non-eaters during the creep feeding period. Likewise, Kim et al. (2005) observed 12.6% greater daily gains in good eaters compared to non-eaters when creep fed from d 12 to 31. In a recent study, Callesen et al. (2007b) found a tendency for an interaction between weaning age (27 d, 'early' vs. 33 d, 'late') and creep consumption category, where late-weaned eaters had higher daily gains than late-weaned non-eaters. In contrast, daily gains were similar between early-weaned eaters or non-eaters. Pluske et al. (2007) also observed a tendency for eaters to grow faster than non-eaters during the last week prior to weaning (d 31); however, overall pre-weaning gain and weaning weights were similar between consumption categories. Kuller et al. (2007b) fed a complex creep diet from d 7 to 24 and showed that eaters had 4% lower daily gains than non-eaters from d 7 to 13, similar growth rates from d 14 to 20, and 16% greater daily gains in eaters compared to non-eaters in the last 3 d prior to weaning. There were no differences in pig weaning weights between eaters and non-eaters of creep feed in this study. In contrast, Sulabo et al. (2008e) observed that eaters were 7 to 8% smaller in body weight and were gaining 5 to 6% less than non-eaters prior to weaning regardless of the complexity of the creep diet. These differences in preweaning gains and characteristics of eaters across the studies may be related to differences in creep feeding duration and weaning ages. In these studies, creep feeding durations varied from 3 to 21 d and weaning ages ranged from 21 to 31 d.

Postweaning effects

Numerous studies evaluating individual piglets have consistently shown that eaters have significantly better postweaning performance than non-eaters of creep feed or non-creep fed pigs (Bruininx et al., 2002, 2004; Kuller et al., 2004, 2007b; Kim et al., 2005; Pluske et al., 2007; Sulabo et al., 2008a,b; 2009). The differences in postweaning gains is mainly due to differences in postweaning feed intake between eaters and non-eaters, which has been fairly consistent (Fraser et al., 1994; Delumeau and Meunier-Salaun, 1995; Bruininx et al., 2002; Carstensen et al., 2005; Sulabo et al., 2008b; 2009); though a few studies did not observe the same findings (Hedemann et al., 2007). Bruininx et al. (2001) found that about 50% of the piglets designated as eaters during the suckling period started eating within 4 h after weaning, whereas non-eaters and non-creep fed piglets needed about 6.7 and 6.9 h, respectively. Bruininx et al. (2004) also showed that eaters had more visits to the feeder associated with eating feed and concomitantly had a greater rate of feed intake. Interestingly, most of these studies provided creep feed for 14 to 21 d and pigs were weaned at an older age (ranging from 24 to 31 d). Sulabo et al. (2009) observed differences in postweaning feed intake and daily gains between eaters and non-eaters of creep feed despite creep feeding for only the last 3 d prior to weaning and weaning at 21 d of age, which suggests that improvements in weaning adaptation can be achieved even for a short creep feeding duration and younger weaning age. Bruininx et al. (2002) and Kuller et al. (2007b) found differences in growth rates and body weights between eaters and non-eaters until 5 and 8 wks post-weaning, respectively. However, no long term effects were observed in ADFI and ADG between eaters and non-eaters until the finishing period (Kuller et al., 2007b).

Sulabo et al. (2009) provided further evidence of the effects of creep feeding in reducing postweaning growth check and improving weaning adaptation. There were significantly less eaters (17%) that were classified as fall back pigs during the initial 3 d postweaning compared to non-eaters (29%) and no creep pigs (28%). The preparedness or ability of pigs to withstand the weaning transition may also be estimated by determining the transition ratio, which is calculated simply by the ratio of average weight gain during the first 3 d postweaning with the weight gain 3 d preweaning. Sulabo et al. (2009) showed that postweaning daily gains of no creep pigs were 33% of their preweaning daily gains, while non-eaters of either a simple or complex creep diet were 29 and 24%, respectively. Eaters of creep feed regardless of the complexity had a higher transition ratio, gaining 45 to 48% of their preweaning daily gains. Overall, the transition ratio for eaters was 1.5 and 2.0 times greater than either non-creep fed pigs or non-eaters of creep feed.

Factors affecting the proportion of eaters of creep feed

It is proposed that if creep feeding behavior can be encouraged and more eaters can be created within litters, nursery performance can be improved. It is therefore important to determine factors that can stimulate individual piglets to consume creep feed when it is offered and create more eaters. Identifying these factors may also help in understanding and managing the variability in consumption typically observed with creep feeding.

Non-dietary factors

Increased nutritional demand or physiological need did not stimulate more piglets to consume creep feed when it was offered. Kuller et al. (2007b) 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; however, IS did not increase the percentage of eaters within a litter (19 and 23% in the control and IS litters, respectively). This suggests that 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. Sulabo et al. (2008a) evaluated the interactive effects of lactation feed intake and creep feeding, where sows were fed either ad libitum or restricted (75% of ad lib) levels of feed. Total creep feed intake of litters did not differ (1,019 vs. 1,034 g/litter) between ad lib and restricted-fed sows. The proportion of eaters within whole litters were also unaffected (57 vs. 62% for restricted and ad lib fed litters, respectively) by lactation feeding level, which suggests that a limited nutrient supply did not drive more piglets to consume creep feed.

Creep feeding duration influenced the proportion of eaters in whole litters (Sulabo et al., 2008b). Litters provided with creep feed for 13 d produced 10% unit more eaters than litters fed creep for both 6 and 2 d (80, 70, and 71% eaters, respectively). The higher rate of eaters in litters creep fed for 13 d suggests that the longer availability of creep feed helps stimulate more piglets to consume creep feed and improves the average creep consumption of piglets categorized as eaters. However, a 10% unit difference in eaters also indicates that the additional 7 to 11 d of creep feeding generated only 1 more eater per litter (for a litter of at least 10 piglets). Therefore, the benefit of longer durations of creep feeding should be weighed based on the economic value of creating more eaters in whole litters.

Creep feeder design also influences the proportion of eaters created among piglets provided with creep feed (Sulabo et al., 2008c). Sulabo et al. (2008c) evaluated three different creep feeder designs: a pan feeder, a rotary feeder, and a rotary feeder with a hopper. In litters using the rotary feeder with the hopper, 69% of piglets were categorized as eaters. On the other hand, litters on the rotary feeder had 22% fewer eaters than with litters on the rotary feeder with the hopper. Likewise, litters using the pan feeder had 27% less eaters than litters on the rotary feeder with the hopper. The higher rate of eaters created using the rotary feeder with the hopper may be a function of both feeder design and piglet creep feed consumption. The addition of the hopper to the rotary feeder significantly increased the percentage of eaters, which may be partially attributed to its design that staved off piglets from wasting feed and provided continuous availability of feed in the troughs. Kuller et al. (2007a) validated that eaters identified using chromium oxide-containing creep feed were those that consumed creep feed in appreciable amounts or in multiple days. Therefore, this feeder enabled more piglets in the litter to consume significant amounts of creep feed.

Dietary factors

Organoleptic properties of the feed may be a dietary factor that can influence the proportion of piglets consuming creep feed prior to weaning. Sulabo et al. (2008d) added a feed flavor in the creep diet that has been previously shown to be effective in stimulating feed intake in the nursery phase (Roura et al., 2008a,b). Addition of the feed flavor to the creep feed did not influence total or daily creep feed intake of litters. Likewise, the proportion of eaters was not affected by flavor addition to the creep diet (73 and 69% for the unflavored and flavored diet, respectively). This lack of effect may suggest age-related differences or greater individual variation in palatability perception in suckling pigs. This also indicates that changing the flavor properties of the creep feed may not be sufficient to positively affect preweaning feed intakes.

However, creep diet complexity influenced the proportion of pigs consuming creep feed in whole litters. Sulabo et al. (2009) observed that litters fed the complex creep diet consumed twice the total (1.24 vs. 0.62 kg) and daily (412 vs. 205 g) creep feed intake of litters fed a simple creep diet. Increasing the complexity of the creep diet also improved the proportion of eaters from 28% to 68%. This suggests that the higher creep feed intake observed in litters fed the complex creep diet was due to a greater number of pigs positively consuming creep feed. Relative to all the non-dietary and dietary factors previously investigated, diet complexity had the greatest influence in creating eaters of creep feed. This indicates that the complexity of the creep diet may be one of the most important factors in stimulating individual pigs in the litter to consume creep feed.

Conclusion

Creep feeding is a management practice that presents opportunities for improving weaning weights and postweaning pig performance. This review indicated that the responses to creep feeding both pre- and postweaning are inconsistent. This may be attributed to differences in creep feeding duration, the type of creep diet, and weaning age across the studies. The effect of creep feeding may be highly dependent on creep feed consumption, which is affected by numerous factors. Majority of the early studies also evaluated creep feeding using whole-litter values in determining creep feed consumption. When individual consumption characteristics are considered, there is greater consistency in the responses to creep feeding especially postweaning.

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CHAPTER 2 - Effects of lactation feed intake and creep feeding on sow and piglet performance

ABSTRACT: A total of 84 sows (PIC Line 1050) were blocked according to day of farrowing and parity and allotted in a 2 × 2 factorial with lactation feed intake (ad lib vs. restricted) and creep feeding (none vs. creep) as factors. Ad lib fed sows were allowed free access to a common lactation diet (3,503 kcal ME/kg, 0.97% SID Lys) while restricted sows were fed 25% less than sows fed ad lib. A creep diet (3,495 ME/kg, 1.56% SID Lys) with 1.0% chromic oxide was offered to creep-fed pigs from d 3 to 21. Fecal samples from creep-fed pigs were taken using sterile swabs on d 7, 14, and 21 and color was assessed to categorize pigs as eaters or non-eaters. There were no interactions ($P > 0.15$) between lactation feed intake and creep feeding. Total and ADFI of ad lib-fed sows (99.4, 4.9 kg) were greater ($P < 0.01$) than limit-fed sows (67.9, 3.6 kg). Ad lib feeding of sows reduced BW loss (-15 vs. -24 kg; $P < 0.01$), improved total (46.7 vs. 43.0 kg; $P < 0.04$) and daily (2.56 vs. 2.36 kg; $P < 0.04$) gains of litters, and increased (90 vs. 71%; $P < 0.03$) the percentage of sows returning to estrus by d 14 compared with limit-fed sows. Creep feeding did not affect ($P > 0.34$) sow BW and backfat loss, but increased days to estrus (5.4 vs. 4.9 d; $P < 0.03$). Creep feeding tended to improve litter weaning weights (60.2 vs. 56.7 kg/d; $P < 0.09$) by reducing mortality after cross-fostering (3.9 vs. 7.3%; $P < 0.06$). Weaning weights were similar (5.7, 5.8, and 5.7 kg; $P > 0.81$) between eaters, non-eaters, and no creep pigs. Post-weaning performance of creep-fed pigs was similar ($P > 0.86$) to non-creep fed pigs. Eaters have greater ($P < 0.05$) ADG (393, 376 and 378) and total gains (11.0, 10.5 and 10.6 kg) than non-eaters or no creep pigs. In conclusion, creep feeding improved survivability, but had no effects

on pre-weaning gain and sow performance. Low feed intake during lactation negatively affected sow and litter performance. Finally, creating more eaters may benefit post-weaning performance.

Key Words: Creep feeding, lactation feeding level, suckling pig

Introduction

Pre-weaning growth is a major determinant of post-weaning pig performance (Klindt, 2003). However, the maximum growth potential of suckling piglets is largely unachieved in commercial production (Pluske et al., 1995; Le Dividich and Sève, 2001). As evidenced in artificial rearing studies, higher pre-weaning growth rates in piglets can be achieved through increased nutrient availability (Hodge, 1974; Harrell et al., 1993). This can be provided by improving the sow's milk output using high density lactation diets (Pettigrew, 1981; Shurson et al., 1986; Yang et al., 2000) or maximizing lactation feed intake (Koketsu et al., 1996; Eissen et al., 2003). Providing a solid, highly digestible creep feed to suckling piglets may also augment declining milk production during late lactation (Lucas and Lodge, 1961; Elsley, 1971) and as a supplemental nutrient source, may increase their nutrient intake and improve pre-weaning daily gains and weaning weights (Mavromichalis, 2006).

The effect of lactation feed intake and creep feeding on pre- and post-weaning performance have been evaluated independently in previous studies (Appleby et al., 1991; Pajor et al., 1991); however, there has been no work done on the potential interactive effects of these two nutritional regimens. In addition, it has been suggested that creep feeding can reduce the nutritional load in lactating sows especially those nursing large litters, which may have positive benefits in reducing lactation weight loss and weaning-to-estrus interval (Pajor et al., 2002). However, there has been no study at present to support this claim.

Therefore, the objectives of this experiment were to evaluate the effect of lactation feed intake and creep feeding on pre- and post-weaning performance, and to determine the effect of creep feeding on body weight loss, back fat thickness, and weaning-to-estrus interval in sows.

Materials and Methods

All animal procedures were reviewed and approved by the Kansas State University Institutional Animal Care and Use Committee.

A total of 84 sows (PIC, Line 1050) and their litters were used in this study conducted at the Kansas State University Swine Research and Teaching Center farrowing facilities. Sows used in this experiment were from three batches of sows farrowed in August, October, and November, 2006, with 28 experimental sows included from each batch. Sows were blocked according to parity and date of farrowing and were allotted to four experimental treatments using a randomized complete block design in a 2 × 2 factorial with lactation feed intake (ad lib vs. restricted) and creep feeding (none vs. creep) as factors. Piglets were cross-fostered within each block to standardize litter weights and litter size (>11 pigs). The sow or litter was the experimental unit with 21 replicates per treatment.

A common lactation diet (3,503 kcal ME/kg, 0.97% SID Lys) was used in the study (Table 2.1). From d 3 of lactation, ad lib sows were allowed free access to feed while restricted sows were fed 25% lower than those fed ad lib. The restricted feeding level was estimated using historical feed consumption data of the farm. In the creep-fed treatments, a creep diet (3,495 kcal ME/kg, 1.56% SID Lys) with 1.0% chromium oxide was offered ad libitum at d 3 until weaning (d 21) using a rotary creep feeder (Rotecna Mini Hopper Pan, Rotecna SA, Spain). This feeder has a 6-liter capacity hopper, which is adjustable to 5 different settings to allow ad lib feeding (Figure 2.1). The creep diet was in pellet form (2-mm pellets). Sufficient amounts of creep feed were placed in the hopper to ensure that feed was always available. The feeder setting was checked daily to ensure ad lib feeding and control feed wastage. The creep feeder was also placed in a location in the farrowing crate where it was most accessible and allow unhindered suckling of piglets to the sow.

Piglets were weighed individually at d 3, 7, 14, and 21 (weaning). Amount of creep feed consumed was determined daily. Daily creep feed consumption per litter was computed as the difference in feeder weights between consecutive days. Creep feed consumption of each individual pig was determined using procedures adapted from Barnett et al. (1989) and Bruininx et al. (2002). Fecal samples from creep-fed pigs were taken using sterile swabs once per sampling day on d 7, 14, and 21. The cotton-tipped swab was inserted in a clockwise motion into the anal opening of the piglet for about 5 cm and was pulled slowly until fecal matter was collected. Fecal color was assessed to categorize piglets as "eaters" or "non-eaters" of creep feed. Piglets were categorized as eaters when the fecal sample was colored green at least once on any of the three sampling days. Piglets were categorized as non-eaters when all of the samples collected were negative for green-colored feces. Pigs that were not provided with creep feed were designated as no creep pigs. From a total of 819 pigs weaned, 624 pigs were blocked according to initial weight and creep access and were used in three nursery trials. Pigs that were not included in these groups were also kept in the same nursery facility and fed a common feeding program. All pigs and feeders were weighed weekly until d 28 post-weaning to calculate for ADG, ADFI, and G:F.

Weekly feed intake of the sows was recorded to calculate total and average daily feed intake. Sows were weighed and P2 backfat thickness (6.5 cm from the midline over the last rib) were measured post-farrowing and at weaning. Estrus detection using back pressure test were performed twice a day from weaning until 14 d after weaning to determine days to estrus and percentage of sows returning to estrus within 14 d. In this study, six sows were removed from the test due to either poor daily feed intake or death of the sow. General health of the piglets was checked daily and use of medication was monitored. Temperature in the farrowing facility was maintained at a minimum of 20°C, and supplementary heat was provided to the piglets using heat lamps when needed.

Periodic and cumulative average daily gain and creep feed intake were calculated for each treatment group. Pre-weaning mortality was also calculated. The coefficient of variation for pig weights within each litter was determined at d 3 and 21. Sow body weight loss, change in P2 back fat thickness, and weaning-to-estrus interval were calculated.

The preweaning data were analyzed as a randomized complete block design using a 2 × 2 factorial treatment structure with sow or litter as the experimental unit. The model included the main effects of lactation feed intake and creep access and the interaction of lactation feed intake × creep access as fixed effects and block as the random effect. Analysis of variance was performed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). Regression models for daily litter creep feed intake were developed using PROC REG of SAS. Logistic regression curves were also developed using PROC LOGISTIC of SAS to determine estimated probabilities of changes in the proportion of eaters as determined by weights on d 0 (birth), d 3, and d 21 (weaning). Chi-square analysis was used to determine the effect of lactation feed intake on the proportion of pigs consuming creep feed. For the postweaning data, the effect of creep feeding was analyzed using PROC MIXED of SAS with pen as the experimental unit. The model included treatment and block as the fixed and random effects, respectively. For the effect of consumption category, data was analyzed using PROC MIXED of SAS with pig as the experimental unit. The model included consumption category as the fixed effect and litter and weaning group as random effects, respectively. When treatment effect was a significant source of variation, differences were determined using the PDIFF option of SAS. Least square means were calculated for each independent variable. Statistical significance and tendencies were set at $P <$ 0.05 and $P < 0.10$ for all statistical tests.

Results and Discussion

The effects of lactation feeding level and creep feeding on sow performance are shown in Sows had an average parity of 1.6 ± 0.7 and lactation length of 21.1 ± 1.9 d (Table 2.2). There were no significant interactions ($P > 0.15$) between lactation feeding level and creep feeding for any of the performance parameters measured; therefore, only main effects will be discussed.

Ad lib-fed sows had 32 and 26% greater total (99.4 vs. 67.9 kg; $P = 0.0001$) and daily (4.9 vs. 3.6 kg; $P = 0.0001$) feed intake than restricted-fed sows, respectively. There were no differences in post-farrowing ($P = 0.37$) and weaning ($P = 0.23$) weights of ad lib and restricted-fed sows. However, ad lib feeding of sows reduced lactation weight loss (-15 vs. -24 kg; $P =$ 0.01) compared to limit-fed sows. Backfat thickness after farrowing ($P = 0.84$) and at weaning (P = 0.44) was also similar; likewise, backfat loss throughout lactation did not differ ($P = 0.27$) between ad lib and limit-fed sows. Days to estrus for sows that returned to estrus by d 14 after weaning were similar ($P = 0.83$) between ad lib and restricted-fed sows. However, ad lib feeding increased (90 vs. 71%; $P = 0.03$) the percentage of sows returning to estrus by d 14.

These results conform with similar studies investigating the effects of energy restriction during lactation or effects of high ambient temperature in lactating sows (Quiniou and Noblet, 1999; Quiniou et al., 2000; Renadeau et al., 2003). Sows with restricted energy intakes lost more weight and backfat during lactation than sows allowed ad libitum intake. One response that was different from previous studies was that differences in backfat loss were not observed in this study. In previous studies (Stahly et al, 1979; Rudd and Simmins, 1994), daily energy intake was restricted to a level (33 to 50%) greater than the feed restriction in this study (26% of ad lib intake), which may help explain the differences in results. The higher rate of sows failing to exhibit estrus within 14 d demonstrate the detrimental effects of limit feeding sows during lactation. Low feed intake during lactation has been previously shown to depress luteinizing hormone (LH) secretion, which is required for the release of eggs from follicles into the ovary and commence another reproductive stage (Barb et al., 1991; Tokach et al., 1992).

Providing litters with creep feed did not affect total ($P = 0.56$) and daily ($P = 0.57$) feed intake of sows. Likewise, there were no differences ($P > 0.27$) in sow weights after farrowing, at weaning, or lactation weight loss between sows with litters provided with and without creep feed. The same effect ($P > 0.14$) was observed in backfat thickness after farrowing, at weaning, and backfat loss. However, creep feeding increased days to estrus (5.4 vs. 4.9 d; $P = 0.03$) for sows that returned to heat by 14 d. There were no differences ($P = 0.77$) in the proportion of sows which returned to estrus within 14 d between sows with creep and non-creep fed litters. There has been no previous study evaluating the effects of creep feeding on sow performance though claims have been made on some potential benefits of the practice. Creep feeding was thought to reduce the nutritional load in lactating sows especially with large litters, which may have corollary effects in reducing lactation weight loss and weaning-to-estrus interval (Pajor et al., 2002). These effects were not observed in this study where creep feeding for 18 d did not have any effect on sow performance except for increasing days to estrus. The amount of litter creep feed intake observed in this study was too small (3.65 Mcal; 1.26% of total energy intake of the sows) to generate any appreciable, nutritional savings to lactating sows that may merit a reduction in mobilized body reserves or improve their metabolic state. The impact of creep feeding on reducing nutrition requirements of the sow may be greater with older weaning ages, but does not appear to be beneficial in a 21-d lactation period.

The effects of lactation feeding level and creep feeding on pig and litter performance are shown in Tables 2.4 and 2.5. Lactation feeding level had no effect ($P > 0.76$) on litter size at weaning or pre-weaning mortality rate. Ad lib feeding of sows improved total ($P = 0.04$) and daily ($P = 0.04$) gains of litters and tended to increase litter weaning weights ($P = 0.10$) compared to limit-fed sows. Likewise, total gain ($P = 0.04$), daily gain ($P = 0.03$), and weaning weights ($P = 0.06$) of individual pigs were higher in ad lib-fed sows. These results agree with other studies, which demonstrate the benefits of high lactation feed intake on pre-weaning growth rate (Eissen et al., 2003). The coefficient of variation (CV) in litters of sows fed ad lib and restricted were similar at weaning ($P = 0.22$); likewise, there were no differences ($P = 0.78$) in litter CV change between the two levels of lactation feeding.

Creep feeding increased litter size at weaning by 0.4 pig per litter; however, this difference was not significant ($P > 0.19$). The increase in litter size was mainly due to a reduction in pre-weaning mortality rate after cross-fostering (3.9 vs. 7.3%; $P = 0.06$) with creep feeding. There were no differences ($P > 0.53$) in total gains, daily gains, and weaning weights of pigs at weaning between creep and non-creep fed litters. Total and daily gains of litters were also unaffected ($P > 0.16$) by creep feeding; however, litter weaning weights tended to be greater ($P = 0.09$) in creep-fed litters due to reduced mortality rates after cross-fostering and greater ($P = 0.04$) litter weights at the start of creep feeding (d 3). There were no differences in litter CV at weaning ($P = 0.25$) and CV change throughout lactation ($P = 0.49$), which indicates the lack of effect of creep feeding in improving litter uniformity.

Litters of restricted-fed sows had greater (54.4 vs. 40.8 g; *P* = 0.02) creep feed intake than litters of ad lib fed sows from d 3 to 7 (Figure 2.2). However, no differences (*P* > 0.41) in litter creep feed intake were observed in other periods. Overall, total creep feed intake was highly variable between litters, ranging 263 to 2,349 g/litter over the 18 d period that creep feed was provided. Total creep feed intake of litters did not differ (1,019 vs. 1,034 g/litter; *P* = 0.93) between ad lib and restricted-fed sows, which suggests that a limited nutrient supply to both sows and litters did not drive piglets to consume more creep feed. About 72 and 77% of the total creep feed intake of litters of restricted and ad-lib fed sows was consumed in the last week prior to weaning. The daily creep feed intake of litters increased quadratically (R^2 = 0.22; *P* = 0.0001) from d 3 to weaning; however, intakes greater than 50 g per litter were attained only from d 13 before weaning (Figure 2.3). For creep-fed piglets, 59% were categorized as eaters (Figure 2.4). Of pigs identified as eaters, 23, 20, and 57% were positive for creep feed consumption on d 7, 14, and 21, respectively (Figure 2.5). The higher intake and percentage of eaters in the last week prior to weaning indicate that piglets more readily accept and consume greater amounts of creep feed at an older age. Thus, creep feed consumption seems to be related to the maturity of the piglets rather than the age of induction of creep feeding.

Lactation feeding level did not influence (*P* > 0.78) the proportion of eaters within whole litters (57 vs. 62% for litters of restricted and ad lib fed sows, respectively; Figure 2.6). Kuller et al. (2007b) 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; however, IS did not increase the percentage of eaters within a litter (19 and 23% in the control and IS litters, respectively). These results conform with the current study, where limited sow milk supply did not stimulate more individual piglets to eat creep feed when it was offered.

Logistic regression analyses showed a positive relationship between birth weight (P = 0.03) and the probability of becoming an eater of creep feed (Figure 2.7). However, there was no relationship between the probability of becoming an eater with d 3 (P = 0.17) and d 21 weights (P = 0.94). It was hypothesized that smaller, less competitive pigs may benefit more from creep feeding; hence, there may be some potential weight relationships. The birth weight relationship suggests that heavier pigs at birth have greater probability of becoming an eater. However, the lack of a relationship at d 3 and d 21 may indicate that individual creep feed consumption is not strongly related to weight attributes.

From d 0 to 28 post-weaning, there was no effect ($P > 0.86$) of creep feeding on d 28 weights, ADG, ADFI, and G:F compared to non-creep fed pigs (Table 2.6). However, when pigs were categorized based on creep feed consumption category, eaters tended to be heavier at d 21 post-weaning (Figure 2.8; P = 0.05) and had higher ($P < 0.05$) ADG and total gains than non-eaters and no creep pigs (Figure 2.9). Eaters and non-eaters were mixed at weaning, which may explain the lack of differences between creep and non-creep fed pigs. The differences in post-weaning gain also agree with previous studies, where eaters, non-eaters, and non-creep fed pigs were compared (Bruininx et al., 2002; Kuller et al., 2004, 2007b; Pluske et al., 2007). These studies have attributed these differences in post-weaning growth efficiency to shorter latency time (interval between weaning and first feed intake) and greater post-weaning feed intake in eaters. A recent study using segment perfusion tests also showed greater net absorption in the small intestine of eaters compared to non-eaters (Kuller et al., 2007c), though some studies have reported no effect of pre-weaning eating activity on gut morphology (Bruininx et al., 2004; Hedemann et al., 2007).

In conclusion, low feed intake during lactation negatively affected both sow and litter performance. Creep feeding tended to improve litter weaning weights due to higher survivability, but had no effects on pre-weaning gain and sow performance. When pigs were categorized based on creep feed consumption category, eaters had greater post-weaning gains and weights than non-eaters and non-creep fed pigs. Creating more eaters in whole litters may be beneficial in improving postweaning performance. Thus, factors, whether dietary or non-dietary, which can enhance the proportion of eaters in litters, should be investigated.

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Table 2-1. Composition of the creep and lactation diet (as-fed basis).

Item	Creep[1]	Lactation[2]
Ingredient, %		
Corn	6.25	60.00
Soybean meal, 46.5% CP	2.32	31.20
Spray dried whey	25.00	-
Fine ground oat groats	30.00	-
Extruded soy protein concentrate	10.00	-
Spray-dried animal plasma	6.00	-
Select menhaden fish meal	6.00	-
Lactose	5.00	-
Choice white grease	5.00	5.00
Monocalcium P, 21% P	0.35	1.45
Chromium oxide	1.00	-
Antibiotic[3]	1.00	-
Limestone	0.40	1.20
Zinc oxide	0.38	-
Salt	0.30	0.50
L-lysine HCl	0.15	-
DL-methionine	0.15	-
Trace mineral premix[4]	0.15	0.15
Vitamin premix[5]	0.25	0.25
Sow add pack[6]	-	0.25
Acidifier[7]	0.20	-
Vitamin E, 20,000 IU	0.05	-
Total	100.00	100.00
Calculated analysis		
CP, %	23.9	19.6
SID Lysine, %[8]	1.56	0.97
ME, kcal/kg	3,495	3,503
Ca, %	0.79	0.87
Available P, %	0.56	0.38
SID Lysine:ME, g/Mcal	4.47	2.77

[1]Diet fed in pellet form (2-mm pellets).
[2]Diet fed in meal form throughout lactation.
[3]Contained 140 mg of neomycin sulfate and 140 mg of oxytetracycline HCl per kg of complete diet
[4]Provided per kg of complete diet: 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.30 mg of Se; 165.4 mg of Zn; and 0.30 mg of I.
[5]Provided per kg of complete diet: 11,023 IU of vitamin A; 1,378 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate); 50 mg of niacin; 28 mg of pantothenic acid (as d-calcium pantothenate); 8 mg of riboflavin; 0.04 mg of vitamin B12; 750 FYT of Ronozyme P® phytase (DSM Nutritionals Products, Parsipanny, NJ)
[6]Sow add pack provided the following nutrients per kg of complete diet: 22 IU of vitamin E; 0.22 mg of biotin; 1.65 mg of folic acid; 5 mg of pyridoxine (as pyridoxine HCl); 551 mg of choline (as choline Cl); 50 mg of L-carnitine; 0.20 mg of chromium (as chromium picolinate)
[7]Calcium propionate
[8]Standardized ileal digestible

Table 2-2. Effects of lactation feeding level and creep feeding on sow performance (Main effects)[1]

Item	Lactation feeding[2]		Creep feeding[3]			*P*-value		
	Restricted	Ad lib	No	Yes	SED	Lactation	Creep	Lactation × Creep
No. of sows	38	40	39	39	-	-	-	-
Lactation length, d	21.1	21.0	21.0	21.1	0.1	0.39	0.25	0.89
Average parity	1.6	1.5	1.5	1.6	0.1	0.56	0.21	0.95
Lactation feed intake, kg								
Total, d 0 to 21	67.9[a]	99.4[b]	84.3	83.0	2.4	<.0001	0.56	0.86
ADFI	3.6[a]	4.9[b]	4.3	4.2	0.05	<.0001	0.57	0.79
Sow weight, kg								
Post-farrowing	218.3	213.6	213.1	218.9	5.3	0.37	0.27	0.90
Weaning	193.0	198.9	194.2	197.6	4.9	0.23	0.48	0.87
Change	-24.0[a]	-15.0[b]	-19.2	-19.7	1.7	<.0001	0.75	0.38
Backfat, mm								
Post-farrowing	16.8	16.6	17.5	16.0	1.0	0.84	0.14	0.56
Weaning	12.4	12.9	13.0	12.2	0.7	0.44	0.21	0.63
Change	-4.5	-3.8	-4.5	-3.8	0.7	0.27	0.34	0.17
Days to estrus[4]	5.2	5.1	4.9[a]	5.4[b]	0.2	0.83	0.03	0.15
Return to estrus, %[5,6]	71.0[a]	90.0[b]	82.1	79.5	-	0.03	0.77	-

[1]Three groups of sows (total = 78, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to 4 treatments in a 2 × 2 factorial with lactation feeding level (Restricted vs. Ad lib) and creep feeding (No vs. Yes) as factors.
[2]Sows on the restricted feeding program were fed 25% lower than those fed ad libitum.
[3]Creep feed with 1.0% chromium oxide was offered ad libitum from d 3 to weaning (21 ± 0.1 d).
[4]For sows returning to estrus within 14 d post-weaning.
[5]Percentage of sows returning to estrus within 14 d post-weaning.
[6]Means evaluated using a χ^2 test.
[a,b]Within row and within main treatment comparison, means with different superscript differ ($P < 0.05$).

Table 2-3. Effects of lactation feeding level and creep feeding on litter and pig performance (Main effects).[1]

Item	Lactation feeding[2]		Creep feeding[3]		SED	Probability, *P*-value		
	Restricted	Ad lib	No	Yes		Lactation	Creep	Lactation × Creep
No. of litters	38	40	39	39	-	-	-	-
Pigs/litter								
d 3 (start creep)	11.0	10.9	11.0	11.0	0.3	0.75	0.99	0.32
d 21	10.4	10.4	10.2	10.6	0.3	0.93	0.19	0.59
Mortality, %	5.9	5.3	7.3[a]	3.9[b]	1.8	0.76	0.06	0.92
Litter weight, kg								
d 3 (start creep)	17.83	17.51	16.96[a]	18.28[b]	0.64	0.53	0.04	0.56
d 21	56.74[a]	60.15[b]	56.65[a]	60.16[b]	2.04	0.10	0.09	0.23
Litter BW gain, kg								
Total	42.96[a]	46.68[b]	43.59	46.04	1.77	0.04	0.17	0.19
ADG	2.36[a]	2.56[b]	2.39	2.53	0.10	0.04	0.16	0.17
Pig weight, kg								
d 3 (start creep)	1.72	1.72	1.68	1.72	0.05	0.66	0.45	0.88
d 21	5.44[a]	5.81[b]	5.58	5.67	0.18	0.06	0.54	0.30
Pig BW gain, kg								
Total	4.13[a]	4.49[b]	4.26	4.35	0.18	0.04	0.55	0.25
ADG	0.24[a]	0.25[b]	0.24	0.25	0.01	0.03	0.53	0.22
Litter CV, %[4]								
d 3 (start creep)	20.4[a]	18.2[b]	20.0	18.7	1.1	0.05	0.25	0.24
d 21	19.3	17.5	18.6	18.3	1.5	0.22	0.84	0.97
Change	1.1	0.7	1.4	0.4	1.5	0.78	0.49	0.39

[1]Three groups of sows (total = 78, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to four treatments in a 2 x 2 factorial with lactation feeding level (Restricted vs. Ad lib) and creep feeding (No vs. Yes) as factors.
[2]Sows on the restricted feeding program were fed 25% lower than those fed ad libitum.
[3]Creep feed with 1.0% chromium oxide was offered ad libitum from d 3 to weaning (21 ± 0.1 d).
[4]CV = coefficient of variation; values were determined from piglet weights within each litter.
[a,b]Within row and within main treatment comparison, means with different superscript differ ($P < 0.05$).

Figure 2-1. Rotary creep feeder with hopper (Rotecna Mini Hopper Pan, Rotecna SA, Spain).

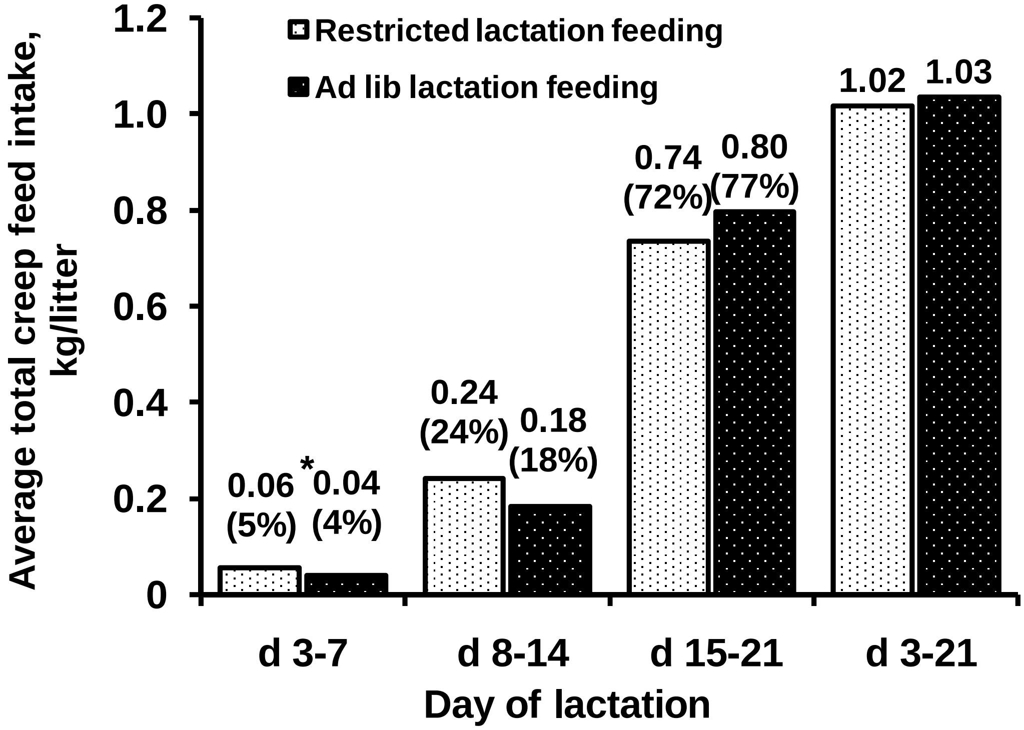

Figure 2-2. Effects of lactation feeding level on litter creep feed intake (% of total litter creep feed intake in parentheses).

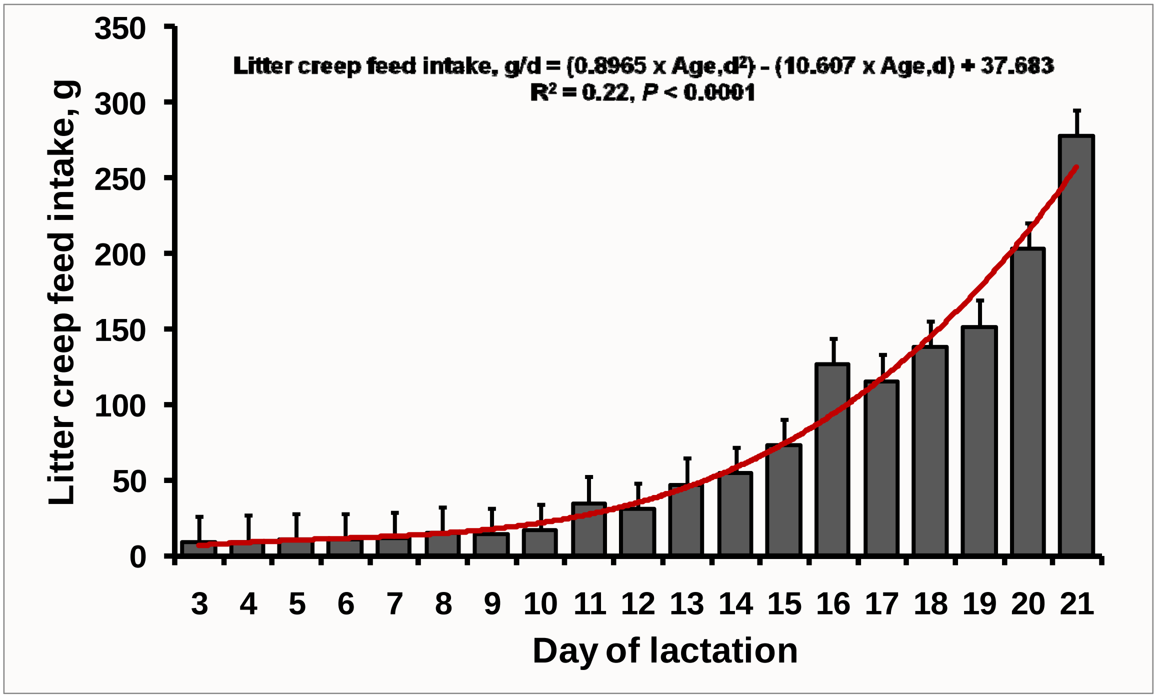

Figure 2-3. Daily litter creep feed intake (from 39 litters).

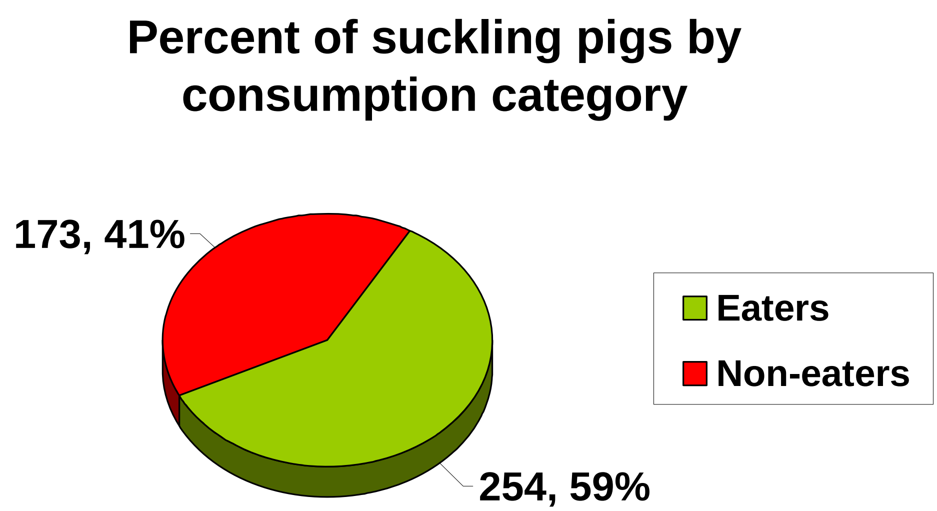

Figure 2-4. Characterization of piglets provided with creep feed based on consumption category.

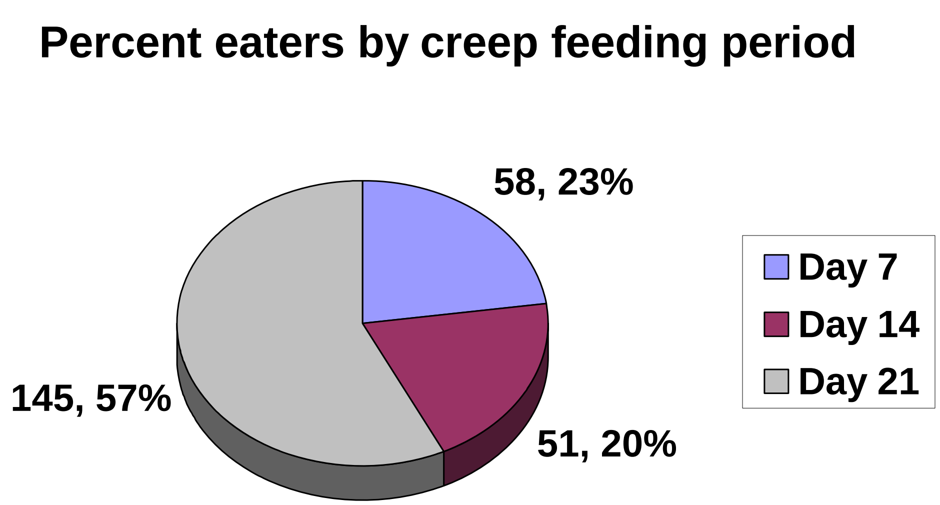

Figure 2-5. Frequency and percentage of pigs identified as eaters on d 7, 14, and 21.

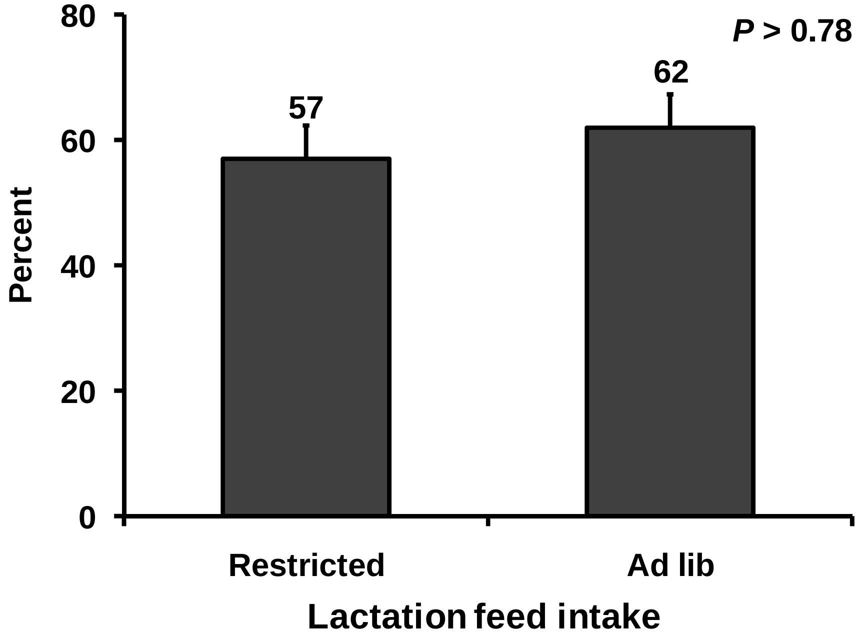

Figure 2-6. Effect of lactation feed intake on the proportion of pigs that consumed creep feed (Eaters).

Table 2-4. Effects of creep feeding on post-weaning growth performance.[1]

Item	Creep feeding		SED	*P*-value
	No	Yes		
n	52	52	-	-
Pig weights, kg				
d 0	6.2	6.0	0.4	0.71
d 14	9.3	9.4	0.6	0.97
d 21	12.9	13.0	0.7	0.87
d 28	17.6	17.5	0.9	0.93
d 0 to 14				
ADG, g	227	240	13.6	0.25
ADFI, g	254	277	13.6	0.15
G:F	893	869	18.1	0.31
d 0 to 21				
ADG, g	621	617	18.1	0.79
ADFI, g	785	776	36.3	0.82
G:F	792	795	22.7	0.92
d 0 to 28				
ADG, g	445	449	18.1	0.86
ADFI, g	553	553	36.3	0.93
G:F	803	811	18.1	0.95

[1]A total of 624 pigs (PIC L337 x C22) were blocked according to initial weight and creep access (no vs. yes); values are means of 52 pens of 6 pigs each, respectively

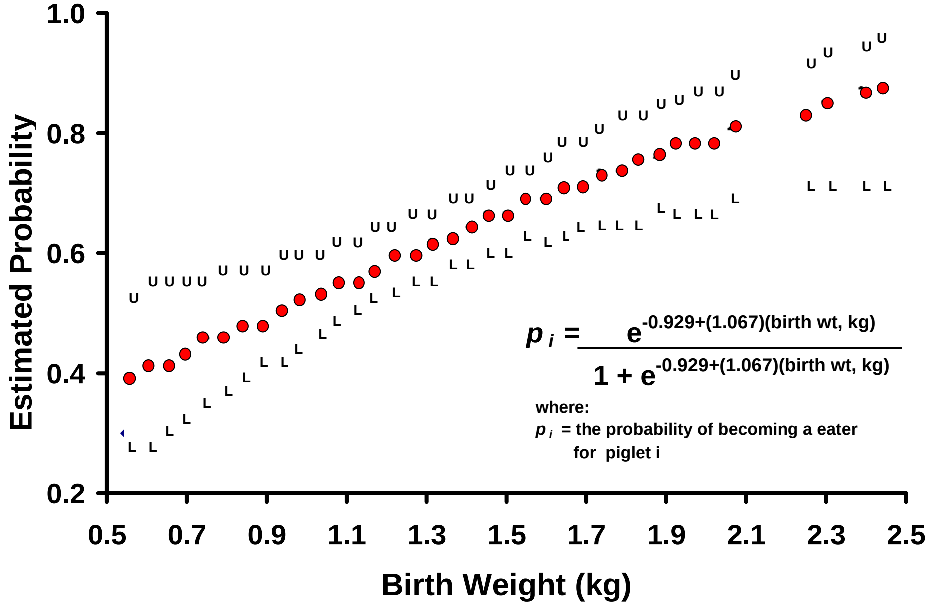

Figure 2-7. Logistic curve of changes in proportion of eaters as affected by changes in birth weight (u=upper limit, l=lower limit).

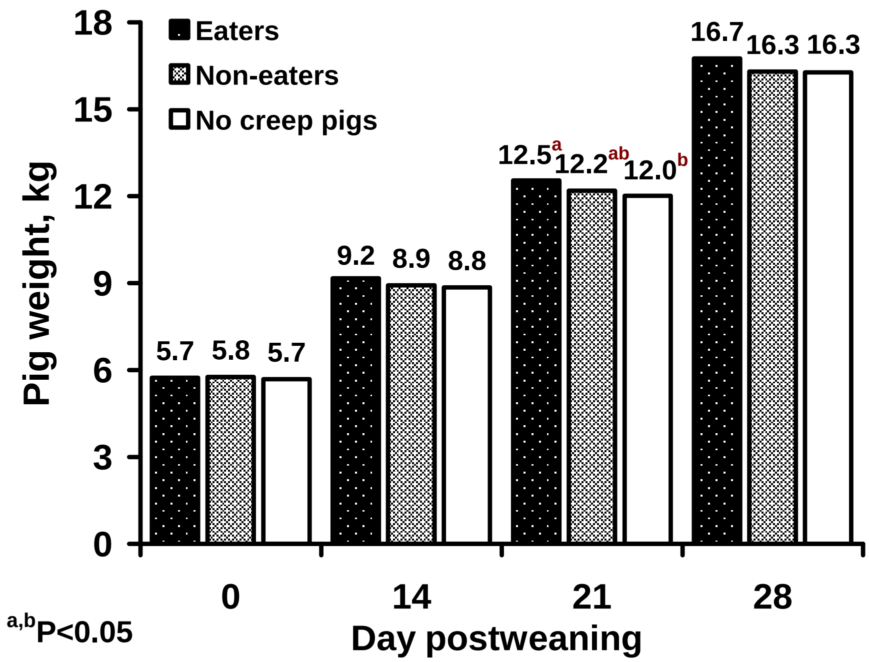

Figure 2-8. Post-weaning live weight trends of piglets according to creep feed consumption category (n = 819).

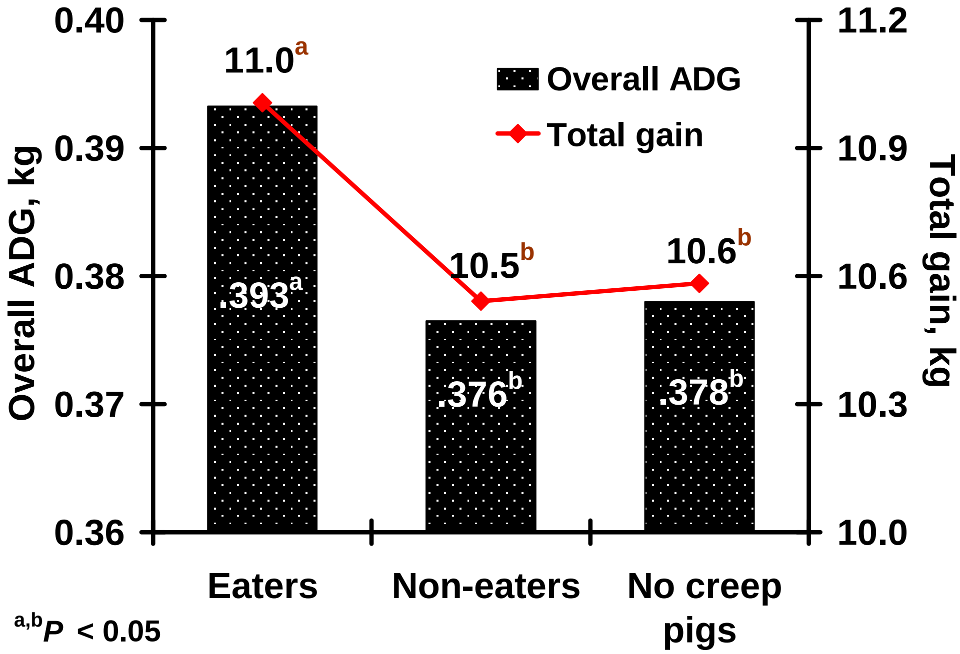

Figure 2-9. Overall post-weaning ADG and total gain (d 0 to 28) of piglets according to creep feed consumption category (n = 819).

CHAPTER 3 - Effects of varying creep feeding duration on the proportion of pigs consuming creep feed and neonatal pig performance

ABSTRACT: In Exp. 1, 54 sows (Line 1050, PIC) and their litters were used to determine the effects of creep feeding duration on the proportion of pigs consuming creep feed and pre-weaning performance. Two groups of sows were blocked according to parity and date of farrowing and allotted to three experimental treatments using a randomized complete block design. Creep feeding was initiated at d 7, 14, and 18 from birth for durations of 13, 6, and 2 d of creep feeding. A creep diet (3,495 kcal ME/kg, 1.56% standardized ileal digestible Lys) with 1.0% chromic oxide was offered ad libitum until weaning (d 20) using a rotary creep feeder with hopper. Fecal samples from all piglets were taken using sterile swabs on d 14, 18, and 20 for Treatment 1, d 18 and 20 for Treatment 2, and d 20 for Treatment 3. Piglets were categorized as eaters when fecal sample was colored green at least once on any of the sampling days. In Exp. 1, there were no differences in weaning weights ($P > 0.61$), total gain ($P > 0.38$), and daily gain ($P > 0.38$) among pigs fed creep for 13, 6, or 2 d, respectively. Total creep feed intake of litters fed creep for 13 and 6 d were greater ($P < 0.01$) than those litters provided creep feed for 2 d. Litters provided with creep feed for 13 d produced 10% more (80 vs. 70%; $P < 0.03$) eaters than litters fed creep for either 6 or 2 d. In Exp. 2, 273 piglets from Exp. 1 (averaging 5.74 kg BW and 20 ± 2 d) were randomly allotted to two treatments (Non-eater or Eater) using a completely randomized design to determine if there are any differences in nursery growth performance between creep feed consumption categories. There were 10 and 33 replications (pens) with 5 to 7 pigs per pen for the Non-eater and Eater treatments, respectively. At d 0, non-eaters were heavier ($P < 0.0001$) than eaters of creep feed. However, eaters had higher ADG ($P < 0.02$) and tended to have higher ADFI ($P < 0.06$) than non-eaters from d 0 to 3 post-weaning. Overall (d 0 to 28), eaters tended to have higher ADFI (441 vs. 420 g; $P < 0.09$) but lower overall G:F ($P < 0.04$) than non-eaters of creep feed. These results showed that longer durations of creep feeding did not affect pre-weaning gain and weaning weights but increased the proportion of eaters in whole litters. Eaters had greater post-weaning feed intake than non-eaters of creep feed, which resulted in higher initial daily gains.

Key Words: Creep feeding, duration, growth, neonatal pig

Introduction

It is widely accepted that neonatal pigs have greater growth potential than what is achieved in commercial practice (Harrell et al., 1993; Le Devidich and Séve, 2001). In addition, achieving greater pig performance prior to weaning elicits positive effects on post-weaning growth. Klindt (2003) demonstrated that increasing nutrient availability during lactation is an important determinant of pre-weaning growth rates, which may improve post-weaning and lifetime pig performance. Creep feeding, or the practice of providing a highly digestible, palatable diet to piglets during lactation, is a feeding strategy that can augment sow milk production and provide an additional nutrient source to suckling piglets (Pluske et al, 1995; Mavromichalis, 2006). However, evidence on the benefits of creep feeding has both been limiting and equivocal, especially for weaning ages less than four weeks.

Recent studies where piglets were categorized into “eaters” and “non-eaters” of creep feed have provided some new insights on the value of creep feeding (Bruininx et al., 2002; Kuller et al., 2004, 2007b; Sulabo et al., 2008). These studies have consistently shown that only a certain proportion of pigs within the litter consume creep feed and that "eaters", which are piglets in the litter that positively consumed creep feed, have better initial postweaning feed intake and growth performance than piglets that did not consume creep feed. This suggests that increasing the proportion of pigs consuming creep feed within litters may elicit positive effects on nursery performance. Therefore, it is important to determine factors that may create more eaters of creep feed in whole litters.

The duration of creep feeding may be an important factor in stimulating more pigs to consume creep feed. Commercial recommendations for initiation of creep feeding vary from as early as 2 to 3 d of age to as late as a few days prior to weaning when milk production of the sow subsides. However, evidence on the effect of creep feeding duration has been limiting. It is also not known if providing creep feed at varying durations will increase the proportion of eaters or affect pre-weaning performance. Therefore, the objectives of this study were 1) to determine the effects of varying durations of creep feeding on the proportion of piglets consuming creep feed and pre-weaning performance (Exp. 1), and 2) determine differences in post-weaning growth performance between eaters and non-eaters of creep feed (Exp. 2).

Materials and Methods

All animal procedures were reviewed and approved by the Kansas State University Institutional Animal Care and Use Committee.

Experiment 1

A total of 54 sows (Line 1050, PIC) and their litters were used in this study conducted at the Kansas State University Swine Research and Teaching Center farrowing facilities. Sows used in this experiment were from two batches of sows farrowed in April and May, 2007, with 27 experimental sows included from each batch. Sows were blocked according to parity and date of farrowing and allotted to three experimental treatments using a randomized complete block design. Cross-fostering was performed within 48 h post-farrowing to standardize litter weights and litter size (>12 pigs). The sow or litter was the experimental unit with 18 replicates per treatment group.

There were three experimental treatments in this study according to the duration of creep feeding. Creep feeding was initiated at d 7, 14, and 18 from birth for Treatments 1, 2, and 3, respectively. These corresponded to durations of 13, 6, and 2 d of creep feeding. A creep diet (3,495 kcal ME/kg, 1.56% standardized ileal digestible Lys; Table 3.1) with 1.0% chromium oxide was offered ad libitum until weaning using a rotary creep feeder (Rotecna Mini Hopper Pan, Rotecna SA, Spain). The feeder has a 6-liter capacity hopper, which is adjustable to 5 different feeder gap settings to allow ad lib feeding. The creep diet was in pellet form (2-mm pellets). A single lactation diet (3,503 kcal ME/kg, 0.97% standardized ileal digestible Lys) was used in the experiment. Sows were allowed free access to feed throughout lactation. Water was made available at all times for both sows and their litters using nipple and bowl drinkers, respectively.

Piglets were weighed individually at d 0 (birth), 7, 14, 18, and 20 (weaning). Creep feeders were weighed daily. Daily creep feed consumption per litter was computed as the difference in feeder weights between consecutive days. Individual piglets were categorized into ‘eaters’ and ‘non-eaters’ of creep feed using procedures adapted from Barnett et al. (1989) and Bruininx et al. (2002). All piglets were evaluated for consumption category on d 14, 18, and 20 for Treatment 1, d 18 and 20 for Treatment 2, and d 20 for Treatment 3 by evaluating fecal material for the presence of green color provided by the chromic oxide marker in the creep diet. Sampling was performed twice on each day of collection. On the morning of each evaluation day, a fecal swab was obtained from each piglet and categorized as an eater if green color was visible from the fecal sample. Piglets without evidence of creep feed consumption were resampled after 9 to 12 h. Piglets were categorized as non-eaters when no green color was detected from all the collected samples.

Sows were weighed after farrowing and at weaning. Weekly feed intake of the sows was recorded to calculate total and average daily feed intake. In this study, two sows from Treatment 3 were removed from the test due to death of the sow. General health of the sows and piglets were checked daily and use of medication was monitored. Temperature in the farrowing facility was maintained at a minimum of 20°C, and supplementary heat was provided to the piglets using heat lamps when needed.

Experiment 2

A total of 273 creep-fed piglets (average initial BW 5.74 kg and 20 ± 2 days, PIC) from Exp. 1 were randomly allotted to two treatments using a completely randomized design. Treatments were either pigs categorized as Eater or Non-eater prior to weaning. The number of replications (pens) and observational units (pigs per pen) for each treatment was dependent on the number of pigs identified for each creep feed consumption category at weaning. The Non-eater treatment had 10 replications with 7 pens containing 5 pigs per pen and 3 pens containing 6 pigs. The Eater treatment had 33 replications with 25, 5, and 3 pens containing 7, 6, and 5 pigs per pen, respectively. Both treatments were fed a commercial Segregated Early Weaning diet for the first 3 d followed by a commercial Transition diet for 7 d. Both diets were in pellet form (2-mm pellets). Pigs were then fed a standard Phase 2 diet until d 28 post-weaning. Each pen contained 1 self-feeder and 1 nipple drinker to provide ad libitum access to feed and water. Pigs were housed in the Kansas State University Swine Teaching and Research Center nursery facilities. Pigs and feeders were weighed on d 3, 7, 14, 21 and 28 following weaning to calculate ADG, ADFI, and G:F. Periodic and cumulative average daily gain and creep feed intake were calculated for each treatment group. Pre-weaning mortality was also calculated.

Data were analyzed as a randomized complete block design using PROC MIXED of SAS (SAS Institute Inc., Cary, NC) with sow or litter as the experimental unit. The model included creep feeding duration as the fixed effect and block as the random effect. The effect of varying creep feeding durations on the proportion of eaters and non-eaters was analyzed using the χ^2 test in SAS. For the postweaning data, results were analyzed as a completely randomized design using PROC GLM of SAS with pen as the experimental unit. Least square means were evaluated using the PDIFF and STDERR options of SAS. Statistical significance and tendencies were set at $P < 0.05$ and $P < 0.10$ for all statistical tests.

Results and Discussion

Experiment 1

Sows had an average parity of 2.1 ± 0.2 and lactation length of 19.9 ± 0.3 d (Table 3.2). Varying the duration of creep feeding had no effect on total ($P > 0.76$) or daily feed intake ($P > 0.53$) of sows during lactation. Likewise, there were no differences in post-farrowing weight ($P > 0.98$), weaning weight ($P > 0.74$), and lactation weight loss ($P > 0.67$) among the treatments. Litter size at weaning ($P > 0.98$) and mortality from d 2 to weaning ($P > 0.93$) was also similar across the treatments.

Overall, differences in litter weaning weights ($P > 0.80$), total gain ($P > 0.50$), and daily gain ($P > 0.52$) among litters fed creep for different durations were not significant (Table 3.3). For individual pigs, differences in weaning weight ($P > 0.61$), total gain ($P > 0.38$), and average daily gain ($P > 0.38$) among creep-fed litters for different durations were also not significant

(Table 3.4). These results showed that the availability of creep feed for longer durations did not improve weaning weights and weight gains of both pigs and litters. This may be due to the relatively small creep feed intake during the first week of creep feeding being insufficient to generate any differences in growth performance.

From d 8 to 14, litters offered creep feed for 13 d had a total intake of 163 g (Figure 3.1). From d 15 to 20, litters fed creep for 6 d had a higher ($P < 0.02$) total creep intake than litters fed creep for 13 d. From d 19 to 20, litters provided with creep feed for 6 and 2 d also tended ($P < 0.09$) to have higher total creep intake than litters fed creep for 13 d. Overall, the total creep feed intake of litters fed for 13 and 6 d were greater ($P < 0.0001$) than those litters provided creep feed for only 2 d (Figure 3.1). There were no differences ($P > 0.69$) in total creep intake between those fed for 13 and 6 d. These results suggest that initiating creep feeding at a later age does not detrimentally affect creep feed intake; instead, older piglets readily accepted creep feed and consumed the same or more feed than piglets started on creep feed at an earlier age. Thus, litter creep intake seems to be more related to the maturity of piglets rather than the period of induction of creep feeding.

The duration of creep feeding influenced ($P < 0.03$) the proportion of eaters in creep-fed litters (Figure 3.2). Litters provided with creep feed for 13 d produced 10% more ($P < 0.03$) eaters than litters fed creep for both 6 and 2 d. There were no differences ($P > 0.98$) in the percentage of eaters between litters fed creep for 6 and 2 d. The higher rate of eaters in litters creep fed for 13 d suggests that the longer availability of creep feed helps stimulate more piglets to consume creep feed and improves the average creep consumption of piglets categorized as eaters. However, a 10% difference in eaters also indicates that the additional 7 to 11 d of creep feeding generated only 1 more eater per litter (for a litter of at least 10 piglets). Therefore, the benefit of longer durations of creep feeding should be weighed based on the economic value of creating more eaters in whole litters.

Experiment 2

At the start of the nursery experiment (d 0), pigs categorized as non-eaters were heavier (3.2%, $P < 0.0001$) than eaters of creep feed. This difference in initial weight was unintentional, as all the pigs in a single farrowing group were used in the experiment. In this farrowing group, there were 273 pigs weaned with 220 (80%) and 53 (20%) pigs categorized as eaters and non-eaters of creep feed, respectively. However, the initial weight difference between the two treatments disappeared after only 3 d post-weaning. Eaters had higher daily gains (25.4%, $P < 0.02$) than non-eaters, which was driven mainly by a tendency for a higher daily feed intake (17.1%, $P < 0.06$) in the first 3 days after weaning. The same effect was observed from d 0 to 7 post-weaning, where eaters had higher ADFI ($P < 0.04$) and tended to have higher ADG (15%, $P < 0.08$) than non-eaters. There were no differences ($P > 0.49$) in G:F between the two groups of pigs in both periods.

Bruininx et al. (2002) provided the first evidence that 'eaters' of creep feed in lactation grew faster in the first 8 d after weaning and until 62 d of age, compared to 'non-eaters' and piglets not offered any creep feed in lactation. Recent studies have supported these results (Kuller et al., 2004, 2007; Callesen et al., 2007a,b; Pluske et al., 2007; Sulabo et al., 2008), including the current study. The difference in initial growth rates between eaters and non-eaters of creep feed is mainly explained by higher post-weaning feed intake, due to shorter latency time and greater number of feeder visits. Bruininx et al. (2001) found that about 50% of the piglets designated as eaters during the suckling period started eating within 4 h after weaning, whereas non-eaters and non-creep fed piglets needed about 6.7 and 6.9 h, respectively. Bruininx et al.

(2001) also showed that eaters had more visits to the feeder associated with eating feed and concomitantly had a greater rate of feed intake. In the current study, eaters consumed greater amounts of feed than non-eaters in the first 7 d post-weaning despite the weight difference at weaning. This would suggest that familiarity with solid food at weaning causes the weanling pig to focus more on feed intake and less on exploratory behavior regardless of body weight.

From d 0 to 14 and d 0 to 21, eaters continued to have greater ADFI ($P < 0.02$) than non-eaters. Overall (d 0 to 28), eaters tended to have higher ADFI (441 vs. 420 g; $P < 0.09$) than non-eaters of creep feed. However, this higher feed consumption was not sufficient to improve pig weights ($P > 0.57$) and daily gains ($P > 0.19$) at d 14, 21, and 28 post-weaning. This resulted in lower G:F ($P < 0.04$) in eaters compared to non-eaters from d 0 to 14, d 0 to 21, and d 0 to 28. In previous studies, Bruininx et al. (2002) and Kuller et al. (2007) found differences in growth rates and body weights between eaters and non-eaters until 5 and 8 wks post-weaning, respectively. However, no long term effects were observed in ADFI and ADG between eaters and non-eaters until the finishing period (Kuller et al., 2007).

In conclusion, longer durations of creep feeding did not affect pre-weaning gain and weaning weights but increased the proportion of eaters of creep feed in whole litters. The adoption of longer creep feeding durations should be evaluated based on practicality and the economic benefits of improved piglet performance attributed to eaters post-weaning. Piglets designated as eaters had higher post-weaning daily feed intake than non-eaters of creep feed, which resulted in improvements in initial post-weaning growth rates. Increasing pre-weaning feed consumption can reduce exploratory behavior, improve initial daily gains, and reduce post-weaning growth check associated with weaning.

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Table 3-1. Composition of the creep and lactation diet (as-fed basis).

Item	Creep[1]	Lactation[2]
Ingredient, %		
Corn	6.15	60.00
Soybean meal, 46.5% CP	2.32	31.20
Spray dried whey	25.00	-
Fine ground oat groats	30.00	-
Extruded soy protein concentrate	10.00	-
Spray-dried animal plasma	6.00	-
Select menhaden fish meal	6.00	-
Lactose	5.00	-
Choice white grease	5.00	5.00
Monocalcium P, 21% P	0.35	1.45
Chromium oxide	1.00	-
Antibiotic[3]	1.00	-
Limestone	0.40	1.20
Zinc oxide	0.38	-
Salt	0.30	0.50
L-lysine HCl	0.15	-
DL-methionine	0.15	-
Trace mineral premix[4]	0.15	0.15
Vitamin premix[5]	0.25	0.25
Sow vitamin premix[6]	-	0.25
Acidifier[7]	0.20	-
Vitamin E, 20,000 IU	0.05	-
Total	100.00	100.00
Calculated analysis		
CP, %	23.9	19.6
SID Lysine, %[8]	1.56	0.97
ME, kcal/kg	3,495	3,503
Ca, %	0.79	0.87
Available P, %	0.56	0.38
SID Lysine:ME, g/Mcal	4.47	2.77

[1]Diet fed in pellet form (2-mm pellets).
[2]Diet fed in meal form throughout lactation.
[3]Contained 140 mg of neomycin sulfate and 140 mg of oxytetracycline HCl per kg of complete diet
[4]Provided per kg of complete diet: 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.30 mg of Se; 165.4 mg of Zn; and 0.30 mg of I.
[5]Provided per kg of complete diet: 11,023 IU of vitamin A; 1,378 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate); 50 mg of niacin; 28 mg of pantothenic acid (as d-calcium pantothenate); 8 mg of riboflavin; 0.04 mg of vitamin B12; 750 FYT of Ronozyme P® phytase (DSM Nutritional Products, Parsipanny, NJ)
[6]Sow add pack provided the following nutrients per kg of complete diet: 22 IU of vitamin E; 0.22 mg of biotin; 1.65 mg of folic acid; 5 mg of pyridoxine (as pyridoxine HCl); 551 mg of choline (as choline Cl); 50 mg of L-carnitine; 0.20 mg of chromium (as chromium picolinate)
[7]Calcium propionate
[8]Standardized ileal digestible

Table 3-2. Effects of varying creep feeding durations on lactating sow performance (Exp. 1).[1,2]

Item	Creep feeding duration, d			SED	*P*-value
	13	6	2		
No. of sows	18	18	16	-	-
Lactation length, d	19.7	19.9	20.0	0.2	0.33
Average parity	2.1	2.1	2.2	0.2	0.95
Lactation feed intake, kg					
Total (d 0 to 20)	102	101	105	6.6	0.76
ADFI	5.2	5.1	5.2	0.3	0.53
Sow weight, kg					
Post-farrowing	218	219	219	6.6	0.98
Weaning	202	204	207	6.6	0.74
Change	-15.7	-14.6	-12.6	3.6	0.67
No. of pigs/litter					
Post-fostering	12.2	12.3	12.2	0.1	0.51
d 20 (weaning)	11.2	11.3	11.2	0.3	0.98
Mortality (d 2 to 20), %	7.7	7.9	8.6	2.3	0.93

[1]Two groups of sows (total =52, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to three treatments (13, 6, and 2 d creep feeding durations).
[2]Creep feed with 1.0% chromium oxide was offered ad libitum from d 7, 14, and 18 to weaning (20 d).

Table 3-3. Effects of varying creep feeding durations on litter performance (Exp. 1).[1,2]

Item	Creep feeding duration, d			SED	*P*-value
	13	6	2		
No. of litters	18	18	16	-	-
No. of pigs	219	221	197	-	-
Litter weight, kg					
Post-fostering	15.4	15.5	15.4	0.5	0.97
d 7	27.4	27.6	27.5	1.2	0.99
d 14	46.3	45.4	45.3	2.3	0.89
d 18	58.5	57.7	57.0	2.8	0.86
At weaning	64.0	62.6	62.1	3.0	0.80
Litter BW gain, kg					
d 8 to14	18.9	17.9	17.6	1.3	0.55
d 15 to 18	12.2	12.2	11.7	0.7	0.75
d 19 to 20	5.5	5.0	5.1	0.5	0.41
d 15 to 20	17.8	17.2	16.9	1.0	0.65
d 8 to 20	36.7	35.1	34.5	2.0	0.50
Litter ADG, kg					
d 8 to 14	2.70	2.55	2.52	0.18	0.55
d 15 to 18	3.06	3.07	2.93	0.19	0.75
d 19 to 20	2.98	2.87	2.81	0.17	0.62
d 15 to 20	2.79	2.50	2.56	0.23	0.41
d 8 to 20	2.82	2.70	2.65	0.15	0.52

[1]Two groups of sows (total =52, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to three treatments (13, 6, and 2 d creep feeding durations).

[2]Creep feed with 1.0% chromium oxide was offered ad libitum from d 7, 14, and 18 to weaning (d 20).

Table 3-4. Effects of varying creep feeding durations on neonatal pig performance (Exp. 1)[1,2]

Item	Creep feeding duration, d			SED	*P*-value
	13	6	2		
No. of litters	18	18	16	-	-
No. of pigs	219	221	197	-	-
Pig weight, kg					
Post-fostering	1.38	1.38	1.38	0.03	0.97
d 7	2.45	2.45	2.45	0.08	0.99
d 14	4.14	4.03	4.06	0.16	0.78
d 18	5.24	5.12	5.10	0.20	0.75
At weaning	5.74	5.56	5.56	0.21	0.61
Pig BW gain, kg					
d 8 to 14	1.69	1.58	1.61	0.10	0.49
d 15 to 18	1.10	1.08	1.04	0.06	0.68
d 19 to 20	0.50	0.44	0.46	0.04	0.19
d 15 to 20	1.60	1.53	1.51	0.08	0.46
d 8 to 20	3.29	3.11	3.11	0.15	0.38
Pig ADG, g					
d 8 to 14	242	226	230	14.1	0.49
d 15 to 18	274	271	260	16.3	0.68
d 19 to 20	252	221	232	17.7	0.19
d 15 to 20	267	254	251	13.6	0.46
d 8 to 20	254	239	239	11.8	0.38

[1]Two groups of sows (total =52, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to three treatments (13, 6, and 2 d creep feeding durations).
[2]Creep feed with 1.0% chromium oxide was offered ad libitum from d 7, 14, and 18 to weaning (d 20).

Table 3-5. Post-weaning performance of pigs according to creep feed consumption category (Exp. 2).[1]

Item	Consumption category[2,3] Non-eater	Eater	SE	*P*-value
n	10	33	-	-
Pig weights, kg				
d 0	5.83	5.65	0.01	0.0001
d 3	6.34	6.30	0.04	0.50
d 7	7.00	7.00	0.07	0.99
d 14	9.68	9.71	0.11	0.83
d 21	13.23	13.10	0.16	0.57
d 28	17.02	16.98	0.19	0.86
ADG, g				
d 0 to 3	130	163	9.1	0.02
d 0 to 7	147	169	8.2	0.08
d 0 to 14	255	270	7.3	0.19
d 0 to 21	336	338	7.3	0.82
d 0 to 28	386	390	6.4	0.67
ADFI, g				
d 0 to 3	111	130	6.8	0.06
d 0 to 7	138	160	6.8	0.04
d 0 to 14	138	181	8.2	0.001
d 0 to 21	299	327	7.7	0.02
d 0 to 28	420	441	7.7	0.09
G:F				
d 0 to 3	1.17	1.25	0.02	0.49
d 0 to 7	1.06	1.06	0.01	0.74
d 0 to 14	1.85	1.49	0.01	0.0004
d 0 to 21	1.12	1.04	0.01	0.003
d 0 to 28	0.92	0.89	0.01	0.04

[1]A total of 273 creep-fed piglets (averaging 5.74 kg and 20 ± 2 days, PIC) were randomly allotted to 2 treatments (non-eater or eater) using a completely randomized design.

[2]Consumption category: Non-eater treatment were pigs whose fecal samples were negative for chromic oxide-containing creep feed while the Eater treatment were creep-fed pigs that were positive for green-colored feces.

[3]The Non-eater treatment had 10 replications with 7 pens containing 5 pigs per pen and 3 pens containing 6 pigs. The Eater treatment had 33 replications with 25, 5, and 3 pens containing 7, 6, and 5 pigs per pen, respectively.

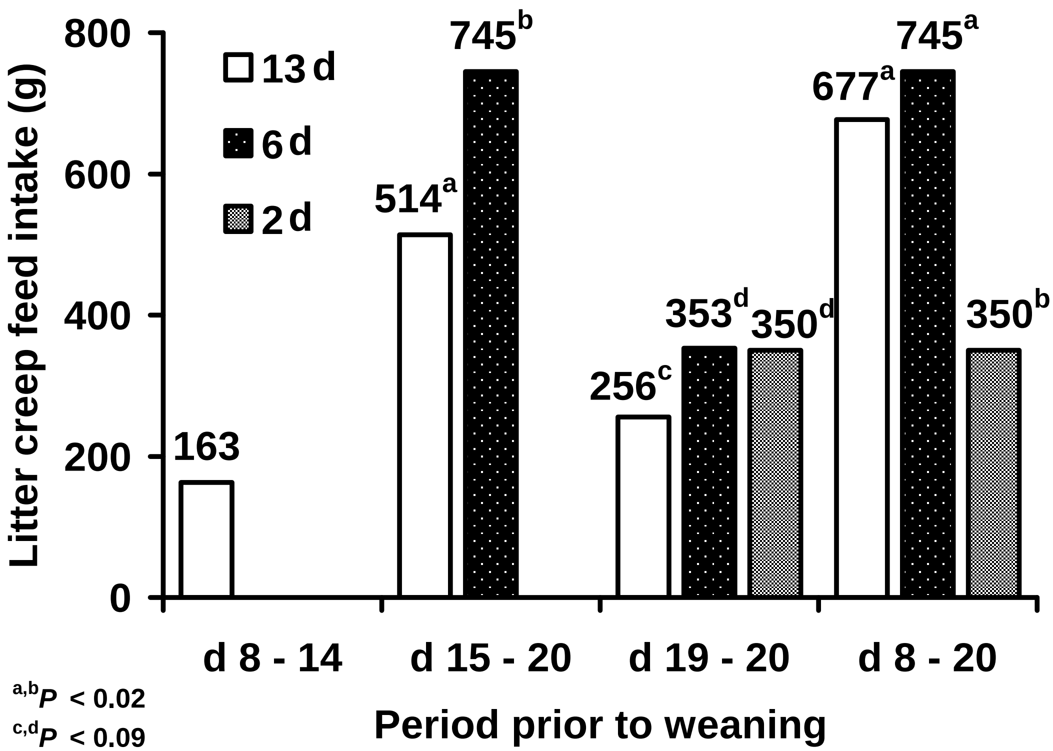

Figure 3-1. Effect of creep feeding duration on total litter creep feed intake.

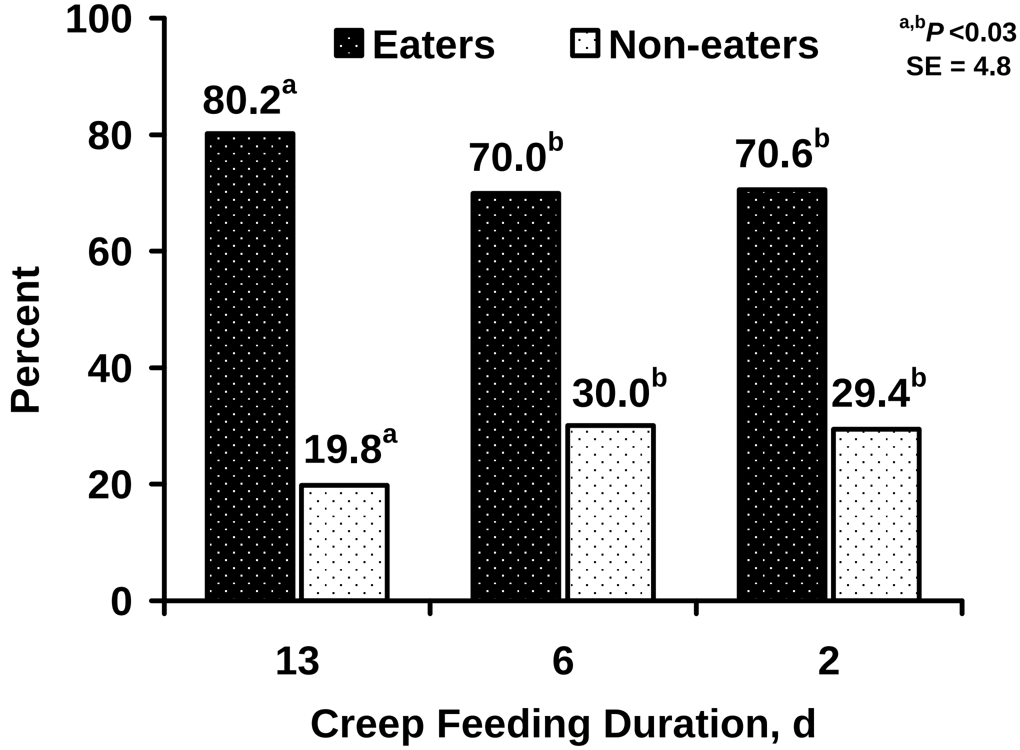

Figure 3-2. Effect of creep feeding duration on the proportion of pigs that consumed (Eaters) and did not consume creep feed (Non-eaters).

CHAPTER 4 - Effects of creep feeder design and feed accessibility on the proportion of pigs consuming creep feed and preweaning pig performance

Summary

Objective: To determine the effects of creep feeder design and feed accessibility on the proportion of eaters of creep feed and preweaning performance.

Materials and methods: A total of 54 sows and their litters were assigned to three treatments: (1) Rotary feeder with hopper, (2) Rotary feeder without hopper, and (3) Pan feeder. A creep diet with 1.0% chromic oxide was offered ad libitum at Day 18 until weaning (Day 21). Fecal samples were taken from piglets twice using sterile swabs between 3 and 12 hours before weaning. Piglets were categorized an "eater" when any of the two fecal samples was colored green; otherwise, they were categorized a "non-eater". Pigs were weighed at Day 0 (birth), 18 and at weaning (Day 21) and litter creep feed disappearance was determined daily.

Results: There were no differences ($P > .05$) in preweaning gains and weaning weights of pigs and litters using the different types of creep feeder. Litters provided creep feed using the rotary feeder with the hopper had 2.7 times lower ($P < .001$) total creep feed disappearance than litters using the rotary feeder without the hopper and the pan feeder. However, the rotary feeder with the hopper produced the highest (80%; $P < .001$) proportion of pigs consuming creep feed within the litter.

Implication: Creep feeder design did not affect litter growth performance but influenced creep feed disappearance and the proportion of piglets in the litter that consumed creep feed.

Keywords: creep feed, growth, feeder design, suckling pig, swine

Introduction

As pig production systems move towards later weaning, there is a greater interest for nutritional strategies that can increase nutrient availability to suckling piglets and improve weaning weights and post-weaning performance. The practice of providing a solid, highly digestible diet to piglets during lactation or 'creep feeding' is one of the strategies that received significant attention.

A number of studies mostly in late-weaned piglets have shown positive benefits of creep feeding in initiating and promoting gut and digestive enzyme development[1-5], reducing pre-weaning mortality[6], increasing pre-weaning growth rate and weaning weights[7-9], and improving post-weaning performance[10-11]. However, these effects have been inconsistently demonstrated thought to be due to low and highly variable creep feed consumption between and within litters[12-14]. Inert markers such as chromic oxide added to the creep feed can be used to identify individual pigs within a litter that actually consume creep feed by detection of the marker in the feces[11,13,15]. Recently, a number of creep feeding studies evaluating individual piglets have consistently shown that "eaters" or piglets that positively consumed creep feed have significantly higher post-weaning feed intake and better growth performance than non-eaters of creep feed or non-creep fed pigs[6,11,16-20]. If creep feeding behavior can be encouraged and more eaters can be created within a litter, then nursery performance can be improved. It is therefore important to determine dietary and non-dietary factors that can stimulate individual piglets to consume creep feed prior to weaning. Identifying these factors can also help in understanding and managing the variability in consumption typically observed with creep feeding.

The design of the creep feeder may be an important factor. Few studies have evaluated the effect of different creep feeder designs and creep feed accessibility on feeding behavior, intake, and performance of suckling piglets. Some of these studies have shown positive improvements on feeder visiting time and intakes of suckling pigs by using a familiar trough[21] or when feeding space was increased[22-23]. However, these studies evaluated whole litters and did not differentiate between eaters and non-eaters of creep feed within a litter. Moreover, the effect of different types of creep feeders on creating eaters has never been evaluated. Therefore, the objective of this experiment was to determine the effects of different creep feeder designs and increasing creep feed accessibility on the rate of creating eaters and pre-weaning performance.

Materials and Methods

Study animals

A total of 54 sows (PIC Line 1050) and their litters were used in this study conducted at the Kansas State University Swine Research and Teaching Center farrowing facility. Sows in this experiment were from two batches of sows farrowed in June and July, 2007, with 27 experimental sows included from each batch. Cross-fostering was performed within 48 hours post-farrowing to standardize litter weights and litter size (>10 pigs). All animal procedures used in this study were reviewed and approved by the Kansas State University Institutional Animal Care and Use Committee (protocol #2457).

Experimental design

Sows were blocked according to parity and date of farrowing and were allotted to three experimental treatments using a randomized complete block design. The sow or litter was the experimental unit with 18 replicates per treatment group. There were three types of creep feeder designs tested in this study. Treatment 1 used a rotary creep feeder (Rotecna Mini Hopper Pan, Rotecna SA, Spain), which is 27 cm in diameter, 86 cm in linear feeding space, and 5.3 cm deep with 5 feeding spaces (Figure 4.1). This feeder design has a 6-liter capacity hopper, which is adjustable to 5 different settings to allow ad lib feeding and minimize feed wastage. The hopper also has a curved rim and wings that help separate piglets while feeding. The feeder can also be latched to the flooring of the pen and fixed on a specific location within the farrowing crate. This feeder design was used in our previous creep feeding studies, and, therefore, served as the Control treatment in this study. In past studies, 60 to 70% of piglets were categorized as eaters using this feeder[6,24-25].

For Treatment 2, a rotary creep feeder without a hopper (Rotecna Mini Pan, Rotecna SA, Spain) was used (Figure 4.2). This feeder design has the same dimensions as the feeder in Treatment 1, and can also be latched on a specific location within the farrowing crate. This feeder represents conventional bowl feeders that are commonly used in the industry. For Treatment 3, a stainless pan feeder was used (Figure 4.3). This feeder is 102 cm long, 13.5 cm wide and 2.5 cm deep. The feeder is placed under the divider of two farrowing crates, which provides a feeding trough for 2 adjacent crates and a 2.8 cm width per trough. The rotary creep feeder (Treatment 1 and 2) was placed in a location where it was most accessible to piglets and sows could not urinate or defecate in it or the side opposite of the supplemental heat lamp. This was chosen to ensure creep feed accessibility, prevent soiling of the creep feed, and allow unhindered suckling of piglets to the sow.

A creep diet (3,494 kcal ME/kg, 1.56% standardized ileal digestible lysine) with 1.0% chromic oxide was offered ad libitum at Day 18 until weaning on Day 21 (Table 4.1) for a creep feeding duration of 3 days. The creep diet was in pellet form (2-mm pellets). The duration of creep feeding (3 days) in this study was used for a number of reasons. First, Sulabo et al.[6] showed that 75% of the total creep feed consumption was consumed in the last 3 days prior to weaning (Day 21) when fed for a duration of 18 days. In another study, results showed that initiating creep feeding at a later age did not detrimentally affect creep feed intake[20]. Older piglets readily accepted creep feed and consumed the same or more feed than piglets started on creep feed at an earlier age. Secondly, creep feeding for 13 days produced 10% unit more eaters (80 vs. 70%) than those creep fed for 6 and 2 days prior to weaning. Therefore, creep feeding for 3 days would allow enough difference to investigate the effect of creep feeder design on the proportion of eaters without any detriment on total creep feed consumption.

For Treatment 1, sufficient amounts of creep feed were placed in the hopper to ensure that feed was always available. The adjustment of the hopper was checked daily to allow ad lib feeding and control feed wastage. For Treatments 2 and 3, small amounts of creep feed were placed on the feeder whenever the feeder was empty. The feeders were checked every 2 hours for 12 hours each day. In every crate, the daily frequency of adding creep feed was recorded. A single lactation diet (3,503 kcal ME/kg, 0.97% standardized ileal digestible lysine) was used in the experiment. Sows were allowed free access to feed throughout lactation. Water was made available at all times for both sows and their litters using nipple and bowl drinkers, respectively.

Performance and fecal sample collection

Piglets were weighed individually at Day 0 (birth), 18, and 21 (weaning). The amount of creep feed offered was weighed daily. Creep feed that was not consumed at the time of weighing was collected and weighed back. All piglets were evaluated for consumption category between 3 and 12 hours before weaning by evaluating fecal material for the presence of green color provided by the chromic oxide marker in the creep diet[12,14]. Sampling was performed twice on each day of collection. On the morning of each evaluation day, a fecal swab was obtained from each piglet and categorized as an eater if green color was visible from the fecal sample. Piglets without evidence of creep feed consumption were resampled after 9 to 12 h. Piglets were categorized as non-eaters when no green color was detected from all the collected samples.

Sows were weighed post-farrowing and at weaning. Weekly feed intake of the sows was recorded to calculate total and average daily feed intake. General health of the sows and piglets were checked daily. Temperature in the farrowing facility was maintained at a minimum of 20°C, and supplementary heat was provided to the piglets using heat lamps when needed. Periodic and cumulative average daily gain and creep feed intake as feed disappearance were calculated for each treatment group.

Statistical analysis

Data were analyzed as a randomized complete block design using PROC MIXED of SAS (SAS Institute Inc., Cary, North Carolina). Sow or litter was the experimental unit. The model included treatment and block as the fixed and random effect, respectively. When treatment effect was a significant source of variation, differences were determined using the PDIFF option of SAS. Least square means were calculated for each independent variable. The effect of different creep feeder designs on the proportion of eaters and non-eaters of creep feed was analyzed using the χ^2-square test in SAS. Statistical significance was set at $P < .05$ for all statistical tests.

Results

The performance of lactating sows used in this study is shown in Table 4.2. Experimental sows had an average parity of 2.1 ± 0.2 and lactation length of 21.1 ± 0.3 days. There were no differences ($P > .05$) in post-farrowing weight, weaning weight, and lactation weight loss among the treatments. Total and average daily feed intake of sows throughout lactation was also similar ($P > .05$) among the treatments.

The effect of different creep feeder designs on pig and litter performance is shown in Table 4.3. There were no differences ($P > .05$) in pig and litter weights at weaning among litters using the different types of creep feeder. Total and daily gains of pig and litters were also similar ($P > 0.05$) across treatments. However, litters using the rotary feeder with the hopper had 2.7 times lower ($P < .001$) total creep feed disappearance than litters using the rotary feeder without the hopper and the pan feeder (Figure 4).

In terms of creating eaters, the type of creep feeder influenced ($P < .001$) the proportion of eaters created among piglets provided with creep feed (Figure 5). In litters using the rotary feeder with the hopper, 69 and 31% of suckling piglets were categorized as eaters and non-eaters at weaning, respectively. These rates were consistent with our previous creep feeding studies using the same feeder and creep diet[20-21]. On the other hand, litters on the rotary feeder without the hopper had 22% fewer eaters ($P < .001$) than with litters on the rotary feeder with the hopper. Likewise, litters using the pan feeder had 27% less eaters ($P < .001$) than litters on the rotary feeder with the hopper.

Discussion

The lack of differences in pig and litter growth rates among the treatments suggest that a large proportion of creep feed offered to litters using the rotary feeder without the hopper and the pan feeder were not consumed but wasted. The design of these two feeders is more open and creep feed is more accessible to piglets compared to the feeder with the hopper. However, these feeders also allowed some piglets to root, lie in, and push feed out of the feeder, which eventually reduced the availability and accessibility of creep feed to other piglets. The higher creep feed disappearance with the pan feeder also confirmed results of other studies where increased access to creep feed was provided[18-19]. The pan feeder in this study was designed to provide more feeding spaces than the rotary feeder but piglets more often approached and consumed creep feed with their bodies parallel to the feeder rather than pigs eating side by side.

The addition of the hopper to the rotary feeder reduced total creep feed disappearance without affecting growth performance. This feeder design has been used in our previous creep feeding trials and has been shown to be capable of measuring none to very small amounts of creep feed intake for whole litters[6,24-25]. This indicates its ability to control feed wastage. Therefore, it can be assumed that the total creep feed disappearance measured with this feeder in this study is closer to the true intake of creep feed by the litter. There are aspects of the design of this feeder that may help explain the lower creep feed disappearance. The conical shape as well as the curved rim and wings at the bottom of the hopper prevented piglets from rooting, standing over, or pushing creep feed out of the troughs. The hopper was also adjusted daily to manage the amount of feed that flowed out of the gap, which controlled the level of feed in the trough.

Feeders were filled for an average of 1, 2.3, and 4.2 times per 12 hours for the rotary feeder with hopper, rotary feeder without hopper, and the pan feeder, respectively. Though the rotary feeder with hopper allowed ad libitum feeding, the daily weighing and re-introduction of the feeder to the litter was counted as one feeding per day. The higher feeding frequency for both the rotary feeder without the hopper and the pan feeder were facilitated to minimize feed wastage. In creep feeding, the typical recommendation is to feed small amounts frequently to stimulate intake and manage feed wastage[26]. This method was performed for both the rotary feeder without hopper and pan feeder. However, the practice still allowed higher creep feed disappearance than the feeder with the hopper. This also demonstrated the extra effort needed to manage these creep feeders, which in the end, did not provide any positive returns.

The higher rate of eaters created using the rotary feeder with the hopper may be a function of both feeder design and piglet creep feed consumption. The addition of the hopper to the rotary feeder significantly increased the percentage of eaters, which may be partially attributed to providing continuous availability of feed in the troughs with reduced feed wastage. In a recent study evaluating chromium oxide as a marker for identifying creep feed-eating piglets, eaters were identified as piglets consuming chromium oxide-containing creep feed in appreciable amounts or in multiple days[15]. Therefore, this feeder enabled more piglets in the litter to consume significant amounts of creep feed. This further supports the assumption that the creep feed disappearance using this feeder is close to the true value of litter creep feed intake.

The lower rate of eaters generated from litters using the rotary feeder without the hopper and the pan feeder also support the notion that more creep feed was wasted than consumed. Greater accessibility and increased feeding spaces resulted in higher creep disappearance, but did not produce more eaters. This is contrary to the assumption of previous studies, where increased feeding space and accessibility was thought to encourage more piglets to imitate others at the feeder and stimulate initial intake of creep feed[9,17-19]. The fewer number of eaters in this study suggest that less creep feed was available in these feeders for piglets to consume in appreciable amounts. Moreover, the rate of feed wastage due to physical activity of piglets on the feeder may be faster than their rate of consumption. Since creep diets are usually expensive, minimizing feed wastage will be an important consideration for implementation of creep feeding.

Implications

Under the conditions of this study:

- Creep feeding for 3 days prior to weaning did not affect pig and litter performance.
- The rotary feeder with the hopper created the most eaters with the lowest creep feed disappearance.
- Increasing feeding space and feed accessibility led to higher creep feed disappearance, but did not generate more eaters.
- The proper choice of creep feeder is essential to manage creep feeding and to maximize the number of eaters in the litter.

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Figure 4-1. Rotary creep feeder with hopper (Rotecna® Mini Hopper Pan, Rotecna SA, Spain). The feeder is 27 cm in diameter, 86 cm in linear feeding space, and 5.3 cm deep with 5 feeding spaces. It has a 6-liter capacity hopper, which is adjustable to 5 different settings of feeder gaps to allow ad lib feeding. The hopper also has a curved rim and wings that helps separate piglets while feeding and to minimize feed wastage. The feeder can also be latched to the flooring of the pen and fixed on a specific location within the farrowing crate.

Figure 4-2. Rotary creep feeder without a hopper (Rotecna® Mini Pan, Rotecna SA, Spain). The feeder is 27 cm in diameter, 86 cm in linear feeding space, and 5.3 cm deep with 5 feeding spaces. This feeder represents conventional bowl feeders that are commonly used in the industry.

Figure 4-3. Stainless pan feeder. This feeder is 102 cm long, 13.5 cm wide and 2.5 cm deep. The feeder is placed in between the divider of two farrowing crates, which provides two feeding troughs per feeder with a 2.8 cm width per trough.

Figure 4-4. Total litter creep feed disappearance between different creep feeder designs.

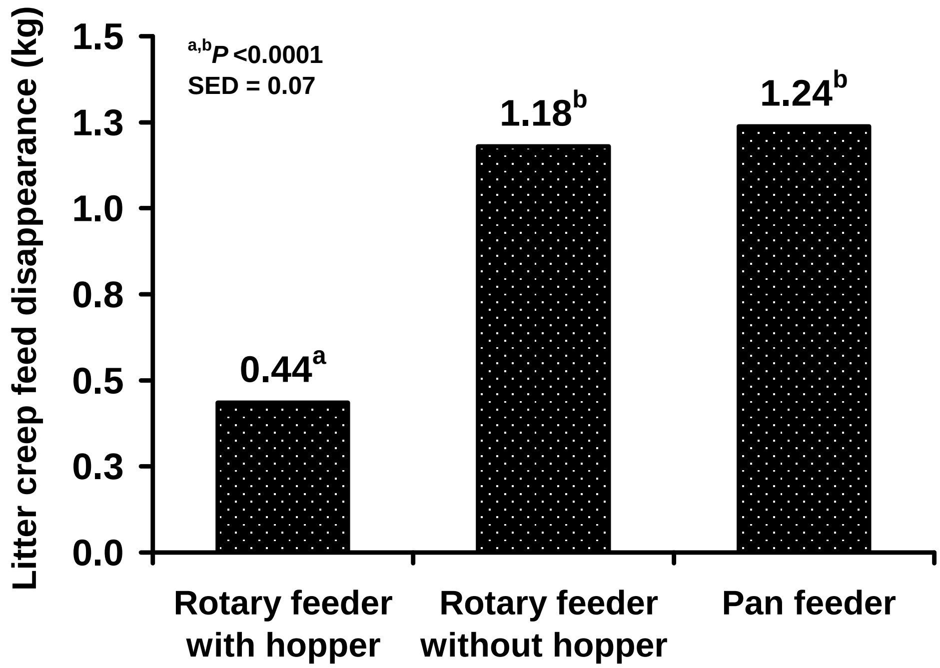
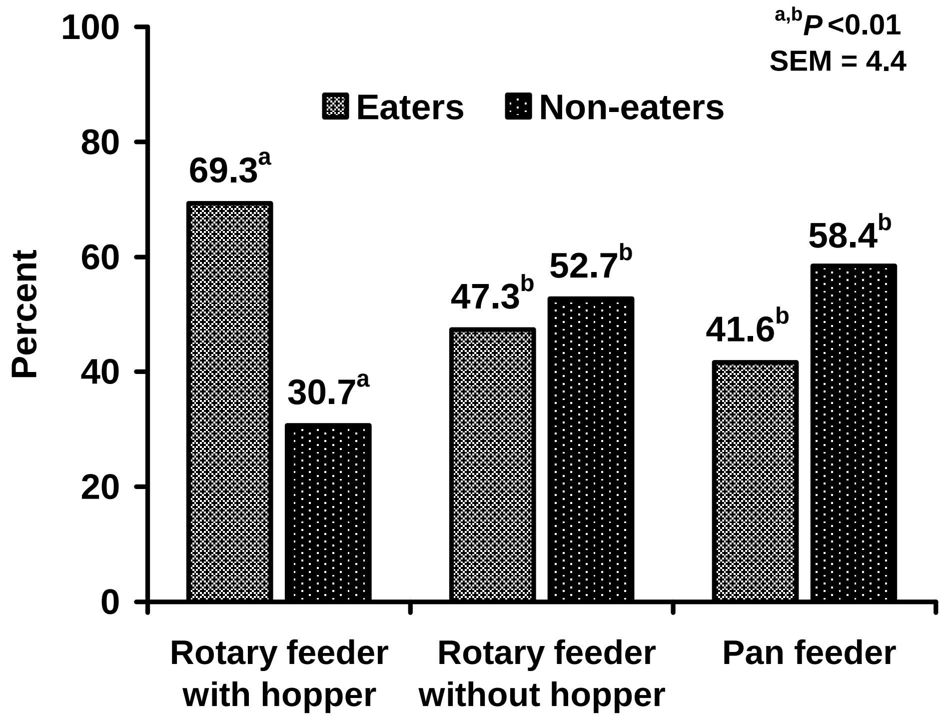


Figure 4-5. Effect of creep feeder design on the proportion of piglets consuming creep feed.



CHAPTER 5 - Effects of adding feed flavors to the creep feed and nursery diet complexity on preweaning and nursery pig performance

ABSTRACT: In Exp. 1, 50 sows (PIC Line 1050) and their litters were used to determine the effects of adding a flavor to the creep feed on the proportion of eaters and preweaning performance. Sows were blocked according to parity and date of farrowing and allotted to 2 experimental treatments: (1) litters fed a creep diet with no flavor (negative control), or (2) the negative control diet with the feed flavor (Luctarom) included at 1,500 ppm. Both creep diets contained 1.0% chromic oxide and were offered ad libitum from d 18 until weaning on d 21. Flavor addition to the creep diet did not affect weaning weights ($P > 0.53$), total gain ($P > 0.77$), ADG ($P > 0.77$), total creep feed intake ($P > 0.66$), daily creep feed intake ($P > 0.66$), and the proportion of creep feed eaters ($P > 0.41$) in whole litters. In Exp. 2, 480 weanling pigs (6.58 kg and 20 ± 2 d, PIC) from Exp. 1 were blocked by initial weight and allotted to 1 of 8 treatments in a randomized complete block design to determine the interactive effects of preweaning exposure to the flavor (exposed vs. unexposed), nursery diet complexity (complex vs. simple), and flavor addition to the nursery diets (with vs. without flavor). Each treatment had 6 pigs per pen and 10 replications (pens). Diets with the flavor were supplemented with the flavor at 1,500 ppm in phase 1 diets and 1,000 ppm in phase 2 diets. A tendency for a three-way interaction for ADG from d 5 to 10 ($P < 0.10$), d 10 to 28 ($P < 0.09$), and d 0 to 28 ($P < 0.06$) was observed. Postweaning ADG of pigs fed diets with the same flavor in the creep and complex nursery diets was greater than that of pigs in any other treatment combination. Increasing diet complexity improved ($P < 0.01$) ADG and ADFI during both phases postweaning. Adding flavor to the creep feed had no effect on G:F ($P > 0.34$) and pig BW ($P > 0.45$) in both periods postweaning. Adding the feed flavor to the starter diets tended to improve ADFI ($P < 0.06$) during d 0 to 5. In conclusion, adding a flavor to the creep feed did not affect litter creep feed intake, the proportion of piglets consuming creep feed, and preweaning performance when creep was provided for 3 d before weaning. Preweaning exposure to the feed flavor improved postweaning daily gain of pigs fed complex diets supplemented with the same flavor but did not influence performance of pigs fed simple diets.

Key Words: creep feeding, diet complexity, feed flavor, growth, pigs

Introduction

Recent studies on creep feeding have shown that “eaters”, which are piglets in a litter known to have consumed creep feed, have better initial postweaning feed intake and growth performance than piglets that do not consume creep feed (Kuller et al., 2004, 2007b; Pluske et al., 2007; Sulabo et al., 2008a). Therefore, identifying factors that can increase creep feed consumption and the proportion of eaters within litters may elicit positive effects on nursery performance.

Organoleptic properties of the feed may be a dietary factor that can influence the proportion of piglets consuming creep feed prior to weaning. Feed flavors are commonly used in nursery diets to improve diet acceptance and stimulate intake (McLaughlin et al., 1983; van Heugten et al., 2002). However, evidence of the potential effects of adding flavors to the creep feed on pre-weaning feed intake and performance is limiting. Preweaning exposure to the flavor may also enhance postweaning responses when the same flavor is added to the nursery diets (King, 1979; Langendijk et al., 2007); however, evidence of this behavior is limited. Some studies have shown nursery pigs having an innate preference for flavored diets during changes in dietary regimes, especially at weaning or during the starter period (McLaughlin et al., 1983; Rohde Parfet and Gonyou, 1991). Reducing differences in performance between pigs fed complex and simple nursery diets through the use of feed flavors may have potential economic benefits.

Therefore, the objectives of this study were to determine 1) the effects of a feed flavor on the proportion of eaters within a litter and preweaning performance (Exp. 1), 2) the effects of diet complexity (complex vs. simple) on response to the inclusion of a feed flavor in nursery pig performance (Exp. 2), and 3) the effects of preweaning exposure to the flavor and flavor addition to nursery diets on postweaning performance (Exp. 2).

Materials and Methods

All animal procedures were reviewed and approved by the Kansas State University Institutional Animal Care and Use Committee.

Experiment 1

A total of 50 sows (Line 1050 PIC) and their litters were used in this study conducted at the Kansas State University Swine Research and Teaching Center farrowing facility. Sows used in this experiment were from 2 batches of sows farrowed in November and December, 2007; 25 experimental sows from each batch were included in the study. Sows were blocked according to parity and date of farrowing and allotted to 2 experimental treatments in a randomized complete block design. Cross-fostering was performed within 48 h postfarrowing to standardize litter weights and litter size (> 10 pigs). The sow or litter was the experimental unit; there were 25 replicates per treatment group.

There were 2 experimental diets in this study. Treatment 1 was a creep diet with no flavor (negative control), and treatment 2 was the negative control diet with the feed flavor (Luctarom, Lucta USA, Inc., Northbrook, IL) included at 1,500 ppm. Both creep diets were formulated to contain 3,496 kcal ME/kg and 1.56% standardized ileal digestible (SID) lysine (Table 5.1). Chromium oxide was added to both diets at 1.0% to serve as a fecal marker. The creep diets were in pellet form (2-mm pellets) and offered ad libitum from d 18 until weaning on d 21 using a rotary creep feeder with hopper (Rotecna Mini Hopper Pan, Rotecna SA, Spain). A single lactation diet (3,494 kcal ME/kg, 0.97% SID lysine) was used in the experiment. Sows were allowed free access to feed throughout lactation. Water was made available at all times for sows and their litters through nipple and bowl drinkers, respectively.

Piglets were weighed individually at d 0 (birth), 18, and 21 (weaning). The amount of creep feed offered was weighed daily. Creep feed that was not consumed at the time of weighing was collected and weighed. Creep feed consumption of individual pigs was determined using procedures adapted from Barnett et al. (1989) and Bruininx et al. (2002). All piglets were evaluated for consumption category between 3 and 12 h before weaning by evaluating fecal material for the presence of green color provided by the chromic oxide marker in the creep diet. Sampling was performed twice on each day of collection. On the morning of each evaluation day, a fecal swab was obtained from each piglet and categorized as an eater if green color was visible from the fecal sample. Piglets without evidence of creep feed consumption were resampled after 9 to 12 h. Piglets were categorized as non-eaters when no green color was detected from all the collected samples.

Sows were weighed postfarrowing and at weaning. Weekly feed intake of the sows was recorded to calculate total feed intake and ADFI. In this study, 1 sow from treatment 2 was removed from the test because of very low feed intake. General health of the sows and piglets was checked daily. Temperature in the farrowing facility was maintained at a minimum of 20°C, and supplementary heat was provided to the piglets by using heat lamps when needed.

Experiment 2

A total of 480 weanling piglets (initial BW 6.58 kg and 20 ± 2 days, PIC) from Exp. 1 were allotted and blocked by initial weight to 1 of 8 treatments as a 2 × 2 × 2 factorial using a randomized complete block design. Treatment factors were preweaning exposure to the flavor (exposed vs. unexposed to the flavor), nursery diet complexity (complex vs. simple diet phase feeding), and flavor addition to the nursery diets (with vs. without flavor). Each treatment had 6 pigs per pen and 10 replications (pens). Each pen contained 1 self-feeder and 1 nipple drinker to provide ad libitum access to feed and water. Pigs were housed in the Kansas State University Swine Teaching and Research Center nursery facilities.

Experimental diets were the combinations of either complex or simple and with or without the flavor for both phases (Table 5.2). For phase 1, simple diets were mainly composed of ground corn and soybean meal with 2.5% fish meal and 10% dried whey. The complex diets contained 30% pulverized oat groats, 25% dried whey, 6% spray-dried porcine plasma, 6% fish meal, and lower levels of ground corn and soybean meal. Lactose content was 7.2 and 18% for the simple and complex diet, respectively. For phase 2, the simple diet was mainly ground corn and soybean meal. The complex diet was also composed of ground corn and soybean meal but also contained 4.5% fish meal and 10% dried whey. The simple and complex diet contained 0 and 7.2% lactose, respectively. For both phase 1 and 2 diets, the simple and complex diets were formulated to the same energy and essential AA specifications (NRC, 1998). Diets with the flavor were supplemented with Luctarom at 1,500 ppm in phase 1 diets and 1,000 ppm in phase 2 diets. Phase 1 diets were in pellet form (2 mm) and fed from d 0 to 10. Phase 2 diets were in meal form and fed from d 11 to 28. Pigs and feeders were weighed on d 5, 10, and 28 following weaning to calculate ADG, ADFI, and G:F.

Preweaning data were analyzed as a randomized complete block design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with sow or litter was the experimental unit. The model included diet and block as the fixed and random effect, respectively. When treatment effect was a significant source of variation, differences were determined using the PDIFF option of SAS. Least square means were calculated for each independent variable. The effect of feed flavor on the proportion of eaters and non-eaters of creep feed was analyzed using the χ^2-square test in SAS. Statistical significance and tendencies were set at $P < 0.05$ and $P < 0.10$ for all statistical tests. In Exp. 2, data were analyzed as a randomized complete block design with a 3-way factorial treatment structure using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with pen as the experimental unit. The model included the main effects of flavor in the creep diet, flavor in the nursery diet, and nursery diet complexity and the interactions between flavor in the creep diet × flavor in the nursery diet, flavor in the creep diet × nursery diet complexity, flavor in the nursery diet × nursery diet complexity, and flavor in the creep diet × flavor in the nursery diet × nursery diet complexity as the fixed effects and bock as the random effect, respectively. Least square means were evaluated using the PDIFF and STDERR options of SAS using the Tukey test. Statistical significance and tendencies were set at $P < 0.05$ and $P < 0.10$ for all statistical tests.

Results and Discussion

Experiment 1

Performance of lactating sows used in this study is shown in Table 5.3. Sows had an average parity of 2.3 ± 0.3 and lactation length of 20.5 ± 0.3 days. There were no differences in postfarrowing weight ($P > 0.88$), weaning weight ($P > 0.80$), and lactation weight loss ($P > 0.17$) between the treatments. Likewise, litter size after fostering, at day 18, and at weaning were similar ($P > 0.50$) between the two treatments. There were also no differences ($P > 0.68$) between treatments in total and ADFI of sows throughout lactation.

Overall, differences in litter weaning weights ($P > 0.94$), total gain ($P > 0.77$), and daily gain ($P > 0.77$) between litters fed creep with and without the feed flavor were not significant (Table 5.4). For individual pigs, differences in weaning weight ($P > 0.53$), total gain ($P > 0.89$), and ADG ($P > 0.89$) between the two treatments were also not significant. Likewise, addition of the feed flavor to the creep feed did not influence total ($P > 0.66$) or daily ($P > 0.66$) creep feed intake of litters (Figure 5.1) or the proportion of creep feed eaters ($P > 0.41$) in whole litters (Figure 5.2).

The lack of response to flavor may be explained by 1) the duration of creep feeding, 2) the high proportion of creep feed eaters within litters, and 3) the role of feed flavors in diets of suckling pigs. The duration of creep feeding may be important, and a minimum period of exposure to the flavor is required to see appreciable effects. However, Sulabo et al. (2008b) showed that creep feed intake is more related to the maturity of piglets than to the period of induction of creep feeding. More importantly, most U.S. pig producers provide supplemental feed for only 2 to 7 days prior to weaning; thus, any effect of flavor addition must be observed in a short feeding duration. It is still undetermined whether dietary changes can increase the proportion of piglets consuming creep feed over the rate determined in our previous studies. The highest rate of creep feed eaters achieved in previous studies was 70% when nondietary factors were manipulated (Sulabo et al., 2008b,c). Any effect of dietary factors on the proportion of piglets consuming creep feed remains to be demonstrated.

Results may also be due to the role taste and olfactory cues play in stimulating higher intakes by suckling pigs (Kennedy and Baldwin, 1972; Houpt and Houpt, 1976; Danilova et al., 1999; Glaser et al., 2000). Few studies have evaluated the effect of feed flavors on stimulating creep feed consumption; most have evaluated flavor exposure prenatally or flavors through the lactation feed (Campbell, 1976; Langendijk et al., 2007). Campbell (1976) suggested that creep feed consumption can be stimulated when piglets are acquainted with specific flavors associated with the sow's milk or diet. When flavors are added to the creep feed, results have been consistent. In one study, the addition of 5 g/kg of monosodium L-glutamate (MSG) to the creep feed led to an increase in creep feed intake from day 18 postfarrowing; however, no differences in weaning weights were observed despite the increase in intake (Gatel and Guion, 1990). Monosodium L-glutamate is the principal source of the umami taste, which increases the intensity and acceptability of inherent flavors of food. In a follow-up study, addition of MSG to an associated commercial flavor in the creep feed did not elicit any effect on creep feed intake or preweaning performance (Gatel and Guion, 1990). Results of the current study agree with these previous findings.

The lack of effect in suckling pigs may suggest age-related differences or greater individual variation in palatability perception. Sulabo et al. (2008a) showed that increased physiological need for nutrients driven by restricted feeding of lactating sows did not stimulate litters to consume more creep feed or increase the proportion of creep feed eaters. This suggests that changing the flavor properties of the creep feed may not be sufficient to positively affect preweaning feed intakes.

Experiment 2

The interactive and main effects of flavor in the creep diet, diet complexity, and flavor in the nursery diets on postweaning performance are shown in Tables 5.5 and 5.6, respectively. Results showed tendencies for a 3-way interaction for daily gains from d 5 to 10 ($P < 0.10$), d 10 to 28 ($P < 0.09$), and d 0 to 28 ($P < 0.06$). No 3-way interaction was observed for pig weights ($P > 0.13$), daily feed intake ($P > 0.27$), or G:F ($P > 0.13$) in any period. Generally, postweaning ADG of pigs exposed to the flavor in creep feed and fed flavored complex diets was greater than that of pigs fed any other treatment.

Increasing diet complexity improved ($P < 0.01$) ADG and ADFI during both phases postweaning (Table 5.6). Pigs fed starter diets with greater complexity were heavier ($P < 0.0001$) than pigs fed simple diets at d 5 (+0.36 kg), 10 (+0.68 kg) and 28 (+1.5 kg). Feed efficiency was also improved ($P < 0.0001$) in pigs fed complex diets from d 0 to 5 and d 0 to 10 but not from d 5 to 10 ($P > 0.58$). However, pigs fed complex diets were less (6.0%; $P < 0.0001$) efficient from d 10 to 28 than pigs fed the simple diets. Overall (d 0 to 28), pigs fed the diets with greater complexity had poorer (2.3%; $P < 0.0001$) G:F than pigs fed simple diets.

These results agree with previous studies evaluating the effects of diet complexity on weanling pigs (Himmelberg et al., 1985; Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003). These studies showed marked improvements in early postweaning ADG, ADFI, and G:F when pigs were fed diets with greater complexity. However, the effect of diet complexity on pig growth and efficiency decreases with increasing time postweaning (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003), which may help explain the poorer feed efficiency from days 10 to 28 observed in this study for pigs fed the complex diets. Though some studies have demonstrated the ability of certain feed flavors to mask less palatable ingredients (Roura et al. 2008a), the negative effect of feeding the simple diets seen in this study may be too great for the effect of flavor to overcome. However, the benefit of feeding starter diets with greater complexity on weanling pig performance should be weighed against the additional feed consumption and the higher unit cost of the feed.

Exposing pigs to the feed flavor in the creep feed did not affect daily gains ($P > 0.27$), G:F ($P > 0.40$), or pig weights ($P > 0.45$) in all periods postweaning. Daily feed intake was also unaffected ($P > 0.29$), except for d 5 to 10 when pigs exposed to the flavor preweaning tended to have lower ($P < 0.07$) daily feed intake than unexposed pigs. Supplementing the starter diet with the feed flavor tended to improve daily feed intake (5.9%; $P < 0.06$) and numerical differences in daily gains (6.3%; $P < 0.15$) during d 0 to 5. However, no differences in daily gain ($P > 0.20$), daily feed intake ($P > 0.42$), or G:F ($P > 0.35$) were observed between pigs fed starter diets with and without the flavor in all succeeding periods. Pig weights were also unaffected ($P > 0.35$) by flavor addition in all periods.

These results show that the addition of flavor in the nursery diet helped achieve modest gains in feed intake and weight gains early postweaning; however, the benefit of flavor addition was not seen throughout the rest of the starter period. In one recent study, addition of an enhanced milky flavor to the starter diet improved daily gains and feed intake numerically only in one trial; another study showed a significant improvement compared with pigs fed unflavored diets during d 0 to 14 (Roura et al., 2008a,b). Overall (d 0 to 28), both of the previous trials showed higher daily gains for weanling pigs when the enhanced milky flavor was added to nursery diets, which is in contrast to the result of the current study. This suggests that the effect of the enhanced milky flavor is variable and may depend on the composition of the diet.

In conclusion, addition of the feed flavor to the creep feed did not affect litter creep feed intake, the proportion of piglets consuming creep feed, or preweaning performance. The benefits of flavor addition preweaning should be assessed on the basis of effects on postweaning intake and performance. Preweaning exposure to the feed flavor improved postweaning daily gains and feed intake of pigs fed complex diets supplemented with the same flavor but did not influence performance of pigs fed simple diets.

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Table 5-1. Composition (as-fed basis) of creep diet for Exp. 1[1]

Ingredient	%
Corn	6.05
Soybean meal (46.5% CP)	2.32
Spray-dried animal plasma	6.00
Select menhaden fish meal	6.00
Spray-dried whey	25.00
Lactose	5.00
Extruded soy protein concentrate	10.00
Pulverized oat groats	30.00
Choice white grease	5.00
Monocalcium phosphate (21% P)	0.35
Limestone	0.45
Salt	0.30
Zinc oxide	0.38
Vitamin premix[2]	0.25
Trace mineral premix[3]	0.15
L-Lysine HCl	0.15
DL-Methionine	0.15
Antibiotic[4]	1.00
Acidifier[5]	0.20
Vitamin E, 20,000 IU	0.05
Chromium oxide	1.00
TOTAL	100.00
Calculated analysis	
SID Lysine, %[6]	1.56
ME, kcal/kg	3,494
Protein, %	23.88
Ca, %	0.81
Available P, %	0.55
Lactose, %	23.00

[1]Supplemented without (Control) and with Luctarom (Lucta USA Inc., Northbrook, IL) at 1,500 ppm (1.4 kg/ton)
[2]Provided per kg of complete diet: 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.30 mg of Se; 165.4 mg of Zn; and 0.30 mg of I.
[3]Provided per kg of complete diet: 11,023 IU of vitamin A; 1,378 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate); 50 mg of niacin; 28 mg of pantothenic acid (as d-calcium pantothenate); 8 mg of riboflavin; 0.04 mg of vitamin B12; 750 FYT of Ronozyme P® phytase (DSM Nutritional Products, Inc., Parsipanny, NJ)
[4]Contained 140 mg of neomycin sulfate and 140 mg of oxytetracycline HCl per kg of complete diet
[5]Calcium propionate
[6]Standardized ileal digestible

Table 5-2. Composition (as-fed basis) of phase 1 and 2 diets for Exp. 2.

	Phase 1 diets[1]		Phase 2 diets[2]	
Ingredient, %	Simple	Complex	Simple	Complex
Corn	42.40	11.60	57.75	54.40
Soybean meal (46.5% CP)	35.90	13.25	36.70	26.50
Spray-dried animal plasma	-	6.00	-	-
Select menhaden fish meal	2.50	6.00	-	4.50
Spray-dried whey	10.00	25.00	-	10.00
Pulverized oat groats	-	30.00	-	-
Soybean oil	5.00	5.00	1.00	1.00
Monocalcium P (21% P)	1.45	0.20	1.60	0.75
Limestone	0.60	0.58	0.95	0.65
Salt	0.30	0.25	0.35	0.30
Zinc oxide	-	0.38	-	0.25
Vitamin premix[3]	0.25	0.25	0.25	0.25
Trace mineral premix[4]	0.15	0.15	0.15	0.15
L-Lysine HCl	0.33	0.20	0.30	0.30
DL-Methionine	0.20	0.17	0.14	0.15
L-Threonine	0.15	0.05	0.11	0.13
Antibiotic[5]	0.70	0.70	0.70	0.70
Acidifier[6]	-	0.20	-	-
Choline chloride	0.05	0.05	-	-
TOTAL	100.00	100.00	100.00	100.00
Calculated Analysis				
SID Lysine, %[7]	1.51	1.51	1.35	1.35
SID Lysine:ME ratio, g/Mcal	4.29	4.25	4.06	4.05
ME, kcal/kg	3,518	3,556	3,324	3,335
CP, %	23.6	23.1	22.4	21.4
Ca, %	0.84	0.84	0.80	0.80
Available P, %	0.52	0.52	0.42	0.42
Lactose, %	7.2	18.0	-	7.2

[1]Supplemented without (Control) and with Luctarom (Lucta USA, Inc., Northbrook, IL) at 1,500 ppm (1.4 kg/ton); diets in pellet form.

[2]Supplemented without (Control) and with Luctarom (Lucta USA, Inc., Northbrook, IL) at 1,000 ppm (0.9 kg/ton); diets in meal form.

[3]Provided per kg of complete diet: 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.30 mg of Se; 165.4 mg of Zn; and 0.30 mg of I.

[4]Provided per kg of complete diet: 11,023 IU of vitamin A; 1,378 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate); 50 mg of niacin; 28 mg of pantothenic acid (as d-calcium pantothenate); 8 mg of riboflavin; 0.04 mg of vitamin B12; 750 FYT of Ronozyme P® phytase (DSM Nutritional Products, Parsipanny, NJ)

[5]Contained 140 mg of neomycin sulfate and 140 mg of oxytetracycline HCl per kg of complete diet

[6]Calcium propionate

[7]Standardized ileal digestible

Table 5-3. Effects of adding flavor to the creep feed on sow performance (Exp. 1).[1,2]

	Feed flavor			
Treatment	No	Yes	SED	Probability, *P* <
No. of litters	25	24	-	-
Average parity	2.3	2.3	0.3	0.94
Lactation length, day	20.7	20.4	0.3	0.35
Sow weight, kg				
Postfarrowing	238.5	239.8	8.7	0.88
Weaning	229.5	227.3	8.5	0.80
Change	-9.0	-12.6	2.5	0.17
No. of pigs/litter				
Postfostering	11.1	11.1	0.3	0.98
d 18 (start creep)	10.3	10.2	0.3	0.74
d 21 (weaning)	10.3	10.1	0.4	0.50
Lactation feed intake, kg				
Total	122.0	119.7	6.0	0.68
ADFI	5.9	5.9	0.3	0.94

[1]Two groups of sows (total = 50, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to 2 treatments.

[2]Creep feed with 1.0% chromium oxide supplemented without (No) and with Luctarom (Yes) at 1,500 ppm (1.4 kg/ton); offered ad libitum from d 18 to weaning (d 20).

Table 5-4. Effects of adding an enhanced feed flavor to the creep feed on pig and litter performance (Exp. 1).[1,2]

	Feed flavor			
Treatment	No	Yes	SED	Probability, $P <$
No. of litters	25	24	-	-
Pig weights, kg				
Postfostering	1.46	1.47	0.04	0.91
d 18 (start creep)	5.62	5.77	0.22	0.51
d 21 (weaning)	6.50	6.65	0.24	0.53
Total gain (d 18 to 21), kg	0.87	0.88	0.05	0.89
Daily gain (d 18 to 21), kg	0.29	0.29	0.02	0.89
Litter weights, kg				
Postfostering	15.3	15.1	0.6	0.65
d 18 (start creep)	57.9	57.8	2.9	0.97
d 21 (weaning)	66.8	66.5	3.2	0.94
Total gain (d 18 to 21), kg	8.9	8.8	0.5	0.77
Daily gain (d 18 to 21), kg	3.0	2.9	0.2	0.77

[1]Two groups of sows (total = 50, PIC Line 1050) were blocked according to day of farrowing and parity and allotted to 2 treatments.
[2]Creep feed with 1.0% chromium oxide supplemented without (No) and with Luctarom (Yes) at 1,500 ppm (1.4 kg/ton); offered ad libitum from d 18 to weaning (d 20).

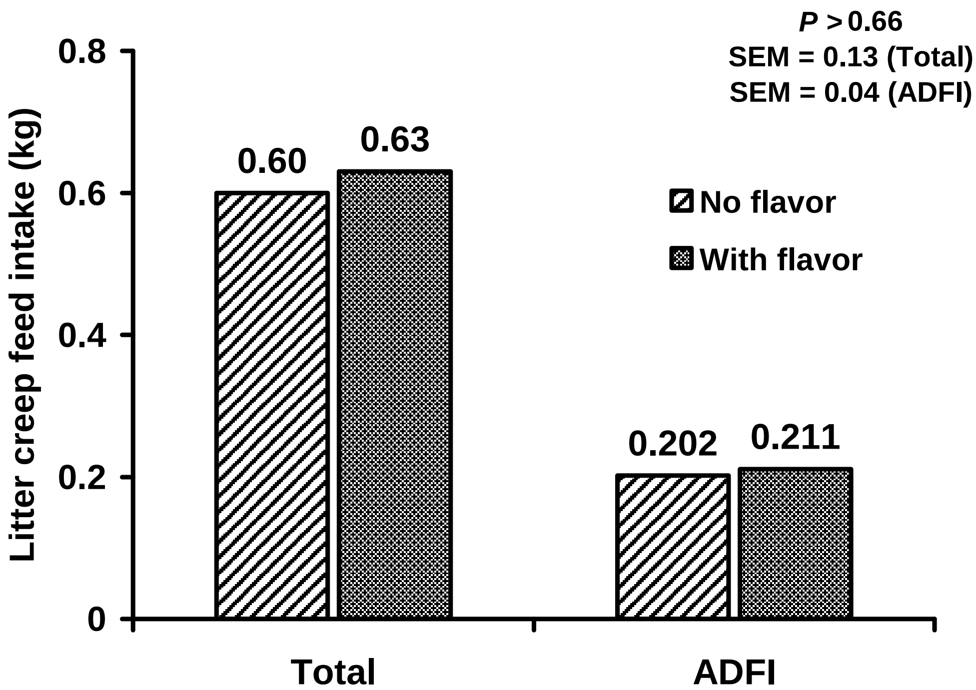

Figure 5-1. Total and daily creep feed intake of litters fed diets with and without an enhanced feed flavor.

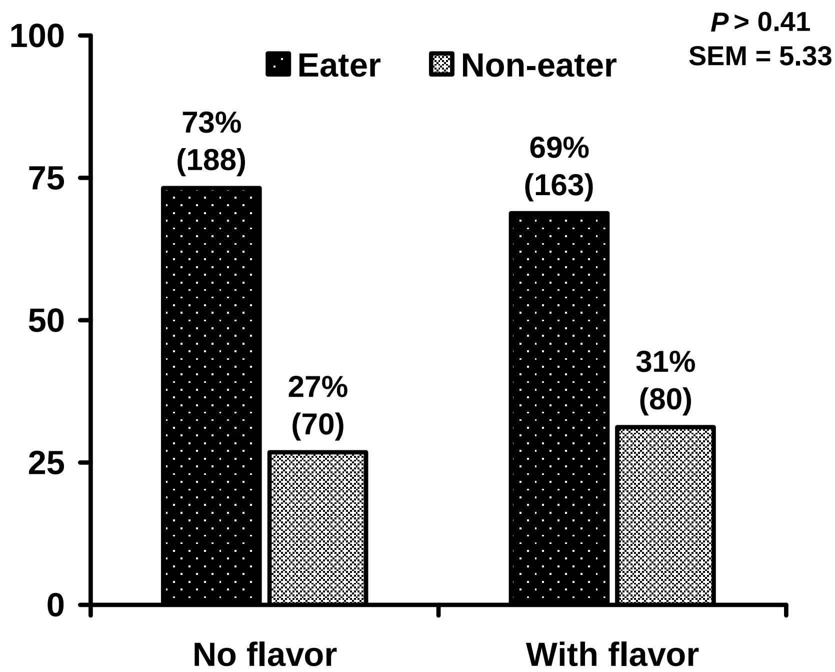

Figure 5-2. Effect of adding an enhanced feed flavor to the creep feed on the proportion of eaters in whole litters (no. of pigs in parentheses).

Table 5-5. Interactive effects of flavor in the creep diet, diet complexity, and flavor in the nursery diets on postweaning performance (Exp. 2).[1,2]

Flavor in Creep:	No				Yes				SED	Probability, $P <$						
Diet Complexity:	Simple		Complex		Simple		Complex						Creep ×	Creep ×	Diet ×	Creep ×Diet
Flavor in Nursery:	No	Yes	No	Yes	No	Yes	No	Yes		Creep	Diet	Nursery	Diet	Nursery	Nursery	× Nursery
Pig weight, kg																
d 0	6.6	6.6	6.6	6.6	6.5	6.6	6.5	6.6	0.1	0.94	0.88	0.88	0.87	0.89	0.88	0.86
d 5	7.1	7.2	7.4	7.5	7.1	7.2	7.4	7.5	0.1	0.83	<0.0001	0.40	0.77	0.78	0.81	0.83
d 10	8.4	8.4	9.0	9.0	8.3	8.3	8.9	9.2	0.2	0.72	<0.0001	0.35	0.26	0.48	0.32	0.38
d 28	17.0	17.3	18.6	18.6	17.1	16.8	18.2	18.8	0.4	0.45	<0.0001	0.52	0.84	0.90	0.50	0.13
d 0 to 5																
ADG, kg	0.11	0.12	0.17	0.18	0.11	0.12	0.18	0.20	0.01	0.70	<0.0001	0.15	0.35	0.76	0.43	0.47
ADFI, kg	0.13	0.14	0.17	0.19	0.13	0.14	0.18	0.19	0.01	0.61	<0.0001	0.06	0.39	0.93	0.59	0.99
G:F	0.62	0.54	0.45	0.47	0.59	0.55	0.48	0.44	0.04	0.77	<0.0001	0.20	0.87	0.89	0.28	0.29
d 5 to 10																
ADG, kg	0.26	0.25	0.31	0.31	0.24	0.22	0.29	0.34	0.02	0.27	<0.0001	0.50	0.04	0.29	0.07	0.10
ADFI, kg	0.26	0.24	0.32	0.31	0.23	0.22	0.30	0.33	0.01	0.07	<0.0001	0.92	0.15	0.23	0.19	0.28
G:F	0.45	0.45	0.47	0.46	0.45	0.46	0.46	0.44	0.01	0.50	0.58	0.35	0.35	0.93	0.25	0.35
d 0 to 10																
ADG, kg	0.19	0.19	0.24	0.24	0.17	0.17	0.24	0.27	0.01	0.58	<0.0001	0.20	0.07	0.35	0.11	0.13
ADFI, kg	0.20	0.20	0.24	0.25	0.18	0.18	0.24	0.26	0.01	0.32	<0.0001	0.42	0.17	0.49	0.22	0.49
G:F	0.48	0.48	0.46	0.46	0.48	0.49	0.47	0.44	0.01	0.78	0.0008	0.35	0.27	0.49	0.23	0.13
d 10 to 28																
ADG, kg	0.48	0.49	0.54	0.53	0.49	0.48	0.52	0.53	0.01	0.57	<0.0001	0.96	0.80	0.90	0.99	0.09
ADFI, kg	0.64	0.65	0.75	0.73	0.64	0.64	0.72	0.74	0.02	0.32	<0.0001	0.88	0.81	0.50	0.94	0.27
G:F	0.61	0.60	0.64	0.64	0.59	0.61	0.63	0.64	0.01	0.44	<0.0001	0.65	0.87	0.14	0.90	0.48
d 0 to 28																
ADG, kg	0.37	0.38	0.43	0.43	0.38	0.37	0.42	0.44	0.01	0.48	<0.0001	0.63	0.68	0.74	0.57	0.06
ADFI, kg	0.49	0.49	0.57	0.57	0.48	0.48	0.55	0.57	0.02	0.29	<0.0001	0.72	0.90	0.43	0.80	0.27
G:F	0.59	0.58	0.60	0.60	0.57	0.59	0.59	0.59	0.01	0.40	0.004	0.93	0.53	0.30	0.77	0.24

[1]A total of 480 pigs (initial BW of 6.6 kg and 21 ± 2 days of age, PIC), with 6 pigs per pen and 10 replications per treatment

[2]Diets provided without (No) and with (Yes) 1,500 and 1,000 ppm of Luctarom per ton of phase 1 (d 0 to 10) and phase 2 (d 10 to 28) diets, respectively.

Table 5-6. Main effects of flavor in the creep diet, diet complexity, and flavor in the nursery diets on postweaning performance (Exp. 2).[1,2]

	Flavor in Creep Diet		Diet Complexity		Flavor in Nursery Diets		SED	Probability, $P <$						
	No	Yes	Simple	Complex	No	Yes		Creep	Diet	Nursery	Creep × Diet	Creep × Nursery	Diet × Nursery	Creep ×Diet × Nursery
Pig weight, kg														
d 0	6.6	6.6	6.6	6.5	6.5	6.6	0.1	0.94	0.88	0.88	0.87	0.89	0.88	0.86
d 5	7.3	7.3	7.1	7.5	7.3	7.3	0.1	0.83	<0.0001	0.40	0.77	0.78	0.81	0.83
d 10	8.7	8.7	8.3	9.0	8.6	8.7	0.1	0.72	<0.0001	0.35	0.26	0.48	0.32	0.38
d 28	17.9	17.7	17.1	18.6	17.7	17.9	0.2	0.45	<0.0001	0.52	0.84	0.90	0.50	0.13
d 0 to 5														
ADG, kg	0.15	0.15	0.11	0.18	0.15	0.15	0.005	0.70	<0.0001	0.15	0.35	0.76	0.43	0.47
ADFI, kg	0.16	0.16	0.14	0.18	0.15	0.16	0.005	0.61	<0.0001	0.06	0.39	0.93	0.59	0.99
G:F	0.52	0.52	0.58	0.46	0.53	0.50	0.02	0.77	<0.0001	0.20	0.87	0.89	0.28	0.29
d 5 to 10														
ADG, kg	0.28	0.27	0.24	0.31	0.27	0.28	0.01	0.27	<0.0001	0.50	0.04	0.29	0.07	0.10
ADFI, kg	0.29	0.27	0.24	0.31	0.28	0.28	0.01	0.07	<0.0001	0.92	0.15	0.23	0.19	0.28
G:F	0.46	0.45	0.45	0.46	0.46	0.45	0.01	0.50	0.58	0.35	0.35	0.93	0.25	0.35
d 0 to 10														
ADG, kg	0.21	0.21	0.18	0.25	0.21	0.22	0.005	0.58	<0.0001	0.20	0.07	0.35	0.11	0.13
ADFI, kg	0.22	0.21	0.19	0.25	0.22	0.22	0.005	0.32	<0.0001	0.42	0.17	0.49	0.22	0.49
G:F	0.47	0.47	0.48	0.45	0.47	0.47	0.005	0.78	0.0008	0.35	0.27	0.49	0.23	0.13
d 10 to 28														
ADG, kg	0.51	0.50	0.49	0.53	0.50	0.50	0.01	0.57	<0.0001	0.96	0.80	0.90	0.99	0.09
ADFI, kg	0.69	0.68	0.64	0.73	0.69	0.69	0.01	0.32	<0.0001	0.88	0.81	0.50	0.94	0.27
G:F	0.62	0.61	0.60	0.64	0.62	0.62	0.005	0.44	<0.0001	0.65	0.87	0.14	0.90	0.48
d 0 to 28														
ADG, kg	0.40	0.40	0.38	0.43	0.40	0.40	0.005	0.48	<0.0001	0.63	0.68	0.74	0.57	0.06
ADFI, kg	0.53	0.52	0.48	0.56	0.52	0.52	0.01	0.29	<0.0001	0.72	0.90	0.43	0.80	0.27
G:F	0.59	0.59	0.58	0.59	0.59	0.59	0.005	0.40	0.004	0.93	0.53	0.30	0.77	0.24

[1]A total of 480 pigs (initial BW of 6.6 kg and 21 ± 2 days of age, PIC), with 6 pigs per pen and 10 replications per treatment

[2]Diets provided without (No) and with (Yes) 1,500 and 1,000 ppm of Luctarom per ton of phase 1 (d 0 to 10) and phase 2 (d 10 to 28) diets, respectively.

CHAPTER 6 - Effects of creep diet complexity on individual consumption characteristics and growth performance of neonatal and weanling pigs

ABSTRACT: In Exp. 1, a total of 96 sows (C29, PIC) and their litters were used to determine the effects of creep diet complexity on pre-weaning performance and the proportion of piglets consuming creep feed. The experimental treatments were: 1) No creep feed (n = 26), 2) Simple creep diet (n = 26), and 3) Complex creep diet (n = 44). Pigs fed the complex creep diet had higher (12.9%; $P < 0.03$) daily gains and tended to have higher (11.1%; $P < 0.06$) total gain than pigs fed the simple creep diet, with no creep pigs being intermediate. Litters fed the complex creep diet consumed twice the total (1.24 vs. 0.62 kg; $P < 0.0006$) and daily (412 vs. 205 g; $P < 0.0006$) creep feed intake of litters fed the simple creep diet. High complexity creep diet improved ($P < 0.0001$) the proportion of eaters from 28% to 68%. A greater ($P < 0.10$) proportion of eaters were nursing in the middle and posterior teats (57 and 52%, respectively) than in the anterior teats (38%). In Exp. 2, 675 pigs from Exp. 1 (initial BW 6.4 kg and 21.2 ± 0.2 d, C29 × 327 PIC) were used to determine if social facilitation occurs between eaters of creep feed and pigs that did not consume or non-eaters of creep feed in commercial nursery groups. The treatments were: Non-eater group - pigs that were not provided any creep feed or non-eaters of creep feed, Eater group - pigs that positively consumed creep feed, and Mix group – pigs that were 51% Non-Eaters and 49% Eaters. Each treatment had 25 pigs per pen and 9 replications (pens). In the initial 3 d post-weaning, eaters had 43% greater (139 vs. 97 g; $P < 0.01$) daily gains and 29% higher ($P < 0.002$) ADFI than non-eaters, with the mix group being intermediate. Overall daily gains of the eater group was 6.2% higher ($P < 0.05$) than the non-eater group. For

social facilitation to occur, weight gains of non-eaters in the mix pens should either be (1) closer to the weight gains of eaters in the mix pen, or (2) greater than the weight gains of the non-eater group. Results showed that non-eaters within the mix pens failed both criteria. In conclusion, the high complexity creep diet improved pre-weaning gains, litter creep feed intake, and the proportion of eaters of creep feed. Eaters of creep feed improved postweaning feed intake, daily gains, weight uniformity, and reduction of postweaning lag. Mixing eaters with non-eaters within pens in large commercial groups did not stimulate feed intake and daily gains of non-eaters, which indicate that social facilitation did not occur.

Key Words: creep feeding, diet complexity, behavior, pigs

Introduction

Maximizing post-weaning pig performance is essential in improving lifetime growth efficiency and productivity. However, weaning is often characterized by a period of low feed intake caused by physical, physiological, and behavioral challenges that may result in a growth check and affect postweaning growth rates (McCracken et al, 1985; Nabuurs, 1993). Improving feed intake of weaned pigs during this transition period may be critical in improving post-weaning growth.

Creep feeding studies that evaluated individual pigs rather than whole litters have consistently demonstrated the benefit of creating “eaters”, which are pigs that positively consumed creep feed, on post-weaning feed intake and growth (Bruininx et al., 2002; Kuller et al., 2004, 2007b; Pluske et al., 2007). Identifying factors that can increase creep feed consumption and the proportion of pigs consuming creep feed may be important in improving success with this practice.

It is hypothesized that creep diet complexity may be an important factor. Previously, Fraser et al. (1994) and Pajor et al. (2002) showed significant improvements in both pre- and post-weaning feed intake in litters fed a more complex creep diet. However, there has been no work on evaluating the effects of creep diet complexity on individual consumption characteristics. It is also commonly speculated that weaned pigs that have pre-weaning experience to solid food may facilitate non-experienced pigs to discover food sources and initiate feeding when housed in large nursery groups (Weary, 2008). However, evidence of this social learning behavior is limiting.

Therefore, the objectives of this study were 1) to determine the effects of creep diet complexity on pre-weaning performance and the proportion of piglets consuming creep feed (Exp. 1), and 2) to determine if social facilitation occurs between eaters of creep feed and pigs that did not consume or had not been offered creep feed in commercial nursery groups (Exp. 2).

Materials and Methods

The experimental protocols used in this study were reviewed and approved by the Kansas State University Institutional Animal Care and Use Committee.

Experiment 1

A total of 96 sows (C29 PIC) and their litters were used in this study conducted at a commercial sow facility in northeast Kansas. Sows used in this experiment were from three batches of sows farrowed in February, 2009. Cross-fostering was performed within 24 h postfarrowing. At the start of the creep feeding experiment (d 18), sows were blocked according to date of farrowing and litter size and allotted to 3 experimental treatments using a randomized complete block design. In Treatment 1, litters were not provided any creep feed (No Creep). In Treatments 2 and 3, litters were provided either a Simple or Complex creep diet, respectively

(Table 6.1). There were 26 replicates for Treatments 1 and 2 and 44 replicates for Treatment 3. The higher number of replicates for Treatment 3 was intended to increase the number of eaters that were used for Exp. 2.

The Simple creep diet mainly contained 60% milo, 32% soybean meal, and 3% choice white grease, which was identical to the lactation diet offered to the sows. It was formulated to contain 3,503 kcal ME/kg and 0.97% standardized ileal digestible (SID) lysine. The Complex creep diet was mainly composed of 30% pulverized oat groats and 25% spray-dried whey, with specialty protein sources such as 10% extruded soy protein concentrate, 6% spray-dried porcine plasma, and 6% select menhaden fish meal. It also contained 5% lactose and 5% choice white grease. The diet included very low levels of soybean meal (2.3%) and corn (6.15%). The diet was formulated to contain 3,495 kcal ME/kg, 1.56% SID lysine, and 23% lactose. Chromium oxide was added to both diets at 1.0% to serve as a fecal marker. The Simple creep diet was in meal form while the Complex creep diet was in pellet form (2-mm pellets). Both creep diets were offered ad libitum from d 18 until weaning on d 21 using a rotary creep feeder with hopper (Rotecna Mini Hopper Pan, Rotecna SA, Spain). A single lactation diet (3,503 kcal ME/kg, 0.97% SID lysine) was used in the experiment. Sows were allowed free access to feed throughout lactation. Water was made available at all times for sows and their litters through nipple and bowl drinkers, respectively.

Piglets were weighed individually at d 0 (birth), 18 (start of creep feeding), and 21 (weaning). A sufficient amount of creep feed was placed on the hopper of the creep feeder at the start of the study (d 18) and the initial weight of the creep feeder was weighed and recorded. Feeders were weighed daily to calculate for daily and total creep feed intake for each litter. Individual consumption characteristics of pigs in creep-fed litters were determined using procedures adapted from Barnett et al. (1989) and Bruininx al. (2002). All creep-fed pigs were evaluated for consumption category at d 20 (48 h after creep feed was provided) by evaluating fecal material for the presence of green color provided by the chromic oxide marker in the creep diet. On the morning of the evaluation day, a fecal swab was obtained from each piglet and categorized as an eater if green color was visible from the fecal sample. Piglets that tested negative on the first fecal sampling were resampled 3 to 12 h before weaning (d 21). Piglets were categorized as non-eaters when no green color was detected from all the collected samples. General health of the sow and piglets were checked daily, and use of medication was monitored. Temperature in the farrowing facility was maintained at a minimum of 20 °C, and supplementary heat was provided to the piglets by using heat lamps when needed.

The relationship of creep consumption category and teat order was also determined. Teat order was defined as the specific teat (pair) nursed by each piglet with respect to the anatomical location of the nursed mammary gland (Kim, 2000). In this study, individual pigs categorized as eaters were marked on their back while non-eaters were unmarked. At d 20 (within 24 h before weaning), suckling bouts from 20 litters were photographed using a digital still camera (Sony Cybershot DSC W55). Litters with less than 50% eaters were chosen to obtain a good distribution of eaters and non-eaters. The photograph of each suckling bout was then used to determine teat location and rank of each individual piglet in the litter. A distribution of teat order in three classes was also made based on the preferred teat pair suckled by the piglets: anterior (teat pairs 1 and 2), middle (teat pairs 3, 4, and 5), and posterior (teat pairs 6 and 7).

Experiment 2

From a total of 1,024 pigs weaned in Exp. 1, 675 pigs (initial BW 6.4 kg and 21.2 ± 0.2 d, C29 × 327 PIC) were allotted to 3 treatments using a completely randomized design. The treatments for this study were: Treatment 1 - composed of pigs that were not provided any creep feed or pigs that did not consume creep feed even when offered (Non-Eater), Treatment 2 - composed of pigs that positively consumed creep feed (Eater), and Treatment 3 – composed of pigs that were 51% Non-Eaters and 49% Eaters (Mix). Each treatment had 25 pigs per pen and 9 replications (pens). Each pen was equipped with 1 10-hole, self-feeder (Farmweld, Inc., Teutopolis, IL) and 1 cup drinker to provide ad libitum access to feed and water. The experiment was conducted at a commercial nursery facility in northeast Kansas.

All pigs were fed a budget of 0.45 and 0.90 kg per pig of commercial SEW and Transition diet (Key Feeds, Clay Center, KS), respectively. Pigs were fed a standard Phase 2 diet until the end of the study (d 28 postweaning). The total amount of feed offered in the first 3 d post-weaning was recorded. To determine total and daily feed intake in the initial 3 d, feed was vacuumed out of the feeders and weighed. Pigs were weighed at d 0 (weaning), 3, 7, and 28 post-weaning to calculate for periodic and cumulative ADG.

In Exp. 1, data were analyzed as a randomized block design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with litter as the experimental unit. The model included creep diet complexity and block as the fixed and random effect, respectively. Except for farrowing group 1, each block included 1 litter each of the no creep and simple creep treatment and 2 litters of the complex creep treatment. This is to increase the number of eaters needed for Exp. 2. To determine the effects of consumption category within creep fed litters, the model included the main effects of creep diet complexity and consumption category and the interaction of creep diet complexity × consumption category as the fixed effects and block as the random effect with pig was the experimental unit. To determine the effects of consumption category within weight categories, the model included the main effects of consumption category and weight category and the interaction of consumption × weight category as the fixed effects and block as the random effect with pig as the experimental unit. Pigs for each consumption category were divided into 3 weight categories: top = least square mean + 1 standard deviation, middle = least square mean ± 1 standard deviation, and bottom = < least square mean - 1 standard deviation. The effects of creep diet complexity, weight category, and teat location on the proportion of eaters of creep feed were analyzed using the χ^2-square test in SAS. When treatment effect was a significant source of variation, differences were determined using the PDIFF option of SAS.

In Exp. 2, data were analyzed as a completely randomized design using the PROC MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with pen as the experimental unit. The model included consumption category and block as the fixed and random effects, respectively. When treatment effect was a significant source of variation, differences were determined using the PDIFF option of SAS. To test for evidence of social facilitation, the effect of consumption category were compared within the mix pens using PROC MIXED of SAS. The model included consumption category as the fixed effect and pen as the random effect with pig as the experimental unit. For the post-study analysis, pairwise comparisons between consumption categories were performed using PROC MIXED of SAS. The model included consumption category as the fixed effect and litter and weaning group as random effects. Pig was the experimental unit. Least square means were calculated for each independent variable. Statistical significance and tendencies were set at $P < 0.05$ and $P < 0.10$ for all statistical tests.

Results and Discussion

Experiment 1

The effects of creep diet complexity on pig and litter performance is shown in Table 6.2. Sows had an average parity of 4.3 ± 0.4 and lactation length of 21.2 ± 0.2 d. The average litter size at d 18 and 21 (weaning) was 10.7 ± 0.3 and 10.5 ± 0.3 piglets, respectively. Mortality rate during the creep feeding period (d 18 to 21) was 1.9% for all the three treatments. Results showed no differences ($P < 0.74$) in pig weaning weights; however, pigs fed the complex creep diet had higher (12.9%; $P < 0.03$) daily gains and tended to have higher (11.1%; $P < 0.06$) total gain than pigs fed the simple creep diet, with no creep pigs being intermediate. Total and daily gains of litters fed the complex creep diet was 4.1 and 5.0% higher than litters fed the simple creep diet, respectively; however, differences were not significant ($P > 0.58$). Likewise, there were no differences ($P < 0.70$) in litter weaning weights.

Fraser et al. (1994) compared a low complexity creep diet based on corn, barley, and soybean meal to a complex, commercial creep diet. In this study, pigs were offered creep feed from d 14 until weaning at d 28. Their results showed a tendency for higher daily gains during the week before weaning and weaning weights in pigs fed the high complexity diet. These results conformed to the current study, where an increase in creep diet complexity improved pre-weaning weight gains. This positive effect of increased diet complexity may be related to the quality of the two creep diets used. The complex creep diet was formulated to match the digestive capacity of young pigs, in which feed digestibility, palatability, and antigenic properties of the feed were considered. These same requirements were disregarded in the design of the simple creep diet. However, the lack of differences in pig and litter pre-weaning gains between the creep fed and no creep pigs would suggest that any benefit of increasing creep diet complexity was insufficient to see appreciable effects, especially when the duration of feeding and the amount consumed is considered.

Litters fed the complex creep diet consumed twice the total (1.24 vs. 0.62 kg; $P < 0.0006$) and daily (412 vs. 205 g; $P < 0.0006$) creep feed intake of litters fed the simple creep diet (Figure 6.1). Fraser et al. (1994) also observed similar differences in creep feed consumption in relation to diet complexity. In their study, the average creep feed intake of pigs fed a high and low complexity creep diet were correlated with their mean creep feeding scores (number of video frames of feeding behavior/pig/day). The slope of the regression line for the high complexity creep diet was double the slope for the low complexity creep diet, which indicates that pigs consumed about twice the amount of the high complexity diet per unit of feeding time. Pajor et al. (2002) also compared a complex creep diet high in CP and fat with a standard diet, and found a 52% greater consumption in pigs fed the high complexity diet.

Creep diet complexity also influenced the proportion of pigs consuming creep feed in whole litters (Figure 6.2). Increasing the complexity of the creep diet improved ($P < 0.0001$) the proportion of eaters from 28% to 68%. This suggests that the higher creep feed intake observed in litters fed the complex creep diet was due to a greater number of pigs positively consuming creep feed. The proportion of eaters achieved in this study for the complex creep diet was consistent with previous studies, where the same creep diet, feeder design, and creep feeding duration was used (Sulabo et al., 2008b,c,d). Relative to all the non-dietary and dietary factors previously investigated, diet complexity had the greatest influence in creating eaters of creep feed (Table 6.3). This indicates that the complexity of the creep diet may be one of the most important factors in stimulating individual pigs in the litter to consume creep feed.

Within the creep-fed treatments, there was no significant interaction between creep diet complexity and consumption category on individual pig performance prior to weaning (Table 6.4). Pigs that became eaters in creep-fed litters were lighter ($P < .0001$) at d 18 and at weaning regardless of the complexity of the creep diet. Eaters also tended to have lower ($P < 0.08$) total gains than non-eaters of creep feed. Daily gains of eaters were 7.2 and 5.6% lower than non-eaters; however, differences were not significant ($P > 0.12$). The distribution and performance of eaters and non-eaters according to weight category were also compared (Table 6.5). There were significant differences ($P < 0.0002$) in pig weights at d 18, at weaning, total gain, and daily gains between the bottom, middle, and top weight category for pigs fed either the simple or complex creep diet. A greater ($P < 0.0001$) percentage of eaters were observed among pigs in the bottom weight category for both creep-fed treatments; 47% in the simple creep diet and 83% in the complex creep diet. There was no interaction ($P > 0.50$; data not shown) between creep consumption category and weight class on any growth parameters in either the simple or complex creep treatments.

There are some contrasting findings in the differences in growth performance of eaters and non-eaters of creep feed prior to weaning. Bruininx et al. (2004) did not observe any differences in weaning weights between consumption categories; however, pigs categorized as good eaters (pigs that showed green feces in all three sampling times) grew 5.8% faster than both moderate eaters (pigs that showed green feces once or twice) and non-eaters during the creep feeding period. Likewise, Kim et al. (2005) observed 12.6% greater daily gains in good eaters compared to non-eaters when creep fed from d 12 to 31. In a recent study, Callesen et al. (2007) found a tendency for an interaction between weaning age (27 d, ‘early’ vs. 33 d, ‘late’) and creep consumption category, where late-weaned eaters had higher daily gains than late-weaned non-eaters.

In contrast, daily gains were similar between early-weaned eaters or non-eaters. Pluske et al. (2007) also observed a tendency for eaters to grow faster than non-eaters during the last week prior to weaning (d 31); however, overall pre-weaning gain and weaning weights were similar between consumption categories. Growth responses may also vary within periods in a single study. For example, Kuller et al. (2007b) fed a complex creep diet from d 7 to 24 of lactation and showed that eaters had 4% lower daily gains than non-eaters from d 7 to 13, similar growth rates from d 14 to 20, and 16% greater daily gains in eaters compared to non-eaters in the last 3 d prior to weaning. There were no differences in pig weaning weights between eaters and non-eaters of creep feed in this study. However, all of these previous studies provided creep feed for longer durations (2 to 3 weeks) and pigs were weaned at an older age (27 to 31 d) compared to the current study. This provided a greater opportunity for pigs to consume more creep feed that may have positively influenced pre-weaning gains, which may help explain the differences in results. In the current study, pigs that were identified as eaters were 7 to 8% smaller in body weight and were gaining 5 to 6% less than non-eaters prior to weaning regardless of the complexity of the creep diet. With the higher proportion of eaters on the bottom weight category, these would suggest that creep feeding is beneficial to smaller piglets within litters as an alternative source of nutrients during lactation.

Brooks and Tsourgiannis (2003) also suggested that teat order may be related to creep feed consumption, wherein pigs nursing in the posterior (less productive) teats may consume creep feed more readily than their counterparts nursing in anterior (more productive) teats. The relationship between teat order and creep consumption category is shown in Table 6. Overall, 37, 45, and 17% of the pigs were found nursing in the anterior (teat pairs 1 and 2), middle (teat pairs 3, 4, and 5), and posterior (teat pairs 6 and 7) teats. There were 49% eaters and 51% non-eaters in the litters evaluated. Results showed a tendency ($P < 0.10$) for differences in the proportion of eaters according to teat location. A greater proportion of eaters were found nursing in the middle and posterior teats (57 and 52%, respectively) than in the anterior teats (38%). Previously, Pluske et al. (2007) found no differences in the preference of eaters for the anterior or posterior teats, which is in contrast with the results of the current study. Typically, piglets that nurse from the posterior teats are smaller and less competitive than those nursing from anterior teats (Pluske and Williams, 1996; Kim et al., 2000). The lower ability of smaller pigs to compete at the udder and extract milk may predispose these pigs to consume more creep feed when it is offered. Therefore, the higher rate of eaters in the middle and posterior teats in the current study may support this assumption.

Experiment 2

The effect of creep consumption category on nursery pig performance and weight variation within pens is shown in Table 6.7. The initial weight of the eater group (at d 21) was numerically lower than the non-eater group and tended ($P < 0.08$) to be lower than the mix group. The lower initial weight of the eater group was expected, since it was a characteristic of the population of eaters weaned from Exp. 1. In the initial 3 d post-weaning (d 21 to 24), eaters had 43% greater (139 vs. 97 g; $P < 0.01$) daily gains than non-eaters, with the mix group being intermediate. The mix group tended to have higher ($P < 0.08$) daily gains than the non-eater group. This was mainly due to differences in initial feed intake (first 3 d post-weaning) between the groups. The eater group had higher ($P < 0.002$) ADFI than the non-eater and mix groups. The mix group also had higher ($P < 0.02$) ADFI than the non-eater group. There were no ($P > 0.23$) differences in G:F between the eater, non-eater, and mix groups during the initial 3 d period.

From d 3 to 7 postweaning (d 25 to 28), there were no ($P > 0.66$) differences in daily gains between the three groups. In the first 7 d post-weaning (d 21 to 28), the eater and mix groups had 12 to 10% higher overall daily gains, but differences were not significant ($P > 0.15$). Pig weights were similar ($P > 0.13$) between the three groups at d 24 and 28. From d 29 to 49, the eater group tended ($P < 0.07$) to have higher daily gains than the non-eater group, with the mix group being intermediate. Overall, daily gain of the eater group was 6.2% higher ($P < 0.05$) than the non-eater group, with the mix group being intermediate. There were no differences ($P > 0.14$) in pig weights at d 49 between the three groups. Though weight differences were numerical, it is worthy to note that despite starting at a lighter weight, eaters were the heaviest group and were 3% heavier (15.46 vs. 15.02 kg) than the non-eater group at d 49.

These results are consistent with previous findings (Bruininx et al., 2002; Kim et al., 2005; Pluske et al., 2007; Kuller et al., 2007b; Sulabo et al., 2008a,b). Bruininx et al. (2002) provided the first evidence that eaters of creep feed had higher daily gains than non-eaters and no creep pigs. Likewise, Kim et al. (2005) and Pluske et al. (2007) observed differences in initial post-weaning daily gains among pigs with varying creep feed consumption, where ‘good eaters’ of creep feed during lactation grew faster immediately after weaning than piglets classified as ‘moderate’ or ‘poor eaters’. The difference in postweaning feed intake between eaters and non-eaters has also been fairly consistent (Fraser et al., 1994; Delumeau and Meunier-Salaun, 1995; Bruininx et al., 2002; Carstensen et al., 2005; Sulabo et al., 2008b); though a few studies did not observe the same findings (Hedemann et al., 2007). Interestingly, most previous studies provided creep feed for 14 to 21 d and were weaned at an older age (ranging from 24 to 31 d) while the current study had a shorter creep feeding duration (3 d prior to weaning) and weaned at a younger age (21 d). These results suggest that individual pigs that do consume creep feed prior to weaning consume more feed and achieve higher daily gains postweaning even when creep fed for a short duration and weaned at 3 weeks of age. However, it is not known if the same responses can be expected in younger (< 3 weeks) weaning ages.

In an earlier trial performed under experimental conditions (Sulabo et al., 2008b), non-eaters were significantly heavier in initial nursery BW than eaters of creep feed. Similar to the current study, the initial weight difference also disappeared after only 3 d postweaning. Eaters had higher daily gains (25.4%, $P < 0.02$) than non-eaters, which was driven mainly by a tendency for a higher daily feed intake (17.1%, $P < 0.06$) in the first 3 days after weaning. The same was observed from d 0 to 7 post-weaning, where eaters also had higher ADFI ($P < 0.04$) and tended to have higher (15%, $P < 0.08$) daily gains than non-eaters. The similarity in the results of the two studies performed in experimental (5 to 7 pigs per pen) and commercial conditions (25 pigs per pen) may suggest a real and consistent effect of preweaning feed consumption of pigs on postweaning feed intake and growth performance.

At d 21 (weaning), there were no differences ($P > 0.16$) in initial pen coefficient of variation (CV) between the three groups. However, the weight variation in the eater group was 1.3 to 1.6 percentage units higher than in the non-eater and mix groups. There were no differences in pen CV at d 24, 28, and 49; however, the reduction in pen CV in the eater group tended to be greater (-3.2 vs. -0.9%; $P < 0.06$) at d 28 than the non-eater group, with the mix group being intermediate. Overall (d 21 to 49), the change in pen CV for the eater group was greater (-5.6%; $P < 0.03$) than both the non-eater and mix groups. These results suggest that individual consumption characteristics of pigs prior to weaning may be an important factor in improving pig weight uniformity in the nursery. The greater reduction in weight variation in eater groups may possibly be driven by faster growth of smaller pigs, especially during the first week postweaning.

Creep consumption category influenced ($P < 0.0001$) the percentage of fall back pigs during the initial 3 d post-weaning (Figure 6.3). Fall back pigs were those that did not gain weight or lost weight in the first 3 d post-weaning. Overall, 25% of the total population of weaned pigs in the study did not gain or lose weight during the initial 3 d post-weaning. However, eaters of creep feed responded better to weaning, with only 17% considered fall back pigs. For no creep pigs and non-eaters, 28 and 29% of pigs lost weight. This indicates that positive consumption of creep feed preweaning can reduce postweaning lag, despite a large proportion of eaters being smaller than non-eaters and no creep pigs.

Social facilitation is a rudimentary form of social learning in which individuals discover resources by following group members that have already learned to exploit these resources (Giraldeau and Caraco, 2000). Nicol and Pope (1994) and Held et al. (2000) both demonstrated that inexperienced pigs could be directed to the location of food by an experienced pig. If social facilitation really occurs, then transmission of information in locating and consuming a new food source between experienced (eaters) and inexperienced (non-eaters) pen mates may be important in reducing problems with low feed intake in newly-weaned pigs and improve weaning transition. In the current study, the mix group had higher ($P < 0.02$) ADFI and tended to have higher ($P < 0.08$) daily gains than the non-eater group during the initial 3 d post-weaning. Overall, the performance of the mix group was mostly intermediate of the eater and the non-eater groups. These differences may suggest that there may be evidence of social facilitation occurring; however, the best criterion is to evaluate the performance of the individual non-eaters and eaters within the mix pens.

In the mix pens, 49% were eaters and 51% were non-eaters (Table 6.8). At d 21 (weaning), eaters were 0.45 kg lighter ($P < 0.02$) than the non-eaters. From d 21 to 24, eaters had higher (162 vs. 69 g; $P < 0.0001$) daily gains than the non-eaters. This resulted in a 62% reduction (0.45 to 0.17 kg) in the weight differences between the eaters and non-eaters after 3 d post-weaning. From d 25 to 28, there were no ($P > 0.48$) differences in daily gains between eaters and non-eaters. However, eaters continued to have greater ($P < 0.04$) daily gains than non-eaters during d 21 to 28, d 29 to 49, and overall daily gains (d 21 to 49). For social facilitation to occur, weight gains of non-eaters in the mix pens should either be (1) closer to the weight gains of eaters in the mix pen, or (2) greater than the weight gains of the non-eater group. Results showed that non-eaters in the mix pens failed both criteria. In fact, the performance of eaters and non-eaters within the mix pens were similar to the performance of separate pens of eaters and non-eaters. This would then suggest that social facilitation did not occur between eaters and non-eaters of creep feed. These results were not consistent with the findings of Morgan et al. (2001), but concurred with Reynolds et al. (2008). Using pairs of pigs, Morgan et al. (2001) observed that the presence of an experienced piglet stimulated feed intake of a pair of piglets housed in the same pen and stimulated the initial feeding behavior of the inexperienced piglet. In another small study, Reynolds et al. (2008) found that the latency time of inexperienced piglets were longer when mixed with experienced (creep fed) piglets, which did not support the hypothesis of social facilitation between piglets differing in exposure to creep feed.

Using the entire population of pigs weaned from Exp. 1, a post-study analysis was performed to evaluate individual pig performance according to creep consumption category from lactation to 28 d post-weaning (Table 6.9). There were 5 categories of pigs compared: no creep pigs, simple non-eaters, complex non-eaters, simple eaters, and complex eaters. ‘Simple’ and ‘complex’ referred to the complexity of the creep diets offered to each individual pig preweaning.

At d 18 and d 21 (weaning), pigs identified as eaters of simple creep diets had lighter ($P < 0.03$) BW than non-eaters of both simple and complex creep diets. Eaters of the complex creep diet were lighter ($P < 0.0001$) than non-eaters of the complex creep diet. Weights of no creep pigs at d 18 and 21 were intermediate ($P > 0.28$). There were no ($P > 0.11$) differences in pre-weaning daily gains across creep consumption categories.

From d 21 to 28, eaters of the complex creep diet had higher ($P < 0.05$) daily gains than no creep pigs, non-eaters of the simple creep diet, and non-eaters of the complex creep diet in the first 3 d post-weaning. Likewise, eaters of the simple creep diet had higher ($P < 0.03$) daily gains than non-eaters of both the simple and complex creep diet. There were no ($P > 0.17$) differences in the initial daily gains of eaters of the simple creep diet and the no creep pigs. Daily gains during d 25 to 28 were similar ($P > 0.50$) across the different creep consumption categories. In the first week post-weaning (d 21 to 28), eaters of the complex creep diet had higher ($P < 0.009$) daily gains than non-eaters of either the simple or complex creep diet. A tendency ($P < 0.10$) for higher daily gains was also observed between eaters of the complex creep diet and no creep pigs. Eaters of the simple creep diet also had higher ($P < 0.004$) daily gains than non-eaters of the simple creep diet. From d 28 to 49, no ($P < 0.70$) differences in daily gains were observed. Likewise, there were no differences in overall post-weaning daily gains (d 21 to 49) between creep consumption categories.

The overall daily gains from d 18 of lactation to d 24, d 28, and d 49 were also evaluated (Table 6.8). From d 18 to 24, eaters of the complex creep diet had higher ($P < 0.04$) daily gains than no creep pigs and non-eaters of either the simple or the complex creep diet. Eaters of the simple creep diet had higher ($P < 0.007$) daily gains than non-eaters of the simple creep diet. From d 18 to 28, eaters of the complex creep diet had higher ($P < 0.006$) daily gains than non-eaters of either the simple or complex creep diet. A tendency ($P < 0.10$) for higher daily gains was observed between eaters of the complex creep diet and no creep pigs. Overall (d 18 to 49), there were no ($P < 0.34$) differences in daily gains across the different consumption categories.

The preparedness or ability of each pig category to withstand the weaning transition may be estimated by determining the transition ratio, which is calculated simply by the ratio of average weight gain during the first 3 d postweaning with the weight gain for the last 3 d before weaning. Postweaning daily gains of no creep pigs were 33% of their preweaning daily gains, while ADG of non-eaters of both the simple and complex creep diet were 29 and 24%, respectively. Eaters of either the simple or the complex creep diet had a higher transition ratio, gaining 45 to 48% of their preweaning daily gains. The calculated transition ratios for each pig category indicate that postweaning lag still occurred, even for those that consumed creep feed. However, the main difference is in the degree of the negative response. Eaters of the simple and complex creep diet responded about 20% better than either no creep pigs or non-eaters of creep feed.

The results also indicate that the benefits of preweaning consumption of creep feed on postweaning daily gains (and intake) can be realized regardless of the complexity of the diet. However, the advantage of greater complexity is the higher proportion of eaters that can be created within litters. In addition, the assumption that non-eaters of creep feed and no creep pigs are the same may be true based on their similar characteristics in growth and response to weaning.

In conclusion, increasing the complexity of the creep diet improved pre-weaning gains when creep feed was offered 3 d preweaning. The high complexity diet improved litter creep feed consumption and the proportion of eaters of creep feed in whole litters. Eaters of creep feed were identified as pigs with lower preweaning gains, lighter weaning weights, and tended to nurse more in the middle and posterior teats compared to non-eaters of creep feed. Individual creep feed consumption characteristics influenced postweaning feed intake, daily gains, weight uniformity, and reduction of postweaning lag. Social facilitation did not occur in weaned pigs housed in large commercial groups. The benefit of preweaning creep consumption on postweaning performance was independent of the complexity of the diet.

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Table 6-1. Composition (as-fed basis) of the simple and complex creep diets used in Exp. 1.

Item	Simple[1]	Complex[2]
Ingredient, %		
Corn	-	6.25
Milo	60.40	-
Soybean meal, 46.5% CP	31.65	2.32
Spray dried whey	-	25.00
Fine ground oat groats	-	30.00
Extruded soy protein concentrate	-	10.00
Spray-dried porcine plasma	-	6.00
Select menhaden fish meal	-	6.00
Lactose	-	5.00
Choice white grease	3.00	5.00
Monocalcium P, 21% P	1.35	0.35
Chromium oxide	1.00	1.00
Antibiotic[3]	-	1.00
Limestone	1.35	0.40
Zinc oxide	-	0.38
Salt	0.50	0.30
L-Lysine HCl	-	0.15
DL-methionine	-	0.15
Trace mineral premix[4]	0.15	0.15
Vitamin premix[5]	0.25	0.25
Sow add pack[6]	0.25	-
Acidifier[7]	-	0.20
Phytase[8]	0.10	-
Vitamin E, 20,000 IU	-	0.05
Total	100.00	100.00
Calculated analysis		
CP, %	19.6	23.9
SID Lysine, %[9]	0.97	1.56
ME, kcal/kg	3,503	3,495
SID Lysine:ME ratio, g/Mcal	2.77	4.47
Ca, %	0.87	0.79
Available P, %	0.38	0.56

[1]Diet fed in pellet form (2-mm pellets).
[2]Diet fed in meal form
[3]Contained 35 mg of Denagard® (Novartis Animal Health, Greensboro, NC) and 400 mg of Chlortetracycline per kg of complete diet
[4]Provided per kg of complete diet: 16.5 mg of Cu; 165.4 mg of Fe; 39.7 mg of Mn; 0.30 mg of Se; 165.4 mg of Zn; and 0.30 mg of I.
[5]Provided per kg of complete diet: 11,023 IU of vitamin A; 1,378 IU of vitamin D; 44 IU of vitamin E; 4 mg of vitamin K (as menadione dimethylpyrimidinol bisulfate); 50 mg of niacin; 28 mg of pantothenic acid (as d-calcium pantothenate); 8 mg of riboflavin; 0.04 mg of vitamin B12
[6]Sow add pack provided the following nutrients per kg of complete diet: 22 IU of vitamin E; 0.22 mg of biotin; 1.65 mg of folic acid; 5 mg of pyridoxine (as pyridoxine HCl); 551 mg of choline (as choline Cl); 50 mg of L-carnitine; 0.20 mg of chromium (as chromium picolinate)
[7]Calcium propionate
[8]Provided 750 FYT of Ronozyme P® phytase (DSM Nutritional Products, Parsippany, NJ)
[9]Standardized ileal digestible

Table 6-2. Effects of creep diet complexity on pig and litter performance.[1,2]

Item	No Creep	Creep diet complexity Simple	Complex	SE	*P*-value
No. of litters	26	26	44	-	-
No. of pigs/litter					
d 18 (start creep)	10.8	11.0	10.3	0.3	0.30
d 21 (weaning)	10.5	10.8	10.2	0.3	0.38
Weaning age, d	21.3	21.2	21.2	0.2	0.86
Pig weights, kg					
d 0 (post-fostering)	1.56	1.53	1.58	0.06	0.70
d 18 (start creep)	5.68	5.64	5.65	0.20	0.95
d 21 (weaning)	6.44	6.37	6.45	0.21	0.74
Total gain (d 18 to 21), g	758[ab]	721[a]	800[b]	0.03	0.06
Daily gain (d 18 to 21), g	292[ab]	278[a]	314[b]	12	0.03
Litter weights, kg					
d 0 (post-fostering)	16.53	16.80	16.35	0.87	0.90
d 18 (start creep)	59.83	60.78	57.87	3.02	0.60
d 21 (weaning)	67.66	68.51	65.87	3.27	0.70
Total gain (d 18 to 21), kg	7.82	7.72	8.04	0.33	0.72
Daily gain (d 18 to 21), kg	3.02	2.98	3.13	0.14	0.58

[1]Three groups of sows (total =96, PIC; avg. parity = 4.3 ± 0.4) were blocked according to day of farrowing and allotted to three treatments: No Creep = litter was not provided any creep feed, Simple = litter was provided a simple creep diet, Complex = litter was provided a complex creep diet. The data were analyzed with litter as the experimental unit.

[2]Creep feed with 1.0% chromium oxide was offered ad libitum from d 18 to weaning (21 d) using a rotary feeder with a hopper.

[a,b]Row values (least square means ± SE) with different superscripts differ ($P < 0.05$).

Table 6-3. Effects of non-dietary and dietary factors on the proportion of eaters in whole litters.

Factor	% Eater
Lactation feed intake[1]	
Restricted	57
Ad libitum	62
Creep feeder design[2]	
Pan feeder	42[a]
Rotary feeder	47[a]
Rotary feeder with hopper	69[b]
Creep feeding duration[3]	
2 days	71[a]
6 days	70[a]
13 days	80[b]
Feed flavor[4]	
Diet without flavor	73
Diet with flavor	69
Creep diet complexity	
Simple	28[a]
Complex	68[b]

[1]Sulabo et al., 2008a; creep fed for 18 days
[2]Sulabo et al., 2008b; creep fed for 3 days
[3]Sulabo et al., 2008c
[4]Sulabo et al., 2008d; creep fed for 3 days
[a,b]Within a factor, means with different superscripts differ ($P < 0.03$)

Table 6-4. Interactive effects of creep diet complexity and consumption category on pre-weaning performance of creep-fed pigs.[1,2]

Item	Simple		Complex		SE	*P*-value		
	Non-eater	Eater	Non-eater	Eater		Complexity	Category	Complexity × Category
n	203	79	145	304	-	-	-	-
Pig weight, kg								
d 0 (post-fostering)	1.53	1.52	1.57	1.56	0.06	0.62	0.63	0.87
d 18 (start creep)	5.74	5.27	5.93	5.52	0.20	0.40	<.0001	0.78
d 21 (weaning)	6.47	5.96	6.75	6.28	0.21	0.29	<.0001	0.82
Total gain, g	734	685	814	774	3.0	0.02	0.08	0.84
Daily gain, g	284	265	323	306	14.1	0.02	0.12	0.93

[1]Three groups of sows (total = 96, C29 PIC; ave. parity = 4.3±0.4) were blocked according to day of farrowing and allotted to three treatments: No Creep = litter was not provided any creep feed, Simple = litter was provided a simple creep diet, Complex = litter was provided a complex creep diet. In the Simple and Complex treatments, individual pigs were sampled at d 19 and 20 using fecal swabs to determine consumption category. Pig was categorized an Eater when they showed green-colored feces in at least one of the two samplings, while pig was categorized a Non-eater when the samples were negative for green-colored feces. The data was analyzed with pig as the experimental unit.

[2]Creep feed with 1.0% chromium oxide was offered ad libitum from d 18 to weaning (21 d) using a rotary feeder with a hopper.

Table 6-5. Effects of creep diet complexity on suckling pig performance according to weight category. [1,2]

	Simple				Complex				
Item	Bottom	Middle	Top	SE	Bottom	Middle	Top	SE	*P*-value
n	45	198	39	-	81	301	67	-	-
% of total	16	70	14	-	18	67	15	-	-
% Eaters	47	25	23	-	83	65	62	-	-
Pig weight, kg									
d 18 (start creep)	4.10	5.64	7.18	0.10	3.67	5.87	7.91	0.09	<.0001
d 21 (weaning)	4.62	6.37	8.06	0.12	4.32	6.68	8.8	0.09	<.0001
Total gain, g	517	729	886	38.1	650	813	893	33.0	<.0001
Daily gain, g	197	287	328	16.9	258	320	350	14.0	0.0002

[1]Three groups of sows (total = 96, C29 PIC; avg. parity = 4.3 ± 0.4) were blocked according to day of farrowing and allotted to three treatments: No Creep = litter was not provided any creep feed, Simple = litter was provided a simple creep diet, Complex = litter was provided a complex creep diet. Creep feed with 1.0% chromium oxide was offered ad libitum from d 18 to weaning (21 d) using a rotary feeder with a hopper. The data was analyzed with pig as the experimental unit.

[2]Weight categories for each population: Top = > Least square mean + 1 standard deviation, Middle = Least square mean ± 1 standard deviation, Bottom = < Least square mean - 1 standard deviation

Table 6-6. Proportion of eaters and non-eaters of creep feed according to teat location.[1]

	Consumption category	
Teat location	Non-eater	Eater
Number of pigs		
Anterior	35	21
Middle	30	39
Posterior	13	14
Percentage of pigs		
Anterior	62	38[a]
Middle	43	57[b]
Posterior	48	52[b]

[1]Eaters of creep feed in a litter were marked and non-eaters were un-marked. Suckling bouts (n = 20 litters) were photographed within 24 h before weaning using a digital still camera to determine each individual pig's preferred teat (or pair) at d 21 of lactation. Anterior = teat pairs 1 and 2, middle = teat pairs 3, 4, and 5, posterior = teat pairs 6 and 7.

[2]Chi-square test: $P < 0.10$.

Table 6-7. Effects of creep consumption category on nursery pig performance and weight variation within pens.[1,2]

	Consumption category				*P*-value		
Item	Non-Eater (N)	Eater (E)	Mix (M)	SE	N vs. E	N vs. M	E vs. M
No. of pens	9	9	9	-	-	-	-
Pig weight, kg							
d 21 (weaning)	6.40	6.33	6.44	0.13	0.41	0.97	0.42
d 24	6.70	6.75	6.82	0.12	0.52	0.13	0.34
d 28	7.43	7.57	7.47	0.18	0.72	0.24	0.39
d 49	15.02	15.46	15.39	0.42	0.14	0.21	0.80
Daily gains, g							
d 21 to 24	97	139	125	21.3	0.01	0.08	0.35
d 25 to 28	182	181	188	20.3	0.97	0.69	0.66
d 21 to 28	146	164	161	10.5	0.15	0.22	0.82
d 29 to 49	362	381	373	16.4	0.07	0.29	0.40
d 21 to 49	307	326	319	13.5	0.05	0.19	0.46
ADFI (d 21 to 24), g	103	133	116	17.1	<.0001	0.02	0.002
G:F (d 21 to 24)	0.92	1.03	1.07	0.09	0.38	0.23	0.75
Pen CV, %[3]							
d 21 (weaning)	23.8	25.1	23.5	0.8	0.26	0.78	0.16
d 24	22.3	22.5	21.3	0.9	0.83	0.42	0.29
d 28	22.9	21.8	21.2	0.9	0.40	0.19	0.63
d 49	20.7	19.5	19.6	1.0	0.40	0.43	0.96
CV change, %[4]							
d 21 to 24	-1.6	-2.5	-2.3	0.8	0.39	0.52	0.82
d 21 to 28	-0.9	-3.2	-2.3	0.8	0.06	0.26	0.43
d 21 to 49	-3.0	-5.6	-3.1	0.8	0.03	0.96	0.02

[1]A total of 675 pigs (initial BW of 6.43 kg and 21.2 ± 0.2 d of age, C29 × 327 PIC), with 25 pigs per pen and 9 replications per treatment. Group composition: Non-eater (N) = composed of non-creep fed pigs and Non-eaters of creep feed, Creep (C) = composed of Eaters of creep feed, and Mix = composed of 51% Non-eaters and 49% Eaters of creep feed. The data was analyzed with pen as the experimental unit.

[2]All treatments were fed a budget of 0.454 and 0.907 kg per pig of a commercial SEW and Transition diet (Key Feeds, Clay Center, KS), respectively.

[3] Pen CV = coefficient of variation within pen.

[4]CV change = difference in pen CV between two time points; final %CV – initial %CV.

Table 6-8. Post-weaning growth performance of Non-Eater and Eater pigs within Mix pens (50% Non-eater:50% Eaters). [1,2]

	Consumption category			
Item	Non-Eater	Eater	SE	*P*-value
n	113	108	-	-
% of total	51	49	-	-
Pig weights, kg				
d 21	6.72	6.27	0.14	0.02
d 24	6.92	6.75	0.14	0.38
d 28	7.73	7.52	0.15	0.35
d 49	15.16	15.43	0.37	0.54
Daily gains, g				
d 21 to 24	69	162	16.1	<.0001
d 25 to 28	202	192	11.4	0.48
d 21 to 28	145	179	10.1	0.002
d 29 to 49	354	377	13.7	0.04
d 21 to 49	302	328	11.4	0.007

[1]A total of 675 pigs (initial BW of 6.43 kg and 21.2 ± 0.2 d of age, C29 × 327 PIC), with 25 pigs per pen and 9 replications per treatment. Group composition: Non-eater (N) = composed of non-creep fed pigs and Non-eaters of creep feed, Creep (C) = composed of Eaters of creep feed, and Mix = composed of 51% Non-eater and 49% Eaters of creep feed. In the Mix treatment, differences between Non-eater and Eater pigs were analyzed with pen as the block and pig as the experimental unit.

[2]Pigs were fed a budget of 0.45 and 0.90 kg per pig of a commercial SEW and Transition diet, respectively.

Table 6-9. Post-study analysis of individual pig performance according to creep consumption category from lactation to 28 d post-weaning.[1,2]

		Simple		Complex		
Item	No Creep	Non-Eater	Eater	Non-Eater	Eater	*P*-value
n	285	203	79	145	304	-
Pig weights, kg						
d 0 (post-fostering)	1.53±.08	1.50±.08	1.51±.08	1.52±.06	1.50±.06	0.89
d 18 (start creep)	5.68±.19[abc]	5.74±.19[bc]	5.39±.21[a]	5.92±.16[c]	5.53±.16[ab]	0.0002
d 21 (weaning)	6.43±.21[abc]	6.47±.21[bc]	6.09±.23[a]	6.74±.17[c]	6.29±.16[ab]	0.0002
d 24	6.66±.22	6.64±.22	6.48±.24	6.91±.18	6.67±.17	0.27
d 28	7.40±.24	7.36±.24	7.18±.26	7.64±.20	7.39±.18	0.27
d 49	14.74±.45	14.87±.45	14.93±.51	15.29±.39	15.03±.36	0.83
Daily gains, g						
d 18 to 21	288±11	279±11	273±14	318±11	301±9	0.11
d 18 to 24	170±9[ab]	160±9[a]	182±11[bc]	172±8[ab]	195±8[c]	<.0001
d 18 to 28	174±8[ab]	162±8[a]	179±9[bc]	173±7[ab]	189±6[c]	0.001
d 18 to 49	294±9	296±9	308±10	302±8	309±7	0.34
d 21 to 24	95±17[ab]	80±17[a]	131±20[bc]	75±15[a]	135±13[c]	<.0001
d 21 to 28	141±10[abc]	128±10[a]	155±11[bc]	131±9[a]	161±8[c]	<.0001
d 21 to 49	299±10	301±10	316±11	305±9	315±8	0.24
d 25 to 28	175±11	160±11	176±14	170±11	180±9	0.50
d 28 to 49	352±11	360±11	369±13	361±10	367±9	0.70
Transition ratio[3]	0.33	0.29	0.48	0.24	0.45	-

[1]A total of 1,016 pigs (C29 × 327 PIC) were used for the analysis

[2]Pig categories: No Creep = pig not provided any creep feed during lactation, Simple = pig provided a simple creep diet during lactation, Complex = pig provided a complex creep diet during lactation, Non-Eater = pig tested negative for green-colored feces, Eater = pig tested positive for green-colored feces; Data was analyzed with pig as the experimental unit.

[3]Transition ratio = weight gain 3 d postweaning (d 21 to 24) divided by the weight gain in the last 3 d before weaning (d 18 to 21).

[a,b,c]Row values (least square means ± SE) with different superscripts differ ($P < 0.05$).

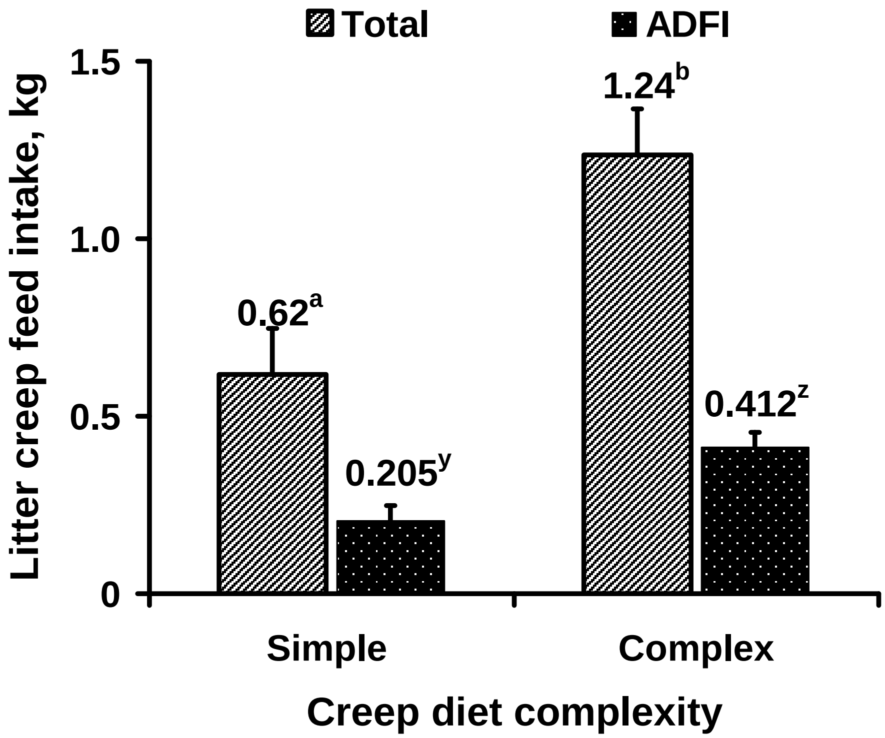

Figure 6-1. Total and daily creep feed intake of litters (mean ± SE) fed either simple or complex creep diets. [a,b]$P < .0006$; [y,z]$P < .0006$.

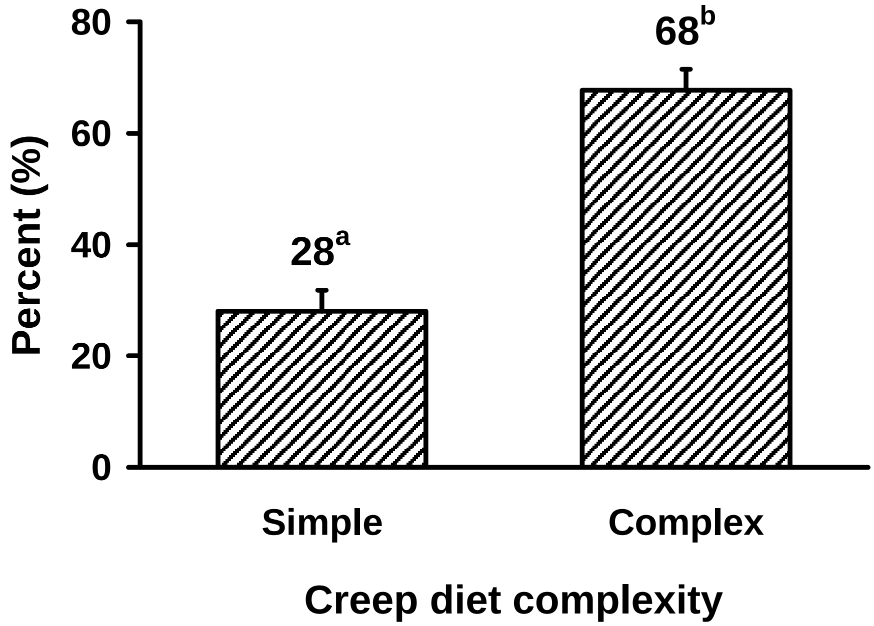

Figure 6-2. Effect of creep diet complexity on the proportion (mean percent ± SE) of eaters in whole litters. [a,b]P < .0001.

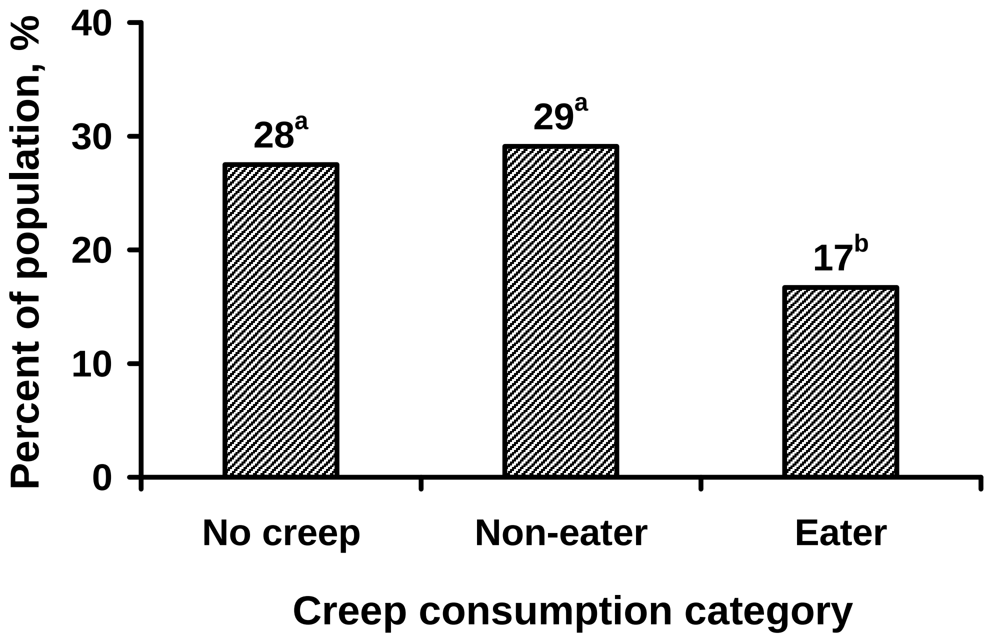

Figure 6-3. Percentage of fall back pigs during the initial 3 d post-weaning within each creep consumption category. Fall back pigs were those that did not gain weight or lost weight in the first 3 d postweaning. No creep = pigs that were not provided creep feed pre-weaning, Non-eater = pigs that were negative for creep feed consumption, Eater = pigs that positively consumed creep feed. $\chi^2 = 18.0$; Category effect, [a,b]$P < .0001$.