JOURNAL OF ANIMAL BEHAVIOUR AND BIOMETEOROLOGY

RESEARCH ARTICLE
Published Online: March 20, 2023
https://doi.org/10.31893/jabb.23007

Milk Supplementation: Effect on piglets performance, feeding behavior and sows physiological condition during the lactation period

Veasna Chem[a] | Hong-Seok Mun[ab] | Keiven Mark B. Ampode[ac] | Eddiemar B. Lagua[ae] | Muhammad Ammar Dilawar[a] | Young-Hwa Kim[d] | Chul-Ju Yang[ae]

[a]Animal Nutrition and Feed Science Laboratory, Department of Animal Science and Technology, Sunchon National University, Suncheon 57922, Korea.
[b]Department of Multimedia Engineering, Sunchon National University, Suncheon 57922, Korea.
[c]Department of Animal Science, College of Agriculture, Sultan Kudarat State University, Tacurong City 9800, Philippines.
[d]Interdisciplinary Program in IT-Bio Convergence System (BK21 plus), Chonnam National University, Gwangju, Korea.
[e]Interdisciplinary Program in IT-Bio Convergence System (BK21 plus), Sunchon National University, Suncheon 57922, Korea.

Abstract The present study aimed to investigate the effect of milk liquid and powder supplements on piglets' performance, drinking behavior, and sow back-fat thickness change during the lactation period. There were four experimental groups (n = 24), and in the control group (n = 6), the piglets were suckled from the sow. For the supplemental groups (n = 18), milk powder (MP), milk liquid by feeding trough (MLFT), and milk liquid feeding by the bucket (MLFB). Data were collected with the weight of a total of 252 piglets measured at birth, at 14 days and at weaning (28 days), respectively. Sow back-fat thickness was measured 3 days before farrowing, 14 days after farrowing and at weaning. There were significant differences in average daily weight gain between day 14 and weaning age for the MP and MLFT ($P < 0.05$) but not in MLFB ($P > 0.05$). For approaches to the feeder, there were significantly higher in MP and MLFT groups ($P < 0.05$). Based on the examination of sow back-fat thickness, the back-fat loss was minimal ($P < 0.05$) in the MP and MLFT compared to the MLFB and the control. Giving the milk supplement as powder and liquid by feeding trough has increased the piglets' average daily gain and body weight on day 14th and the weaning day. Moreover, the back-fat thickness reduction of sows in the supplemental groups is lower compared to the control group.

Keywords: birth, milk replacer, piglets, sow, weaning

1. Introduction

In the swine industry, breeding for hyper prolificacy has led to sows with larger litter sizes, increased piglets than the sow can sustain naturally, and lower average birth weights (Foxcroft et al. 2009). It is challenging for a sow to feed more piglets than the functioning teats due to the nursing style of pigs. As a result, management techniques like using nursing sows in herds of hyper-productive sows have become prevalent (C. Kobek-Kjeldager et al. 2020; Amdi et al. 2021). Regarding lactation, sow milk yield often reaches a maximum even if milk supply increases with the piglet's demand. In recent decades, the number of born alive piglets has increased, but this individual limit has not, and as a result, the actual amount of milk per piglet has reduced. Sows often generate 10 to 12 liters of milk each day. That quantity would usually be adequate, but with highly prolific breeding lines, there may be repercussions (Novotni-Dankó et al. 2015). For sows, feeding large litter indicates that they will have to use a lot of their body resources to fulfill the high milk demand, which may negatively impact performance in the following litter and cause weight loss in the sow (Pustal et al. 2015).

Moreover, it resulted in sibling competition for access to the teats when the piglets want to suck from their mother (Milligan, Fraser, and Kramer 2001; Ocepek, Newberry, and Andersen 2017). Lower piglet weight at weaning might severely influence the health of the affected animals and result in a loss of profitability for the farmer. The growth of a pig's weight between birth and weaning is determined by several factors, including the herd/sow, the litter, the piglets, and the enclosure (Johansen et al. 2004).

The management alternatives that are now available to rear these big litters include the utilization of nursing sows, artificial rearing systems, or providing additional milk (Ocepek, Newberry, and Andersen 2017). The previous studies (Zijlstra et al. 1996; de Greeff et al. 2016; van Oostrum, Lammers, and Molist 2016) found that providing milk supplementation before or around weaning age increased the piglet's body weight at post-weaning, improved survival rate, and piglet performance in the weaning phase. Milk replacer, which is more analogous than solid feed, may be easier for smaller and younger piglets to consume because it is more akin to sow milk (although it is still far from equivalent). However, when cross-fostered piglets of normal birth weight piglets compared to same-sized, low birth weight piglets in litters of 11–12 did not demonstrate a higher intake of milk replacers (Douglas, Edwards, and Kyriazakis 2014).

Received: February 5, 2023 | Accepted: March 15, 2023

Revealing that low birth weight piglets typically did not benefit from the technique of supplemental milk feeding while significantly increasing their competitive disadvantage. However, the inability to reach a teat at every milk drop in larger litters may increase the desire to begin foraging, leading to increased milk replacer consumption. Although hybrid sows have produced more milk over the past few decades, several environmental factors still impact how well they actually perform. Providing milk supplementation can be a good way to reduce risk, balance milk production depending on piglet demand, and eventually increase weaning weight. This present study aimed to investigate the effect of milk liquid and powder supplements on piglets' performance, drinking behavior, and sow back-fat thickness change during the lactation period. Moreover, we discuss a realistic on-farm experiment on litters with and without additional milk provided via milk powder, milk liquid by feeding trough, and milk liquid feeding by bucket placed directly in the farrowing pens, as well as potential effects on sow and piglet performance and health.

2. Materials and Methods

2.1. Study design, experimental animal, and housing

The study consisted of 24 sows [(Landrace x Yorkshire) x Duroc] and their litters (N=252 piglets) and was conducted from July until September 2022. There are two treatments in the experiment. The first treatment was control without access to supplementation. The other treatments had access to supplementation, divided into three groups: milk powder, milk liquid by feeding trough, and milk liquid by the bucket (Figure 1). Two days after farrowing, piglets from the supplemental groups were provided with milk supplementation as powder and liquid until weaning age (28 days). The milk supplements were added daily, and the refusal was weighed and recorded daily. Piglets were individually weighed at birth, 14 days after farrowing, and on the weaning day. The mortality of piglets was recorded from birth to the weaning day. Sows back-fat thickness was measured 3 days before farrowing, 14 days after farrowing, and on the weaning day using an electronic device minitube (Minitube, Model REF. 11907/0100, Tiefenbach, Germany). Feces samples were collected on day 14 and day 28 for microorganism analysis.

The experiment was carried out at Suncheon National University's experimental swine farm. The farrowing facility consisted of 24 farrowing pens (2.9 x 2.1 m). Sows were moved from the gestation pen to the farrowing pen seven days before farrowing. The drinking water for both sow and piglets was available at ad libitum in nipple and trough drinker, respectively. A camera full HD CCTV 5-megapixel (Xpeed, No.: KCE-KCIR TIA 7048, Korea) was installed in the farrowing house to monitor the piglet's feeding behavior. A recommended housing room temperature in the farrowing room was 22 to 23 °C.

2.2. Experimental treatments and supplemental piglet feeding

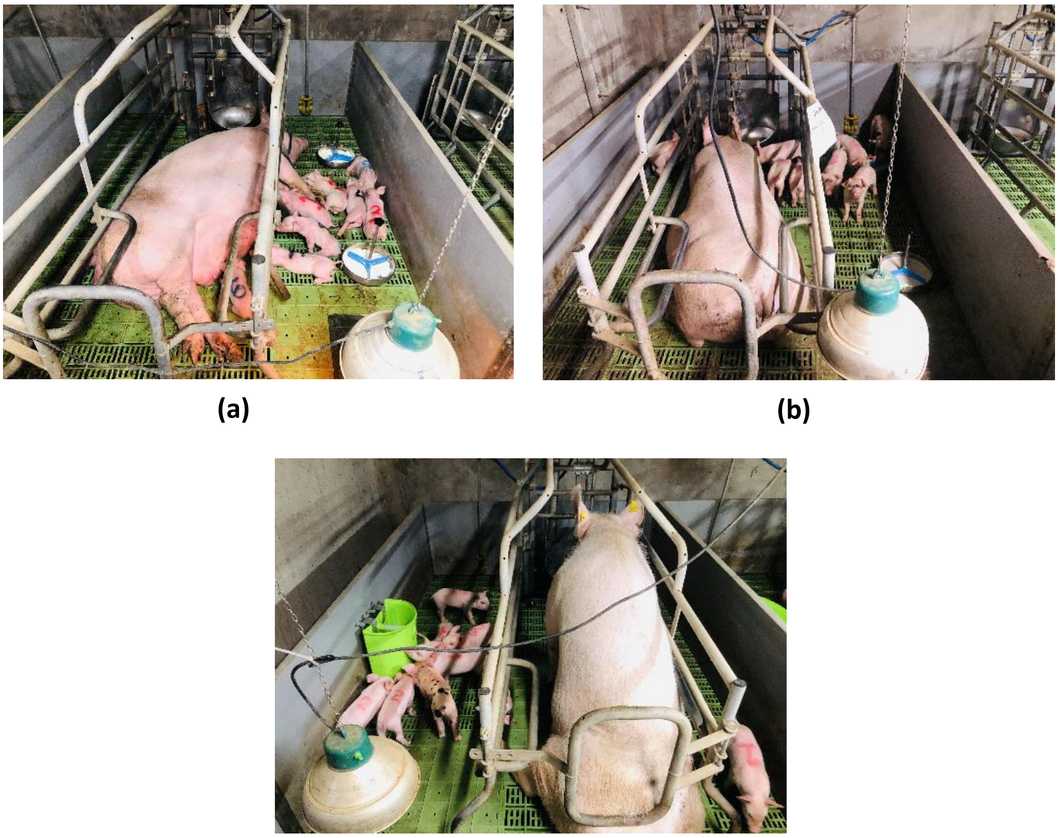
There were four treatments: Treatment 1, control only included the piglets suckling from the sow's milk; Treatment 2, in which the piglets were suckling from the sow's milk and got powdered milk replacer by feeding trough; Treatment 3, in which the piglets were suckling from the sow's milk and got milk liquid by feeding trough; and Treatment 4, in which the piglets were suckling from the sow's milk and got the milk liquid by feeding bucket.

In the control group, the piglets were sucking from birth till weaning and were access to ad libitum in the farrowing pen. The piglets in the experimental groups, from days 2 to 14, were supplemented with milk replacer Safe Milky and from days 15 to 28, were supplemented with milk replacer Milky (Table 1). Milk liquid replacer was prepared by hand-mixing, 400g of milk powder mixed with 1L of warm water for days 2-4 after farrowing, and 250g of milk powder mixed with 1L of warm water for days 5 to weaning. The chemical composition of supplemental piglet feed is shown in Table 1. The milk powder was mixed with 25-40 °C water and was followed according to the product formula in the necessary concentration provided (Novotni-Dankó et al. 2015). The feeder of milk powder and the liquid were cleaned every day before adding the new milk supplement to the feeder.

Table 1 The nutritional content of the piglet supplemental feed.

Chemical composition		Safe Milky[1]	Milky[2]
Crude protein	%	19.5	23.0
Crude fat	%	15.0	12.0
Crude fiber	%	3.0	3.0
Crude ash	%	11.0	9.0
Calcium	%	0.6	0.6
Phosphorus	%	1.5	1.5
Lysine	%	NA	1.45
Vitamin A	IU/kg	25 000	NA
Digestible energy (DE)	Kcal/kg	NA	3 800
Digestible crude protein (DCP)	%	NA	12.5

[1] provided from day 2 to day 14 after birth as powder and liquid.
[2] provided from day 15 to day 28 (weaning age) as powder and liquid.
NA: Not applicable



(a) (b) (c)

Figure 1 An overview of the piglet supplementation groups: (a) Milk powder, (b) Milk liquid feeding through, and (c) Milk liquid feeding by bucket.

2.3. Sow back-fat thickness measurement

The back-fat thickness of the sow was measured three times in the experiment: 3 days before farrowing, 14 days after farrowing, and at weaning day (28 days). We measured the back-fat thickness using the electronic device Minitube (Minitube, Model REF. 11907/0100, Tiefenbach, Germany) 6.5 cm from the midline at the level of the last rib of the sow (Quiniou and Noblet 1999; Renaudeau and Noblet 2001).

2.4. Piglet feeding behavior monitoring

The current study provided data supporting a low early intake as only a few liters were observed to consume milk replacers on day 3. The low drinking frequency on day 3 indicates that the piglets may require a few days to learn to drink milk replacer from the feeder they need to activate. Although it was unknown whether several or only a few piglets participated in the drinking observations, it still suggests that they consumed less frequently than on days (C. Kobek-Kjeldager et al. 2020).

In our present study, during the lactation period, a single and highly trained researcher counts the frequency of the activities of piglets (approaching the feeder and suckling bout from the sow) and monitored 12 hours per day on days 9, 16, and 23 from 9:00 to 21:00 by watching the cameras full HD CCTV 5-megapixel (Xpeed, No. KCE-KCIR TIA 7048, Korea) that were placed over each pen in the farrowing house about 2.8 m pointing downward to get the top view of the pen. The observation was recorded at the litter level on how many times any piglets ate and drank the milk supplementation. The frequency of suckling bouts was counted if 50% of the piglets suckled their dams' teats. To facilitate individual identification during behavioral observation, piglets were marked by painting their back with red color. Eating and drinking from a milk replacer feeder was defined as a piglet immersing its snout in the feeder for at least 2 seconds (C. Kobek-Kjeldager et al. 2020).

2.5. Sample collection and microbiological analysis

Feces samples were collected via piglet rectal stimulation on day 14 and day 28 (before transportation to the weaning house). Subsamples of feces were collected and stored at -20°C for microorganism analysis (Poulsen et al. 2017).

About 1g of feces samples were examined for microorganisms. Dilutions were prepared according to the recommendation of the International Organization for Standardization (ISO, 1995). For microbial enumeration, a 20 µl sample from each serial dilution was transferred with the help of a sterilized micro-pipette and spread onto Dif co-Mac Conkey Sorbito agar plates for *Escherichia coli* enumeration and BBL Salmonella Shigella agar plates for *Salmonella* enumeration. Duplicate plates were incubated at 37°C for 48 hours for each dilution, and colonies were promptly counted. The number of microbes was counted, and the multiplied value was computed as follows: multiplied value = no. of colonies ×10n × (100/20), where n=dilution value. The log of the multiplied value was then computed, and log10CFU/g was used to indicate the derived log value of the microbial count.

2.6. Statistical Analysis

The growth performance of piglets, number of approaches to the feeder, piglet mortality, suckling bout, and sow back-fat thickness were tested using a One-way Analysis of Variance (ANOVA) test using the Statistical Analysis System (SAS, 2011, Version 9.3, SAS Institute, Cary, NC, USA), and the data were expressed as mean ± standard error of the mean (SEM). The R Statistical Software (Version 4.4.2) was used to analyze the correlation of suckling time, back-fat thickness, piglet weight, feed intake, and approach to the feeder. The differences were statistically evaluated at $P < 0.05$, and Tukey's Honest Significant Difference (HSD) was used to examine the data with significant differences further.

3. Results

The effects of milk supplementation on the performance of the piglets are shown in Table 2. On the birth weight of the piglets, there was no significant difference ($P > 0.05$) in all groups. The survival rate of the piglets was numerically better in groups with milk powder (MP) and milk liquid feeding through (MLFT), but not in the group with milk liquid using feeding bucket (MLFB) ($P > 0.05$). The supplementation of milk significantly ($P < 0.05$) improved the body weight of the piglets on the 14th day and the weaning day. The highest weaning weights were observed in piglets supplemented (MLFT) and (MP) with 9.28 kg and 8.99 kg, respectively. The weaning weight of piglets in control and MLFB were the same at 7.28 kg and 7.52 kg, respectively. The same trend was also observed in the average daily gain of the piglets, wherein the supplementation improved the piglets' growth. The milk supplementation intake was significantly different ($P < 0.05$) among the supplemental groups at day 2-14, day 15-28, and the overall intake from day 2 to 28. The MLFT had the highest overall intake, followed by MP with 1,179.33 g/head and 1,104.48 g/head, respectively. The MLFB group had the lowest intake, with only 311.87 g/head. The feed conversion ratio (FCR) was affected by the supplementation ($P < 0.05$).

The sow mobilizes the back-fat thickness of the sow for milk production (Tani, Piñeiro, and Koketsu 2018). The sows' back-fat thickness is considered an objective measure of their physical health and may affect their ability to reproduce after weaning (Charette, Bigras-Poulin, and Martineau 1996; Maes et al. 2004; Farmer et al. 2017). Therefore, there is a loss of back-fat thickness during the lactation period depending on the sow's energy requirement and energy intake. Additionally, the back-fat thickness indicates the sow's body condition, which is important for the succeeding reproductive performance. The reproductive effectiveness of sows is negatively impacted by a back-fat thickness that is either too low or too high (Azain et al. 1996 and Miller et al. 2012). As shown in Table 3, the sow's back-fat thickness three days before farrowing ranged from 17.66 mm to 18.23 mm and was not significantly different ($p>0.05$). However, significant differences were observed in back-fat thickness at 14 days after farrowing and weaning. Sows in the supplemental groups had significant ($p<0.05$) thicker back-fat compared to the control group. Furthermore, the back-fat loss was minimal ($p<0.05$) in the MP and MLFT compared to the MLFB and the control with losses of 0.40, 0.23, 1.63, and 2.24 mm, respectively. The suckling bouts of the piglets might be correlated with back-fat loss. In this study, the suckling bouts were higher ($p<0.05$) in groups with higher back-fat loss (control and MLFB) compared to other supplemental groups. The frequency of approaches to the feeder with the milk supplements increased based on the collected data from 9:00 AM to 9:00 PM on days 9, 16, and 23 (Figure 2). Piglets from MLFT had the highest ($P < 0.05$) approaches to the feeder, followed by the piglet in the MP. Piglets in the MLFB tend to suckle more than to consume milk supplements.

In this study, there was no detected *E. coli* and *Salmonella* from the manure samples of the piglets in all groups.

As shown in Figure 3, groups with high suckling time had low back-fat thickness, low piglet weight, low milk supplementation intake, and low frequency of approaches to the feeder. High suckling time means that the piglets rely on milk as a nutrient source, and the sows tend to produce more milk to meet the demand, resulting in a high back-fat loss. Back-fat loss can be minimized by supplementing milk in powder or liquid forms. However, feeder design is more important to increase piglets approaching the feeder and eventually increase intake and weaning weight. In this study, piglets in MLFB had a similar trend in all parameters as in control.

4. Discussion

Piglets' primary source of nutrients is milk, which is crucial for their survival and growth. It is the safest, most efficient feed and most nutritious food for young piglets (Blavi et al. 2021). Piglets rely on the sow's colostrum to acquire immunity because they are born with relatively immature immune systems. Modern genetics of sows are hyper-prolific and can produce more than 15 piglets born alive in a litter with a limited number of teats (Tani, Piñeiro, and Koketsu 2018). The consequences of this productivity are loss of body condition in sows and high piglet mortality during lactation because of low birth weight and high competition over milk (Oliviero n.d.). Providing piglets with other nutrients, like milk supplementation, may alleviate these problems and improve farm productivity. In the current study, positive effects were found on the performance of the piglets supplemented with milk from the second day after farrowing until weaning.

Table 2 Effect of milk supplementation on piglet performance.

Parameters	Treatment				Mean	SEM	*P*-value
	Control	MP	MLFT	MLFB			
Total piglets	64	58	62	68	-	-	-
Mortality rate (%)							
At birth- 28	9.76	2.38	1.38	11.66	6.29	1.748	0.076
Body Weight (kg)							
At birth	1.44	1.57	1.39	1.52	1.48	0.033	0.243
Day 14	4.05^{b}	5.40^{a}	5.22^{a}	4.16^{b}	4.71	0.131	<0.001
Day 28	7.28^{b}	8.99^{a}	9.28^{a}	7.52^{b}	8.27	0.194	<0.001
Average Daily Weight Gain (kg)							
At birth - 14	0.19^{b}	0.27^{a}	0.27^{a}	0.19^{b}	0.23	0.009	<0.001
Day 15 - 28	0.23^{b}	0.26^{b}	0.29^{a}	0.24^{b}	0.25	0.007	0.008
At birth - 28	0.20^{c}	0.26^{b}	0.28^{a}	0.21^{c}	0.24	0.006	<0.001
Feed Intake/Litter (kg)							
Day 2 - 14	-	1.41^{a}	1.63^{a}	0.50^{b}	1.18	0.141	<0.001
Day 15 - 28	-	9.40	10.57	3.06	7.68	0.929	<0.001
Day 2 - 28	-	10.81^{a}	12.21^{a}	3.56^{b}	8.86	1.675	<0.001
Feed Intake/head (g)							
Day 2 - 14	-	150.64^{a}	155.56^{a}	42.29^{b}	116.16	0.013	<0.001
Day 15 - 28	-	953.84^{a}	1,023.78^{a}	269.58^{b}	749.06	0.083	<0.001
Day 2 - 28	-	1,104.48^{a}	1,179.33^{a}	311.87^{b}	865.23	0.095	<0.001
Average Daily Feed Intake (kg)							
Day 2 - 14	-	0.11^{a}	0.12^{a}	0.04^{b}	0.09	0.010	<0.001
Day 15 - 28	-	0.67^{a}	0.75^{a}	0.22^{b}	0.55	0.066	<0.001
Day 2 - 28	-	0.40^{a}	0.45^{a}	0.13^{b}	0.32	0.039	<0.001
Feed Conversion Ratio							
Day 2 - 14	-	0.37	0.42	0.19	0.32	0.032	0.004
Day 15 - 28	-	2.78	2.65	0.92	2.12	0.265	0.001
Day 2 - 28	-	1.54	1.55	0.59	1.23	0.139	0.001

MP: Milk Powder, MLFT: Milk Liquid by Feeding Trough, MLFB: Milk Liquid Feeding by the Bucket
$^{a, b}$ Values with different alphabets differ significantly
Level of significant $P < 0.05$

Giving the milk supplement as powder and liquid by feeding trough has increased the piglets' average daily gain and body weight on the 14th day and the weaning day. This is to the results of (Pustal et al. 2015) and (Farmer 2013), wherein litter weaning weight of supplemental groups is better compared to the control group. In contrast, the finding of (Wolter et al. 2002) did not find improvement in growth performance and uniformity of the piglets with low birth weight supplemented with milk supplement during lactation. The piglet's birth weight has a higher influence on their ability to develop after weaning, and individual weaning weights of piglets were not different between supplemental groups and control groups. This variation is due mainly to the various experimental approaches used in previous research that used an equal number of lactation piglets in the supplemented and control groups (Wolter et al. 2002; Azain et al. 1996; Miller et al. 2012). Differences in response to supplementation might be due to the milk supplement's composition and the methodology applied during the experiment.

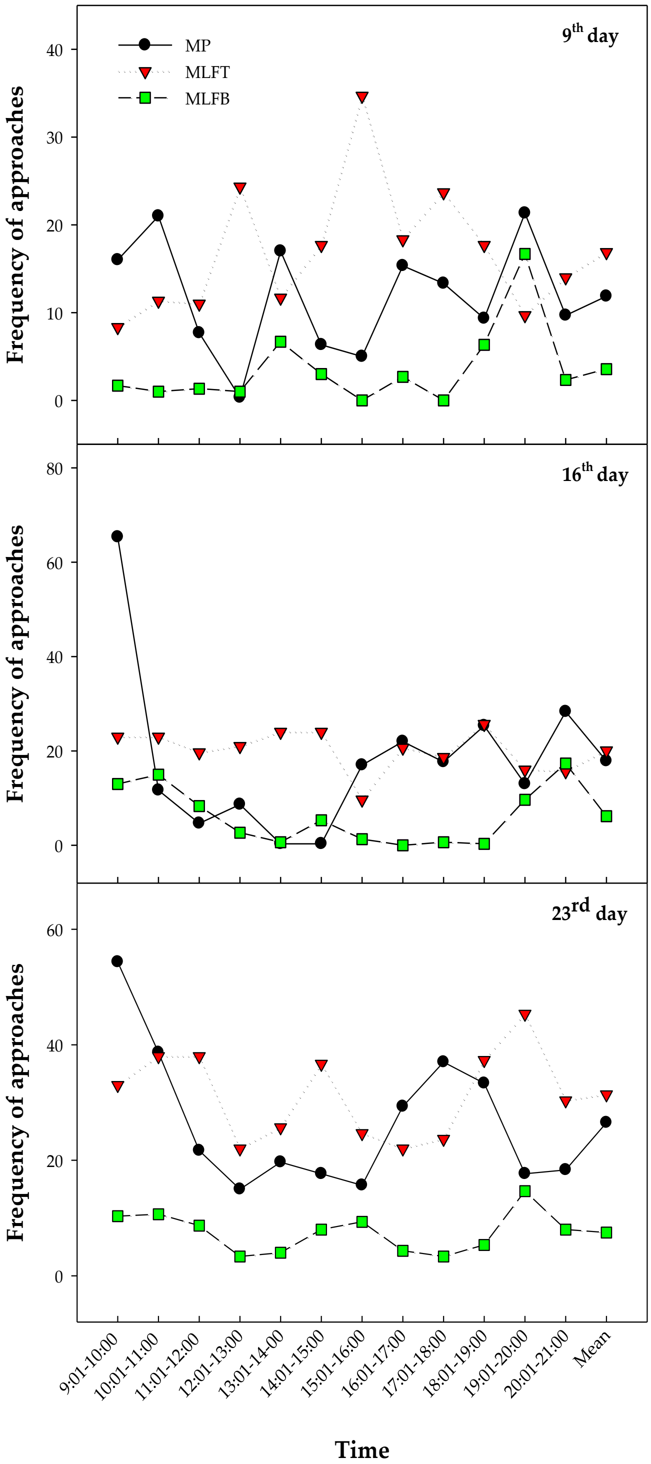


Figure 2 The number of piglets approaching to the feeder at day 9, 16 and 23 from 9:00 AM to 09:00 PM.

Moreover, on days 11, 12, and 13, the piglets' birth weight had no impact on whether they consumed more supplemental feed, but weaning weights were greater on day 35, and they tended to consume less feed per piglet the day before weaning (Cecilie Kobek-Kjeldager et al. 2021). The improvement of piglets' growth performance is correlated to the intake of milk supplements. Piglets in MP and MLFT groups had more milk supplement intake and heavier piglets at weaning than those in MLFB and piglets without supplementation. This indicates that milk supplementation during the lactation period is beneficial for the piglets' growth and vitality before and after weaning. Piglets with a heavier weight at weaning have a higher survival rate after weaning and better lifetime performance than piglets with a lighter weight (Collins et al. 2017). Milk intake is crucial for the piglets' survival and growth. The milk intake of the piglets can be affected by the sow's milk production, litter size, survival, and welfare (Peltoniemi et al. 2021). Milk supplementation can improve the milk intake and nutrient intake of the piglets. The milk supplement can be cow's milk or a milk compliment and can be given in powdered form or liquid form (Hojgaard, Bruun, and Theil 2020).In the current study, the forms of milk supplements did not significantly affect the intake of the supplement. However, the liquid form was slightly higher than the powdered form. Additionally, the design of the feeding trough is more important than the form of the milk supplement. There are some difficulties for piglets to get used to bucket feeding, lack of milk sensing, and young piglets don't know how to suck the milk from the bucket nipples.

Piglets given with milk liquid supplement using a feeding bucket had the lowest intake compared to piglets supplemented either powdered or liquid using a feeding trough. This intake is positively correlated to the frequencies of the piglets approaching the feeder. There were high piglets approaches using feeding troughs. It was also observed that the piglets from the groups with high approaches to supplemental feed had less suckling bouts. This is in accordance with the study of (Cecilie Kobek-Kjeldager et al. 2021). These findings indicate that piglets consuming milk supplements do not rely much on the sow's milk for nourishment during lactation. This is also beneficial for the piglet's post-weaning performance. According to (Blavi et al. 2021) piglets with high creep feed intake pre-weaning stimulate feed intake post-weaning resulting in better growth performance.

Milk is the perfect food not only for piglets but also for bacteria. Liquid milk feeding has a high risk of bacterial contamination that may affect the health of the animals (Jorgensen et al. 2017). However, in the current study, there were no detected E. coli and Salmonella bacteria in the feces sample of the piglets in all groups. This means that there was no contamination of such bacteria during the study. The body condition of the sow is critical for its reproductive performance (Novotni-Dankó et al. 2015; Čechová and Tvrdoň 2006). Back-fat thickness is one of the indicators for the assessment of the body condition of the sow. The sow will utilize this fat for milk production during the lactation period. Ideally, the sow must have between 13 to 20 mm of back-fat at farrowing for optimum reproductive performance (Hu and Yan 2022). In the current study, the sows used had the ideal back-fat thickness ranging from 17.66 to 18.23 mm. Milk production is a high-energy consuming process, and feed intake is crucial for optimum production. The demand for milk is high for hyper prolific sows and undernutrition during this period will lead to catabolic sows. Severe tissue mobilization means excess loss of body condition but may also indicate the better mothering ability of the sow (Maes et al. 2004; Lavery et al. 2019). However, this has a negative impact on the succeeding gestation and the sow's farrowing performance. Therefore, intervention is needed to prevent or minimize this problem. In the current study, milk supplementation to the piglets during lactation had significantly less than the back-fat loss in sows. This is supported by the negative correlation between back-fat loss, the piglets' milk supplementation intake, and the suckling bouts. These findings indicate that the catabolic condition of the sows is alleviated because of the reduction of milk demand by the piglets during the lactation period. The piglets were able to meet their milk demand through the milk supplement.

Table 3 The sow back-fat thickness (mm) changes during the suckling period, piglets suckling bout (mn), and piglets approaching the feeder.

Parameters	Treatment				Mean	SEM	*P*-value
	Control	MP	MLFT	MLFB			
Sow back-fat							
3 days before farrowing	18.04	17.66	18.23	17.60	17.93	0.149	0.517
14 days after farrowing	17.06[b,c]	17.66[a,b]	18.23[a]	16.76[c]	17.43	0.175	0.006
28 days after farrowing	15.80[b]	17.46[a]	18.00[a]	15.96[b]	16.80	0.231	<0.001
Sow back-fat loss	2.24[c]	0.40[a]	0.23[a]	1.63[b]	1.12	0.179	<0.001
Piglet suckling bout							
Day 9	261.33[b]	200.00[a]	200.33[a]	277.67[c]	234.83	7.600	<0.001
Day 16	283.00[d]	207.00[b]	178.00[a]	233.33[c]	225.33	8.300	<0.001
Day 23	277.00[c]	191.33[a]	186.00[a]	255.33[b]	227.42	8.663	<0.001
Piglet approach to the feeder							
Day 9	-	142.33[b]	202.33[a]	42.67[c]	129.11	16.186	<0.001
Day 16	-	214.33[b]	241.00[a]	74.33[c]	176.56	18.065	<0.001
Day 23	-	318.33[b]	376.67[a]	90.00[c]	261.67	30.860	<0.001

MP: Milk Powder, MLFT: Milk Liquid by Feeding Trough, MLFB: Milk Liquid Feeding by the Bucket
[a, b,c,d] Values with different alphabets differ significantly
Level of significance $P < 0.05$

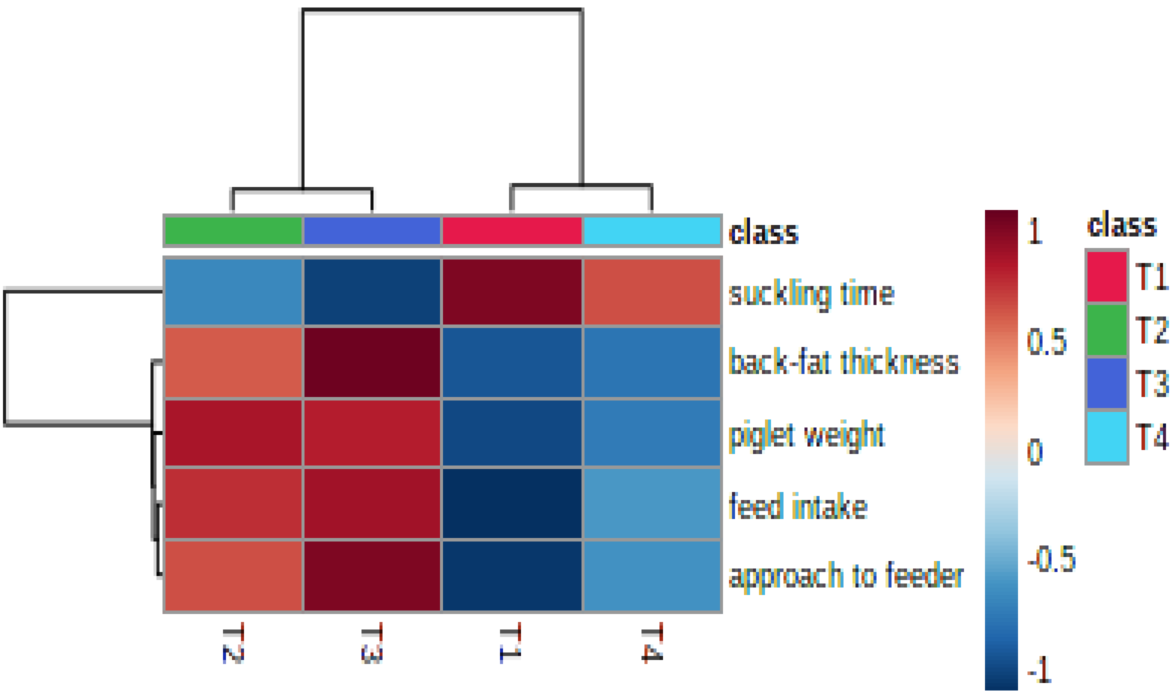


Figure 3 The heatmap of the correlation of suckling time, back-fat thickness, piglet weight, feed intake, and approach to the feeder (T1: Control, T2: Milk powder, T3: Milk liquid feeding through, T4: Milk liquid feeding by bucket).

5. Conclusions

Milk powder and milk liquid supplementation during the lactation period have positive effects on the piglet's performance from the second day after farrowing until weaning. Giving the milk supplement as powder and liquid by feeding trough has increased the piglets' average daily gain and body weight on the 14th day and on the weaning day. Moreover, the back-fat thickness reduction of sows in the supplemental groups is lower compared to the control group. Our findings provide the basis for additional studies on economics and reproduction related to giving milk supplementation in the farrowing house.

Acknowledgement

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project title: Development of high-yielding sow feeding and management technology to improve PSY, Project No. PJ016943012022)" Rural Development Administration, Republic of Korea.

Ethical considerations

Good animal husbandry procedures were used to handle and care for the pigs used in the experiment. The method was reviewed and authorized by Sunchon National University's Institutional Animal Care and Use Committee (IACUC) (SCNU IACUC-2022-03).

Conflict of interest

The authors declare that they have no competing interests.

Funding

The authors declare no conflict of interest.

References

Amdi C, Pedersen MLM, Klaaborg J, Myhill LJ, Engelsmann MN, Williams AR, Thymann T (2021) Pre-Weaning Adaptation Responses in Piglets Fed Milk Replacer with Gradually Increasing Amounts of Wheat. British Journal of Nutrition 126: 375–82. doi: 10.1017/S000711 4520004225.

Azain MJ, Tomkins T, Sowinski JS, Arentson RA, Jewell DE (1996) Effect of Supplemental Pig Milk Replacer on Litter Performance: Seasonal Variation in Response. Journal of Animal Science 74:2195–2202. doi: 10.2527/1996.7492195x.

Blavi, Laia, David Solà-Oriol, Pol Llonch, Sergi López-Vergé, Susana María Martín-Orúe, and José Francisco Pérez (2021) Management and Feeding Strategies in Early Life to Increase Piglet Performance and Welfare around Weaning: A Review. Animals 11: 302. doi: 10.3390/ani11020302.

Čechová M, Tvrdoň Z (2006) Relationships between Backfat Thickness and Parameters of Reproduction in the Czech Large White Sows (Short Communication). Archives Animal Breeding 49: 363–69. doi: 10.5194/aab-49-363-2006.

Charette, Robert, Michel Bigras-Poulin, and Guy-Pierre Martineau (1996) Body Condition Evaluation in Sows. *Livestock Production Science* 46: 107–15. doi: 10.1016 /0301-6226(96)00022-X.

Collins, Cherie L, John R, Rebecca SM, Trevor NM, Robert JS, David JH, Ingunn S, Frank RD (2017) Post-Weaning and Whole-of-Life Performance of Pigs Is Determined by Live Weight at Weaning and the Complexity of the Diet Fed after Weaning. Animal Nutrition 3: 372–79. doi: 10.1016/j.aninu.2017.01.001.

Douglas, SL, Edwards SA, Kyriazakis I (2014) Management Strategies to Improve the Performance of Low Birth Weight Pigs to Weaning and Their Long-Term Consequences1,2. Journal of Animal Science 92: 2280–88. doi: 10.2527/jas.2013-7388.

Farmer, C (2013) Review: Mammary Development in Swine: Effects of Hormonal Status, Nutrition and Management. Canadian Journal of Animal Science 93: 1–7. doi: 10.4141/cjas2012-066.

Farmer C, Martineau JP, Méthot S, Bussières D (2017) Comparative Study on the Relations between Backfat Thickness in Late-Pregnant Gilts, Mammary Development and Piglet Growth1. Translational Animal Science 1: 154–59. doi: 10.2527/tas 2017.0018.

Foxcroft GR, Dixon DT, Dyck MK, Novak S, Harding JCS, Almeida FCRL (2009) Prenatal Programming of Postnatal Development in the Pig. Society of Reproduction and Fertility Supplement 66: 213–31.

Greeff A, Resink JW, Van Hees HMJ, Ruuls L, Klaassen GJ, Rouwers SMG, Stockhofe-Zurwieden N (2016) Supplementation of Piglets with Nutrient-Dense Complex Milk Replacer Improves Intestinal Development and Microbial Fermentation1. Journal of Animal Science 94: 1012–19. doi: 10.2527/jas.2015-9481.

Hojgaard, Camilla K, Thomas SB, Peter KT (2020) Impact of Milk and Nutrient Intake of Piglets and Sow Milk Composition on Piglet Growth and Body Composition at Weaning. Journal of Animal Science 98: skaa060. doi: 10.1093/jas/skaa060.

Hu, Jian, Peishi Y (2022) Effects of Backfat Thickness on Oxidative Stress and Inflammation of Placenta in Large White Pigs. Veterinary Sciences 9: 302. doi: 10.3390/vetsci9060302.

Johansen, Markku, Lis A, Helle DK, Poul B (2004) Factors Associated with Suckling Piglet Average Daily Gain. Preventive Veterinary Medicine 63: 91–102. doi: 10.1016/j.prevetmed.2004.01.011.

Jorgensen MW, Adams-Progar A, de Passillé AM, Rushen J, Godden SM, Chester-Jones H, Endres MI (2017) Factors Associated with Dairy Calf Health in Automated Feeding Systems in the Upper Midwest United States. Journal of Dairy Science 100: 5675–86. doi: 10.3168/jds.2016-12501.

Kobek-Kjeldager C, Moustsen VA, Theil PK, Pedersen LJ (2020) Effect of Litter Size, Milk Replacer and Housing on Production Results of Hyper-Prolific Sows. Animal 14: 824–33. doi: 10.1017/S175173111900260X.

Kobek-Kjeldager, Cecilie, Dar'ya V, Charlotte L, Nuria C, Lene JP (2021) Impact of Supplemental Liquid Feed Pre-Weaning and Piglet Weaning Age on Feed Intake Post-Weaning. Livestock Science 252: 104680. doi: 10.1016/j.livsci.2021.104680.

Lavery A, Lawlor PG, Magowan E, Miller HM, O'Driscoll K, Berry DP (2019) An Association Analysis of Sow Parity, Live-Weight and Back-Fat Depth as Indicators of Sow Productivity. Animal 13: 622–30. doi:10.1017/S1751731118001799.

Maes DGD, Janssens GPJ, Delputte P, Lammertyn A, de Kruif A (2004) Back Fat Measurements in Sows from Three Commercial Pig Herds: Relationship with Reproductive Efficiency and Correlation with Visual Body Condition Scores. Livestock Production Science 91: 57–67. doi: 10.1016/j.livprodsci.2004.06.015.

Miller YJ, Collins AM, Smits RJ, Thomson PC, Holyoake PK (2012) Providing Supplemental Milk to Piglets Preweaning Improves the Growth but Not Survival of Gilt Progeny Compared with Sow Progeny. Journal of Animal Science 90: 5078–85. doi: 10.2527/jas.2011-4272.

Milligan, Barry N, David F, Donald L K (2001) Birth Weight Variation in the Domestic Pig: Effects on Offspring Survival, Weight Gain and Suckling Behaviour. Applied Animal Behaviour Science 73: 179–91. doi: 10.1016/S0168-1591(01)00136-8.

Novotni-Dankó G, Balogh P, Huzsvai L, Győri Z (2015) Effect of Feeding Liquid Milk Supplement on Litter Performances and on Sow Back-Fat Thickness Change during the Suckling Period. Archives Animal Breeding 58: 229–35. doi: 10.5194/aab-58-229-2015.

Ocepek, Marko, Ruth CN, Inger LA (2017) Trade-Offs between Litter Size and Offspring Fitness in Domestic Pigs Subjected to Different Genetic Selection Pressures. Applied Animal Behaviour Science 193: 7–14. doi:

10.1016/j.applanim.2017.03.008.

Oliviero, Claudio ND Offspring of Hyper Prolific Sows: Immunity, Birthweight, and Heterogeneous Litters. Molecular Reproduction and Development. Accessed December 15, 2022. doi: 10.1002/mrd.23572.

Oostrum, Van M, Lammers A, Molist F (2016) Providing Artificial Milk before and after Weaning Improves Postweaning Piglet Performance. Journal of Animal Science 94 : 429–32. doi: 10.2527/jas.2015-9732.

Peltoniemi, Olli, Jinhyeon Y, Stefan B, Taehee H (2021) Coping with Large Litters: The Management of Neonatal Piglets and Sow Reproduction. Journal of Animal Science and Technology 63: 1–15. doi: 10.5187/jast.2021.e3.

Poulsen, Ann-Sofie R, Nadieh DJ, Sugiharto S, Jeppe LN, Charlotte L, Nuria C (2017) The Microbial Community of the Gut Differs between Piglets Fed Sow Milk, Milk Replacer or Bovine Colostrum. British Journal of Nutrition 117: 964–78. doi: 10.1017/S0007114517000216.

Pustal J, Traulsen I, Preißler R, Müller K, Beilage TG, Börries U, Kemper N (2015) Providing Supplementary, Artificial Milk for Large Litters during Lactation: Effects on Performance and Health of Sows and Piglets: A Case Study. Porcine Health Management 1: 13. doi: 10.1186/s40813-015-0008-8.

Quiniou, Noblet J (1999) Influence of High Ambient Temperatures on Performance of Multiparous Lactating Sows. Journal of Animal Science 77: 2124–34. doi: 10.2527 /1999.7782124x.

Renaudeau D, Noblet J (2001) Effects of Exposure to High Ambient Temperature and Dietary Protein Level on Sow Milk Production and Performance of Piglets. Journal of Animal Science 79: 1540–48. doi: 10.2527/2001.7961540x.

Tani, Satomi, Carlos P, Yuzo K (2018) High-Performing Farms Exploit Reproductive Potential of High and Low Prolific Sows Better than Low-Performing Farms. Porcine Health Management 4: 15. doi: 10.1186/s40813-018-0091-8.

Wolter BF, Ellis M, Corrigan BP, DeDecker JM (2002) The Effect of Birth Weight and Feeding of Supplemental Milk Replacer to Piglets during Lactation on Preweaning and Postweaning Growth Performance and Carcass Characteristics1. Journal of Animal Science 80: 301–8. https://doi.org/10.2527/2002.802301x.

Zijlstra RT, Whang KY, Easter RA, Odle J (1996) Effect of Feeding a Milk Replacer to Early-Weaned Pigs on Growth, Body Composition, and Small Intestinal Morphology, Compared with Suckled Littermates. Journal of Animal Science 74: 2948–59. doi: 10.2527/1996.74122948x.