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Early Gestation Feeding Method Improves Reproductive Performance of Sow

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ABSTRACT

The relationship between feed intake during early gestation and sows' reproductive performance is controversial. The purpose of this experiment was to investigate the effects of different feeding strategies during early gestation on reproductive performance in sows. A total of 24 primiparous sows were randomly assigned to one of the following three treatments: Treatment 1: Feed 1.5 kg from mating to day 30 of gestation; Treatment 2: Feed 1.5 kg from mating to day 7, then feed 2.5 kg from days 8 to 30; Treatment 3: Feed 2.5 kg from days 0 to 30. Increased feed intake affected body weight during early gestation. The treatment provided 2.5 kg per day resulted in the highest litter size. While there was no significant difference in litter size between Treatment 2 and Treatment 3, the birth weight and weaning weight of piglets in Treatment 2 seemed better than those in Treatment 3. Increasing feed intake during early gestation (days 0–30) significantly increased litter size. However, Treatment 2, which increased feed intake from days 8 to 30, improved growth performance but did not enhance reproductive performance. In conclusion, high feed intake throughout early gestation significantly increased litter size but also had the potential to increase the number of stillbirths.

Keywords: early stage; feeding level; gestation; reproductive; sow

INTRODUCTION

During a sow's pregnancy, the first month is the most crucial gestation phase for pigs, lasting until Day 35 (Peltoniemi *et al.,* 2016). Generally, the embryo number should be around 30-40, but it will decrease by 60%-70% due to many factors, such as the uterine space, hormone secretion, nutrient supply, and management in the early gestation stage. The abnormal development of the embryo between days 18 and 30 of early gestation had an overall mortality rate of 10%-20% (Bidarimath & Tayade, 2017). Feeding is an important factor in reproductive performance in the principle. According to the principle demonstrated by Parr *et al.* (1993), a high level of feed intake will increase the sow's body weight and metabolic rate; meanwhile, increasing the steroid hormone clearance rate by the liver causes the progesterone concentration to decrease in the blood. However, progesterone is the hormone that can stabilize the uterine, and when the progesterone level decreases, it leads to a loss in the embryos' survival rate (Dyck & Strain, 1983). When the progesterone concentration decreases, it will cause the asynchronous in-utero development of conceptuses and deficits in vasculature in the endometrium and placenta (Bidarimath *et al.,* 2017). Foxcroft (2020) claimed that progesterone positively correlates with embryonic survival rate. Thus, since the late 19th century and early 20th century, animal husbandry has provided relatively low feed intake during the early gestation period.

However, some recent studies have shown that increased feed intake during early gestation can increase progesterone concentration (Athorn *et al.,* 2013), embryo survival rate (Condous *et al.,* 2014), pregnancy rate (Dyck and Strain, 1983; Quesnel *et al.,* 2010), and reduce stereotypic behavior (Spoolder & Vermeer, 2015). Meanwhile, the researchers pointed out that the increased consumption of the feeds did not affect the embryo survival rate (Toplis *et al.,* 1983; Athorn *et al.,* 2012; Athorn *et al.,* 2013). The controversial principles confuse the feed intake level in the sow's early gestation. Lyderik *et al.* (2023) mentioned that the requirements for the conceptus growth are low during early gestation. Inconsistent results of early gestation feeding are influenced by factors in sows, such as low birth weight (Magnabosco *et al.,* 2016), back fat thickness, and body weight changes (Ha *et al.,* 2024). Feeding strategies, especially, can directly affect physical parameters. Based on the two principles we reviewed, there is a conflict regarding their impact on litter size. Therefore, this experiment incorporated different feeding durations as a factor to assess reproductive performance. The objective of this experiment was to investigate whether the timing of feed intake during the early gestation stage influences the reproductive performance of first-parity sows.

MATERIALS AND METHODS

Animal Treatment

This experiment used 24 gilts with an average weight of 194.52 kg and a body condition score of 3.08. The measurements were taken 1 day before mating. The sows were then randomly assigned to 3 treatments on the same day. Treatment 1: Feed intake 1.5 kg/day (0-30 days), Treatment 2: Feed intake 1.5 kg/day (0-7 days) and 2.5 kg/day (8-30 days), and Treatment 3: Feed intake 2.5 kg/day (0-30 days). The calculated composition of the experimental diets is presented in Table 1. Each treatment had 8 replicates. Gilts were kept in individual stalls. After mating, the total number of pregnant gilts was 18; each treatment had 5, 7, and 6 replicates separately. The gilts were in the dry sow house in the pre-mating, mating, and gestation of 0–79 days. On day 80 of gestation, the gilts were moved to the chamber containing the farrowing pen until weaned.

Animal Care and Ethics Approval

Female pigs were housed in partially slotted and solid concrete floor pens with a feeder and a nipple drinker. Feed was restricted during the experimental period, and the water supply was unlimited. In the early gestation, the feed would follow the treatment mentioned above. The same feeding strategies were provided for all sows during the middle gestation, late gestation, and lactation stages. All the animals were under the supervision of the International Animal Care and Use Committee of the National Pingtung University of Science and Technology (NPUST112-121).

Table 1. Composition and calculated nutrient content of dietary diets

Ingredient %	Gestation feed	Lactation feed
Corn	68.9	63.6
Soybean	17.1	22.1
Wheat bran	8.0	8.0
Soybean oil	3.0	3.0
Dicalcium phosphate	1.4	1.7
Calcium carbonate	1.1	0.9
Salt	0.3	0.5
Minerals[1)]	0.1	0.1
Vitamins[2)]	0.1	0.1
Energy digestible	3486	3484
Crude protein, %	14.4	16.4
Calcium, %	0.8	0.86
Phosphorus, %	0.38	0.46
Lysine, %	0.74	0.88
Methionine + cysteine, %	0.38	0.44

Note: [1)]Mineral contained Fe at least 150,000 mg; Zn 90,000-100,000 mg; Mn at least 60,000 mg; Cu 20,000-25,000 mg; I at least 600 mg; Se at least 300 mg; and Co at least 300 mg, [2)]Vitamin contained vitamin: A 12,000,000 IU; D3 1,500,000 IU; E 60,000 mg (total vitamin E 150 IU); K3 2,000 mg; B1 2,000 mg, B2 10,000 mg; B6 5,000 mg; B12 60 mg; pantothenic acid 30,000 mg; niacin 35,000 mg; folic acid 3,000 mg; and biotin 300 mg.

Data and Sample Collection

The data collected from sows included the number of times the sow received artificial insemination (mating frequency), mating stability score (MSS: 1= totally unstable to 5= extremely stable), and body dimensions (width, depth, and length) measured using a caliper. For each period, backfat thickness was measured using a Renco LEAN-MEATER®, along with loin eye muscle area (measured using an ultrasound machine), body condition score, and body weight. After farrowing, the following data were recorded: pregnancy rate (i.e., farrowing number/mating number × 100), litter size, farrowing duration (in minutes), farrowing time period, and the weaning-to-estrus interval. Additionally, parameters for 261 piglets (average litter size was 15.35) were recorded, including birth weight, weaning weight, and weaning number.

Statistical Analysis

Completed data will be collected and subjected to a statistical analysis system in SAS (SAS Institute, 2021). Differences among treatment means were determined using analysis of variance (ANOVA) and Duncan's new multiple range test at the $p<0.05$ significance level.

RESULTS

At 30 days post-mating, high feed intake only affected body weight, not back fat or body condition score (Table 2). Notably, sows had the most significant body depth in Treatment 1. Table 3 shows that successful pregnancy is primarily related to physical status and is not associated with feeding treatments. The table demonstrates that higher sow body weight and increased mating frequency positively influenced pregnancy rates (Table 3). Sows exhibiting a stable standing response to the boar were inseminated even on the third mating day, resulting in varying mating frequencies. However, sow body dimensions did not directly affect pregnancy rates.

Table 4 shows physical parameter changes among treatments. Treatments 2 and 3, with high early gestation feed intake, significantly increased gestational weight gain, with Treatment 3 showing the highest gain from mating to 80 days gestation. Treatment 2 had significantly lower body condition score loss from mating to farrowing (Table 5). However, back fat changes were insignificant in any period (Table 6). The loin eye muscle area increased from 80 days gestation to farrowing/weaning (Table 7) in the treatment with high feed intake from 8-30 days gestation.

Table 8 shows that Treatment 3, with high feed intake during early gestation (0-30 days), resulted in the largest litter size. Treatment 2 led to a longer farrowing duration and weaning-to-estrus interval. Treatment 3 showed potential piglet loss before weaning due to lower birth weights, although this was not statistically significant.

Table 2. Physiological parameters of sows after 30 days of mating under different early gestation feeding strategies

Physiological variables	Treatments			SEM	p-value
	Treatment 1	Treatment 2	Treatment 3		
Mating BW (kg)	197.25	193.94	192.37	0.74	NS
BW after mating 30 days	201.41[a]	209.43[b]	213.22[b]	1.41	**
Mating BF (mm)	22.25	22.22	23.22	0.79	NS
BF after mating 30 days	22.25	23.44	23.89	0.84	NS
Mating BCS	3.13	3.00	3.11	0.06	NS
BCS after mating 30 days	3.00	3.00	3.06	0.04	NS
Mating frequency	5.00	5.11	5.00	0.27	NS
MSS	4.56	4.58	4.30	0.13	NS
Gilt body width (mm)	300.87	309.91	311.62	4.86	NS
Gilt body depth (mm)	427.95[b]	378.41[a]	374.00[a]	6.71	**
Gilt body length(cm)	136.06	138.00	138.22	1.66	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. BW= body weight, BF= back fat, BCS= Body Condition Score (1= emaciated, 3= optimal, 5= obese), MSS=mating stable score (1, totally unstable to 5, extremely stable). [a,b]= Means in the same row with different superscript differ significantly, NS p>0.05,** p<0.01.

Table 3. Physiological parameters of sows during early gestation associated with pregnancy success

Physiological variables	Successful pregnancy		SEM	p-value
	Success	Failure		
Mating BW (kg)	194.52	194.17	0.65	NS
BW after mating 30 days	209.81[b]	204.84[a]	1.24	*
Mating BF (mm)	22.28	23.25	0.70	NS
BF after mating 30 days	23.11	23.50	0.74	NS
Mating BCS	3.11	3.00	0.05	NS
BCS after mating 30 days	3.03	3.00	0.10	NS
Mating times	5.33[b]	4.38[a]	1.00	*
MSS	4.43	4.55	0.11	NS
Gilt body width (mm)	309.00	304.84	4.29	NS
Gilt body depth (mm)	396.21	382.95	5.92	NS
Gilt body length (cm)	137.64	137.13	1.47	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. BW= body weight, BF= back fat, BCS= Body Condition Score (1= emaciated, 3= optimal, 5= obese), MSS=mating stable score (1, totally unstable to 5, extremely stable). [a,b]= Means in the same row with different superscript differ significantly, NS p>0.05,*p<0.05.

Table 4. Body weight changes of sows across different reproductive periods under various early gestation feeding strategies

BW variables	Treatments			SEM	p-value
	Treatment 1	Treatment 2	Treatment 3		
Mating 0 days to 30 days	4.05[a]	20.32[b]	21.31[b]	1.07	***
Mating 0 days to 80 days	40.55[a]	45.34[ab]	50.87[b]	2.68	*
Mating 0 days to 100 days	76.82	77.34	87.08	4.38	NS
Mating 0 days to farrowing day	43.85	39.90	48.92	7.96	NS
Mating 0 days to farrowing after 2 weeks	37.40	32.44	34.12	8.96	NS
Mating 0 days to farrowing after 4 weeks	21.76	20.22	26.64	10.94	NS
Gestation 100 days to farrowing	32.97	37.44	38.16	6.66	NS
Farrowing day to after 2 weeks	-6.45	-7.46	-14.80	3.94	NS
Farrowing day to after 4 weeks	-22.09	-19.68	-22.28	2.98	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. BW= body weight. [a, b]= Means in the same row with different superscript differ significantly, NS p>0.05, *p<0.05, ***p<0.0001.

Table 5. Body condition score changes of sows across different reproductive periods under various early gestation feeding strategies

BCS variables	Treatments			SEM	p-value
	Treatment1	Treatment 2	Treatment 3		
Mating 0 day to 30 days	-0.17	0.00	-0.07	0.07	NS
Mating 0 day to 80 days	0.00	0.00	-0.07	0.05	NS
Mating 0 day to 100 days	0.33	0.50	0.50	0.03	NS
Mating 0 day to farrowing day	-0.30[a]	0.10[b]	-0.25[a]	0.07	**
Farrowing day to after 2 weeks	-0.20	-0.10	-0.20	0.09	NS
Farrowing day to after 4 weeks	-0.40	-0.30	-0.40	0.17	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. BCS = Body Condition Score (1= emaciated, 3= optimal, 5= obese). [a,b]= Means in the same row with different superscript differ significantly, NS p>0.05, ** p<0.01.

Table 6. P2 thickness (mm) changes of sows across different reproductive periods under various early gestation feeding strategies

BF variables	Treatments			SEM	p-value
	Treatment1	Treatment 2	Treatment 3		
Mating 0 day to 30 days	0.50	1.00	1.14	0.45	NS
Mating 0 day to 80 days	1.67	1.60	2.24	0.72	NS
Mating 0 day to 100 days	4.33	4.60	5.20	1.40	NS
Mating 0 day to farrowing day	2.00	2.20	2.40	1.06	NS
Farrowing day to after 2 weeks	2.80	0.40	1.40	1.15	NS
Farrowing day to after 4 weeks	1.80	-0.40	0.00	1.25	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. BF= back fat, NS p>0.05. P2 thickness= a measurement of the backfat thickness of a sow at the P2 position, which is 65 mm from the midline of the pig's left side.

Table 7. Loin eye muscle area (cm²) changes in sows during late gestation and lactation under different early gestation feeding strategies

Loin eye muscle area variables	Treatments			SEM	p-value
	Treatment1	Treatment 2	Treatment 3		
Gestation 80 days to farrowing (AV.)	-6.60	2.56	-7.40	3.04	NS
Gestation 80 days to weaned (AV.)	-8.60	-8.46	-11.96	4.04	NS
Gestation 80 days to farrowing (%)	-8.60[a]	4.38[b]	-9.90[a]	3.93	*
Gestation 80 days to weaned (%)	-11.18[a]	7.50[b]	-13.44[a]	5.33	*

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. [a,b]= Means in the same row with different superscript differ significantly, NS p>0.05, *p<0.05.

Table 8. Reproductive performance of sows under different early gestation feeding strategies

Reproductive performance variables	Treatments			SEM	p-value
	Treatment1	Treatment 2	Treatment 3		
Sow traits					
Farrowing length (minutes)	132.83[a]	212.75[b]	152.00[a]	16.12	*
Farrowing time period	3.33	3.00	2.50	0.51	NS
Weaned to estrus interval (days)	3.50[a]	4.00[b]	3.30[a]	0.13	**
Progeny traits					
Litter size (head)	13.83[a]	14.50[a]	17.14[b]	0.69	*
Number Born Alive	12.00	13.75	13.67	1.36	NS
Stillbirth number	0.33	0.50	2.50	0.80	NS
Birth weight (kg)	1.57	1.52	1.40	0.07	NS
Weaning weight (kg)	8.53	8.09	7.52	0.49	NS
Weaned number	9.60	11.00	11.5	0.85	NS

Note: Treatment 1= 1.5 kg feed per day for 30 days post-artificial insemination. Treatment 2= 1.5 kg for the first 7 days, then 2.5 kg from days 8 to 30. Treatment 3= 2.5 kg per day for 30 days post-artificial insemination. Farrowing time period= 1, 12 am-6 am, 2, 6 am-12 pm, 3, 12 pm-6 pm 4, 6 pm-00 am. [a,b]= Means in the same row with different superscript differ significantly, NS p>0.05, *p<0.05, **p<0.01.

DISCUSSION

The nutrition opinions on sow feed intake during early gestation vary widely. This experiment investigated whether high feeding levels during early gestation (days 0–30) could improve litter size. The results were consistent with previous studies showing that increased feed intake during days 1–25 (Condous *et al.*, 2014) of early gestation improved progesterone concentrations and embryo survival rates, respectively. However, in this study, increased feed intake during days 8–30 did not substantially improve litter size. Mallmann *et al.* (2020) similarly found no significant increase in litter size when diet intake was increased (1.8, 2.5, and 3.2 kg/day) during days 6–30 of early gestation. These findings suggest that the timing of feed intake during early gestation affects litter size, but further research is needed on the first week of early gestation. Additionally, treatments 2 and 3 showed higher body weights 30 days after mating, and Table 3 indicates that sows that successfully became pregnant had higher body weights.

Langendijk (2021) identified progesterone as crucial for endometrial remodeling, facilitating implantation and nutrient delivery to embryos, particularly supporting preimplantation embryo survival. Che *et al.* (2015) found that increased dietary intake does not affect peripheral progesterone but increases luteal tissue progesterone in early-pregnant Large White gilts. This explains the results in Treatment 3, where increased body weight after 30 days of gestation, without changes in body condition score or back-fat thickness, maintained progesterone concentration via an alternative pathway, leading to the positive results on litter size in the present study.

However, Parr *et al.* (1993) and Mattos *et al.* (2017) mechanism is inconsistent with recent studies (Athorn *et al.*, 2013; Condous *et al.*, 2014) regarding how high feed intake affects litter size. High energy intake has shown conflicting results: some studies report improvements in luteal function and embryo survival rate (Langendijk, 2015; Leal *et al.*, 2019), while others show no improvement in litter size (Wang *et al.*, 2016). An excessively low feed intake during embryo elongation can compromise embryonic survival by affecting ovarian function in the days following fasting restriction (Langendijk *et al.*, 2017). Researchers investigating factors affecting reproductive performance have focused on feed intake, as well as protein and fat levels. Studies have shown that an excessively high protein level negatively impacts offspring development (Silveira *et al.*, 2022) and that a maternal diet high in fat suppresses placental development (Wang *et al.*, 2015). Investigations into protein levels (Pedersen *et al.*, 2019) concluded that increased protein in early gestation diets does not affect reproductive performance. These studies were conducted at various times during early gestation.

On the other hand, increased feed intake starting 8 days after mating can improve body weight and body reserves. However, the decrease in embryo survival rate is due to the relatively lower nutrition provided during the first week of the preimplantation period, which inhibits progesterone synthesis and subsequently causes unsuccessful embryo implantation in the endometrium. Progesterone is the hormone that controls the nutrients and signals when the embryo is attached to the uterus (Langendijk, 2021). In the receptive endometrium, progesterone activates endometrial stromal cells, prompting their differentiation into decidual cells. This process is crucial for the establishment of endometrial receptivity during the implantation period (Okada *et al*., 2018). A low number of endometrial progesterone receptors or low levels of circulating progesterone during the luteal phase may result in embryo implantation failure or miscarriage.

Nutrition before mating is also crucial for optimizing reproductive performance in sows. The flushing method, commonly used prior to mating, aims to increase egg number or litter size (Bruun *et al.*, 2021), especially in first-parity or weak sows. Faccin *et al.* (2020) claimed that the gilt should have optimal body reserves (Table 2) but not be over-conditioned, as this could impact mammary gland development and, consequently, reproductive performance. The body weight increase in early gestation had a positive effect on the pregnancy rate (Table 3), as published by Tummaruk and Kesdangsakonwut (2014), showing the body weight and ovulation rate of the sow had significant positive interaction. This research assessed sow body measurements, aiming to identify dimensional characteristics linked to reproductive efficiency. Treatment 1 had greater body depth than the other treatments, yet this did not enhance reproduction (Table 8), as this study focused on nutrition rather than body size. It is possible that a larger sow size, without adequate nourishment, may not necessarily lead to improved reproductive outcomes. Further research could be conducted with different body sizes and the same nutrient intake to confirm the relationship between reproductive performance and body size. Table 4 showed that sows from mating to four weeks after farrowing (weaning) had increased body weight, indicating that they experienced less fat and lean tissue loss during the first lactation, which will benefit subsequent reproductive performance (Małopolska *et al*., 2018) and longevity (Muro *et al.*, 2023).

The reproductive performance showed results similar to those of recent studies (Table 8). Although a higher feed intake (Treatment 3) increased litter size, it also led to an increase in the stillbirth rate. As a result, the number of weaned piglets was nearly the same in Treatments 2 and 3. This is because a larger litter size results in lower average birth weights, leading to reduced production (Magnabosco *et al.*, 2016) and a higher preweaning mortality rate (Magnabosco *et al.*, 2015). Sows in Treatment 3 consistently had the highest body weight and litter size throughout the experiment, which may have caused higher oxidative stress compared to the other two treatments. High oxidative stress can reduce oxytocin and prolactin levels (Lee *et al.*, 2023) and lower placental efficiency (Hu & Yan, 2022). Although assistance during delivery shortened the delivery time, the stillbirth rate was slightly higher in Treatment 3. Still, the difference was not statistically significant, even with varying back fat conditions between the treatment groups (Roongsitthichai *et al*., 2021). Additionally, piglets in Treatments 1 and 2 exhibited higher birth weights due to smaller litter sizes. Litter size is a key factor influencing piglet survival, as it directly impacts thermoregulatory capacity and growth. Piglet vitality, closely linked to survival and growth, is also strongly affected by the degree of intrapartum hypoxia experienced by the piglet (Muns *et al*., 2015).

Therefore, high feed intake during the early gestation stage should be carefully considered as a factor for increasing litter size, although there are potential hazards. Additionally, increased feed intake may also raise the levels of other nutrients. Further research is needed to determine the specific nutrient requirements during the early gestation stage of sows to improve overall reproductive performance.

CONCLUSION

The results of the present study demonstrated that supplemental high feed intake throughout the entire gestation period (0-30 days) increased litter size. Furthermore, increasing feed intake from days 8 to 30 of early gestation provided significant benefits in litter size but led to the same number of weaned piglets as the high feed intake treatment due to the lower stillbirth rate. This study indicated that the increased feed intake during the first 30 days of gestation can improve litter size.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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