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Retrospective Study

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Study on Reproductive Performance of Breeding Sows and Ultrasound Monitoring of Ovarian Follicle Activity and Ovulation of Post-Weaning Sows in a Commercial Pig Farm of Central Ethiopia

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ABSTRACT

Introduction: The aim of the study was to assess the reproductive performance of breeding sows under farm conditions and to identify the factors affecting it, as well as performing the ultrasound monitoring of ovarian follicle activity and determining the time of ovulation in post-weaning sows.

Materials and Methods: Retrospective study was conducted to analyze the reproductive performance of 1200 primiparous and multiparous sows (experiment I) under tropical condition in a commercial pig farm of central Ethiopia. Reproductive data including weaning -to-estrus interval (WEI), age at first service (AFS), litter size (LS), farrowing rate (FR) and number of litters per sow and year of sows were collected and analyzed. Moreover, a regular observation of 25 randomly selected post-weaning sows (experiment II) was undertaken for estrus detection and for performing the transabdominal ultrasound (US) monitoring of ovarian follicle development and ovulation.

Result: Gilts are usually bred at the age of 7 to 8 months. Lactation period for the sows in the farm was fixed; the piglets were weaned at the age of 30 days. About 69.6% of females showed estrus between 3 and 6 days post-weaning. The average WEI was 5.6 (±1.7) days and the percentage of females showing estrus within the 2 days after weaning was 5.8%. The overall average FR was 86.1%. In both the primiparous and multiparous females, the WEI of 1-2, 7-9 and 10-12 days resulted in a lower FR ($p<0.05$) than those observed for WEI of 3-6 days. Mean LS, number of litters per sow and year and total piglets born per sow and year of the farm were 9.07 (±2.1), 1.90 (±0.2), and 17 (±3.7), respectively. In both the parity classes, the lowest LS was observed in females with WEI of 1-2 days ($p<0.05$). In primiparous and multiparous females, LS increased significantly ($p<0.05$) from WEI of 1-2 days to WEI of 3-6 days, it decreased in females with WEI of 7-12 days and increased again in females with WEI of 13 to 20 days. The mean diameter of the pre-ovulatory follicles was 6.91 (±1.28) mm ranging from 6 to 10 mm. Ovulation lasted between 2-6 hours, with an average duration of 4.82 (±1.69) hours.

Conclusion: The current study revealed that the reproductive performance indicators, FR and LS were affected in sows with WEI of 1-2 and 7-12 days post-weaning. Ultrasound examination of the ovaries facilitated the detection and monitoring of pre-ovulatory follicles and the ovulation process during the estrus period.

KEY WORDS: Ovarian follicle; Ovulation; Pig; Reproductive performance; Weaning-to-estrus interval; Ultrasound.

ABBREVIATIONS: AFS: Age at first service; d: Day(s); FR: Farrowing Rate; GnRH: Gonadotrophin releasing hormone; h: Hour(s); hCG: Human chorionic gonadotrophin; LS: Litter Size; MHz: Megahertz; mm: Millimeter; n: Number; $p>1$: Multiparous; P1: Parity one; SD: Standard Deviation; US: Ultrasound; WEI: Weaning-to-estrus interval.

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INTRODUCTION

Reproductive performance of breeding sows is among the major factors that control the efficiency of swine production,[1] low reproductive performance can therefore be considered of economic significance to the pig industry.[2] Farrowing rate (FR) and litter size (LS) at birth and fertility index are among the primary parameters used to measure the reproductive performance of female pigs.[2] Existing studies report that reproductive performance is influenced by the weaning-to-estrus interval (WEI). It is observed that females with WEI of 7-10 days gave birth to a fewer number of piglets which were born alive and showed a lower FR than those with WEI of 3-6 and 11-14 days.[3] Similarly, Poleze et al[4] reported the lowest litter size in females with WEI of 6-8 and 9-12 days. The authors reported that the litter size increased significantly from WEI of 0-2 days to WEI of 3-5 days, which in turn decreased in females with WEI of 6-8 days and increased again in females with WEI of 9-21 days. Lower FR was also reported in females with WEI of 6-8 days and 9-12 days in both primiparous and multiparous sows.[4]

WEI, the period between the day of weaning and the first day on which the sow shows standing heat, is one of the major components of non-productive days. According to Dial et al[5], WEI may be influenced by the duration of lactation, parity order, LS, season, nutrition, boar exposure after weaning, genetic constitution, diseases and management. The optimum breeding of pigs under farm conditions is related to the resumption of the cyclical ovarian activity following weaning. The return of the ovaries to their cyclical function after lactation is often accompanied by a number of disorders, which may be a significant cause of lowered fertility in pig herds in farms.[6] Moreover, the conventional methods of estrus detection become increasingly insufficient as the number of animals in a herd increases. This demands the use of combined estrus detection methods to accurately determine the optimal time for the breeding of estrous sows.[7] Ultrasound examination of the reproductive organs has been used to monitor and evaluate the development of ovarian follicles during the post-weaning period that was aimed at determining the time of ovulation, and the diagnosis of ovarian disorders.[6,8]

In Ethiopia, the first large scale swine production was started after the Second World War. Though a considerable duration of time has elapsed since then, the acceptance of pork, as well as the growth and production of swine did not show the expected increase. The main reason for this could be the members of the Ethiopian Orthodox Church as well as the people of Islamic faith who were not in the favor of pork consumption. Thus, swine production is mainly associated with the foreign community. As a result of this, there has been a limited market for pork consumption within Ethiopia.[9] Contrary to commercial swine farms; small scale pig production was introduced recently as a form of economic activity in Ethiopia.[9] The total populations of pigs were estimated as 29,000 heads representing 0.1% of the African pig population and are primarily concentrated in the central part of the country.[10]

In the recent years, backyard and commercial pig farms have increased in number, particularly in the periphery of the big cities of central Ethiopia.[9,11] Consequently, the situation governing both swine production and consumption of pork in Ethiopia is changing, where pork products are beginning to draw a lot of attention in the market. This is mainly due to an ever increasing human population, and an increasing number of tourists and other foreigners who come to Ethiopia for various business activities. Moreover, pork is increasingly becoming a favorable source of meat for young Ethiopian and Diasporas who have experiences of foreign trips and travelling.[11] The increasing trend in the production and consumption of pork, particularly among the younger generation, is believed to have a pivotal role in promoting the pig farming sector to contribute towards sustainable food security of the country. Pigs are one of the most prolific and fast growing livestock species that can convert food waste to valuable products.[12] Pig production is becoming an increasingly important economic activity on account of high production efficiency per unit area of land.[13] To this end, a better understanding of the current systems and key factors that affect pig reproductive performance and production are required to promote and design efficient intervention methods.[14] Although, a few reports exist on the smallholder pig production system,[9] information on the reproductive performance of sows in commercial herds in Ethiopia is lacking. Similarly, reports on ultrasound monitoring of ovarian activities of female pigs are lacking completely in the Ethiopian literature.

The aim of the study was thus to assess under farm conditions, the reproductive performance of breeding sows and the factors affecting it, as well as performing the ultrasound evaluation of ovarian follicular activity and the time of ovulation in post-weaning sows.

MATERIALS AND METHODS

Study Area

The study was conducted at the Bishoftu town, located 47.9 km south east of the Capital Addis Ababa at 9°N latitude and 40°E longitude and at an altitude of 1,850 meters above sea level. This region shows a bimodal pattern of rainfall, where the main rainy season lasts from June to September with an annual average rainfall and temperature of 866 mm and 20 °C, respectively.[15]

Study Animals and Design

Experiment I: In experiment I, a retrospective study of the reproductive performance of breeding sows was conducted, which were kept in a private owned commercial farm with about 2000 pigs. Breeds involved were Large White, Duroc, Dutch Landrace and their crosses. The study deals with collecting and analyzing data from the registered documents of 1200 primiparous and multiparous sows during a period from

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November 2013 to April 2015. Reproductive data such as date of service, farrowing date, LS, weaning age, number of litters per sow and year and age at first service (AFS), WEI, and FR as well as the number of piglets born per sow and year were collected and analyzed. FR was a measure of the percentage of farrowings excluding the breeding records of females that died or that were culled from the herd for non-reproductive reasons. For the LS, the total number of born piglets (alive and stillborn) was considered. Moreover, information on breeding management and estrus detection was gathered. The farm practiced an intensive management system (housing and feeding). Breeding sows were kept in separate clean and ventilated rooms. Extra care was provided for pregnant sows and weaned piglets. They were housed and fed separately. The farm utilized commercial feed which was a combination of concentrates, grains, forage and mineral. The farm practiced deworming regularly but the vaccination in practice was against foot and mouth disease (FMD). Other infectious diseases including those affecting reproduction in pigs were not evident during the entire study period.

In the pig farms, gilts are usually bred at the age of 7 to 8 months. The age during the first farrowing was approximately between 11 to 12 months, which could be calculated by observing the day of standing heat and adding approximately 3 months, 3 weeks, and 3 days (length of pregnancy).

Estrus detection was performed by the farm personnel by exposing the sow to the boar twice daily following the day of weaning. Common signs of estrus observed were a swollen and congested vulva and vaginal discharge, accompanied by restlessness, mounting of other animals and frequent urination. Peculiar repetitive grunt was also recorded. At the climax of estrus period, the sows assumed a stationary, rigid attitude when being checked for standing heat by the farm personnel in the presence of a sexually mature boar. Cyclic females after weaning were introduced into the boar's barn, after checking for standing heat. The farm generally practiced natural service. The sows were presented to the boar two times, at an interval of 12 hours following the estrus detection post-weaning. Artificial insemination (AI) was conducted in cases, where the farm needed to introduce new genes into the farm in order to reduce the incidence of inbreeding. The farm practiced double insemination: the first AI was conducted within 12-14 hours of estrus detection post-weaning followed by the second AI which was performed 12 hours later. Lactating sows had their own stalls adjacent to the farrowing pens where they were housed with their piglets until the end of the lactation period. The lactation period for the sows in the farm was fixed; the piglets were weaned at the age of 30 days, where they were reared separately, until slaughtered or sold.

Experiment II: The study included a regular observation of 25 randomly selected post-weaning sows for estrus detection and for performing the ultrasound (US) monitoring of ovarian follicle development and ovulation. Estrus detection and the time of service of the sows were a part of a routine breeding program of the farm. The sows were observed two times per day by the stockperson of the farm for possible manifestations of estrus, checking for standing heat as it is described in experiment I.

The trans-abdominal method of US examination of the ovaries[16] was performed using ultrasound scanner with a 5 MHz linear array transducer Aloka, Japan, starting from the day of weaning (Day 0) until day 5 to 10 afterwards until the end of ovulation. The scanning of the sows was performed by placing a probe on the right side of the animal abdomen, at about 30 cm above the mammary ridge, where the head of the probe was directed towards the left shoulder joint.[8,16] The examination of the ovaries was performed twice a day (6:00-7:00 a.m. and 6:00-7:00 p.m.) during the first two days and at a 4 hour interval during the culmination of estrus period in order to follow the ovarian follicle development: the presence and size of the ovarian follicles and the monitoring of the ovulation process. Based on the findings of clinical-gynecological examinations, observations of sexual behavioral changes and US examination, the following reproductive characteristics were calculated: duration of estrus and ovulation, the WEI and the interval from the onset of estrus to the end of ovulations. Ovulation length was measured by considering 2 consecutive examinations; where occurrence of ovulation was considered to be the moment half-way between 2 consecutive examinations, in the first of which a dominant ovarian follicle was visible, while in the second it became invisible.[6,8] Follicular diameter during the pre-estrus and pre-ovulatory period was also determined.

Data Analysis

Data was entered in a Microsoft Excel spread sheet (2003) and transported to the Statistical Package for the Social Sciences (SPSS) (Version for 15, USA). Descriptive statistics (mean, standard deviation) was used to summarize the data where the following reproductive performance indicators were calculated: average value for WEI, duration of the estrus and ovulation, and mean LS. Moreover, the number of litters per sow and year, total piglets weaned per sow and year and the weaning age of piglets were determined. Data was separated, according to the parity class, for the primiparous (P1) and multiparous sows (p>1). The influence of WEI on the LS and FR were compared using the Chi-square test, with a significance level of 5%.

RESULTS

Experiment I

Reproductive performance indicators: The summary of reproductive performance indicators of the sows have been shown in Table 1. Sows came into estrus when they were separated from their piglets. Average weaning-to- estrus interval in this study was 5.6 (±1.7) days. The majority of the sows (75.4%) came in estrus within 6 days after weaning. A few of the sows were characterized by the effects of estrus as early as 1 to 2 days (5.8%)

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Table 1: The Overall Reproductive Performance of Sows Based on Retrospective Data from Registered Documents (n=1200).

Indicators of reproductive performance	Values (Mean ±SD)
Age at first service (months)	7.0
Weaning-to-estrus interval (d)	5.6 (±1.7)
Litter size per sow (n)	9.07 (±2.1)
Number of litters per sow and year (n)	1.90 (±0.2)
Total piglets born per sow and year (n)	17 (±3.7)
Lactation length (d)	30.0

and as late as 35 to 40 days after weaning.

The overall mean LS or live born piglets per farrowing and sow was 9.07 (±2.1), ranging from 7 to 9 and 7 to 11 piglets in primiparous and multiparous sows, respectively, whereas number of litters per sow and year were found to be 1.90 (±0.2). Based on this recorded data, the average total born piglets per sow and year was calculated and found to be 17 piglets (1.90*9 piglets). In both primiparous and multiparous sows, lower LS was observed in sows with WEI between 1-2 days and 7-12 days ($p<0.05$), whereas an increased LS was recorded for WEI of 3-6 days and WEI of 13-20 days in both the parity classes. The LS according to the WEI and parity class has been shown in Table 2.

Distribution of females and FR according to the parity class and WEI has been shown in Table 3. Sows showing estrus between 1-2 days after weaning represented 5.8% of the female population. About 69.6% of the females showed estrus between 3-6 days post-weaning. The lowest FR was observed when estrus occurred on days 1 and 2 after weaning both in primiparous and multiparous sows. Females showing estrus between 3-6 days post-weaning showed the highest FR in both the parity classes with a value of 84.3% and 87.8%, respectively. In general, FR increased from WEI of 1-2 days to WEI of 3-6 days. It decreased in sows with WEI of 7 to 12 days and increased again in sows with WEI between 13-20 days. In both the parity classes, WEI of 1-2 days, 7-9 days and 10-12 days resulted in lower FR ($p<0.05$) than those observed for WEI of 3-6 days.

Experiment II

The transabdominal US imaging technique employed for monitoring the development of ovarian follicles and ovulation process revealed that it was possible to detect numerous follicles with diameters ranging from 3-10 mm during the entire post-weaning period on both the ovaries. The mean diameter of the pre-ovulatory follicles recorded was 6.91 (±1.28) mm, ranging from 6 to 10 mm. At the height of standing heat, the event of ovulation could also be monitored using the trans-abdominal US imaging of the ovaries and enabled the determination of the duration of ovulation. Ovulation lasted between 2-6 hours, with an average duration of 4.82 (±1.69) hours. The reproductive activities of the sows (n=25) exhibited during the post-weaning period have been shown in Table 4.

Distribution of the sows (n=25) in relation to parity and WEI is shown in Table 5. Sows came into estrus after they were separated from their piglets. Average WEI in this study was 5.2 (±1.68) days. The majority of the sows (84%) came in estrus within 6 days after weaning. A few of the sows showed the

Table 2: Litter Size (LS) in Relation to Parity and Weaning-to-Estrus Interval (WEI).

WEI (days)	P1 n	P1 Litter size (Mean±SD)	p>1 n	p>1 Litter size (Mean±SD)
1-2	18	7.8.0±2.6^a	28	7.5±2.9^a
3-6	118	9.66±2.8^b	448	11.0±3.1^b
7-9	23	8.44±2.5^c	80	9.01±2.6^c
10-12	17	8.84±2.6^c	59	9.02±2.5^c
13-20	16	9.22±3.1^b	27	10.0±2.9^b

Values followed by different letters in the column differs ($p<0.05$)

Table 3: Distribution of Sows and Farrowing Rate (FR) in Relation to Parity and Weaning-to-Estrus Interval (WEI).

WEI (days)	n (%)	FR P1 n/n (%)	FR p>1 n/n (%)
1-2	70 (5.8)	18/28 (64.3)^a	28/42 (66.6)^a
3-6	835 (69.6)	118/140 (84.3)^b	448/510 (87.8)^b
7-9	138 (11.5)	23/32 (71.8)^c	80/104 (76.9)^c
10-12	102 (8.5)	17/24 (70.8)^c	59/75 (78.6)^c
13-20	55 (4.6)	16/20 (80.0)^b	27/32 (84.4)^b

Values followed by different letters in the column differs ($p<0.05$).

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Table 4: Weaning-to-Estrus Interval, Duration of Estrus and Ovulation; Intervals between Onset of Estrus and Ovulation as well as the Beginning of Estrus and End of Ovulations in Sows (n=25).

Parameters	Values (mean±SD)
Average weaning to estrus interval (d)	5.2 (±1.68)
Length of estrus (h)	52.6 (±6.69)
Interval from onset of estrus to the end of ovulation (h)	48.8 (±8.25)
Duration of ovulations (h)	4.82 (±1.69)
Weaning-to-ovulations interval (d)	6.23 (±1.86)
Mean follicular diameter during the pre-estrus period (mm)	4.72 (±1.12)
Average diameter of pre-ovulatory follicles (mm)	6.91 (±1.28)

Table 5: Distribution of Sows in Relation to Parity and Weaning-to-estrus Interval (WEI).

WEI (days)	n (%)	Multiparous n (%)	Primiparous n (%)
1-2	3 (12)	2 (66.7)	1 (33.3)
3-6	18 (72)	14 (77.8)	4 (32.2)
7-9	4 (16)	2 (50)	2 (50)

effects of estrus as early as 1 to 2 days (12%) and as late as 7-9 days (16%) after weaning.

DISCUSSION

In sows, suckling and subsequent weaning have a profound effect on ovarian rebound. The physical stimulus of suckling blocks the hypothalamus to inhibit GnRH release. In most cases, there will be no return to estrus and ovulation until the piglets are removed. Sows show estrus soon after weaning when the frequency and intensity of the suckling stimulus ceases[17] that results from the resumption of cyclic ovarian activity post-weaning.[18] The percentage of sows showing estrus within 2 days post-weaning (5.8%) in the present study was less than that previously reported for females with WEI up to 2 days.4 In the present study, piglets were weaned at the age of 30 days. International practices showed that piglets could be weaned at the age of 17, 21 and 35 days,[19] the latter two being the optimum weaning age, after which estrus can be expected within four to seven days, if sows were provided with optimum nutrition. Although, early weaning at 3 weeks may be economically desirable, the disadvantages are that subsequently heat will be delayed or will not show with the chances of development of cysts in the ovaries.[19] In general, it is believed that the latter the time of weaning, the shorter the time interval to the first estrus postpartum.[20] Hence, the duration of lactation of 30 days that was practiced in the farm in the present study was seen as an optimal weaning age.

In the present study (experiment I), most of the sows came into estrus within 6 days after weaning with an average WEI of 5.6 (±1.7) days, which was in agreement with the internationally accepted time interval between the weaning and first estrus (4 to 7 days). However, it was more than 4.8 (±2.8) days reported by Poleze et al[4], where the management conditions including the accuracy of estrus detection as well as the lower number of sows was probably responsible for the observed difference in the present study. Few sows exhibited external manifestation of estrus as late as 35 to 40 days after weaning. This may be due to the failure to identify sows in estrus, infertile mating or embryonic mortality. In the group of animals that were subjected to regular observations for the detection of estrus and US monitoring of the ovarian follicular activity (experiment II, n=25), the average WEI was slightly reduced to 5.2 (±1.68) days compared with WEI of sows in experiment I. The observed slight differences in WEI were probably due to an intensive follow up of the females for possible estrus manifestation which was linked with US monitoring of follicular development and ovulation, emphasizing the need for combined estrus detection. Efficient heat detection was essential to minimize the number of non-productive days and the average WEI in breeding sows. The failure to detect estrus or to breed a sow when not in heat automatically added another 21 days to the number of non-productive days, contributing to the lower reproductive performance of the sows.

The litter size of both the parity classes of females with short WEI (1-2 days) was reduced when compared with sows showing estrus between 3-6 days after weaning (p<0.05) in the present study. The higher LS observed in females with WEI of 13-20 days was concordant with the increase of LS in females with WEI between 13-21 days[4] and with WEI between 10-20 days.[21] This could probably be related to the additional period that the females may need to recover from the catabolism during lactation and to the longer period of uterine involution.[22] The average litter size per farrowing and sow and the annual number of born pigs per sow in the present study were recorded as 9 (±2.1) and 17 (±3.7), respectively, which were far lower than that of the internationally accepted 10 to 15 litter size and 23 to 25 weaned piglets per sow and year.[2] To maximize the annual number of weaned pigs per mated female, an optimal number of litters per female must be achieved. The most significant factor affecting litters per sow per year was nonproductive days. The best opportunity for improving throughput and minimizing non-productive days is by reducing the interval from weaning to re-mating or insemination. According to See[2], areas of focus in reducing the non-productive days among others include sow

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feeding programs, breeding and estrus detection.

In the present study, the overall FRs of primiparous and multiparous sows with short WEIs (1-2 days) were low. Similarly, Poleze et al[4] reported lower farrowing rate for primiparous females with WEI of 0-2 days in comparison to those with WEI between 3-5 days. The compromised reproductive performance observed in females with short WEI (1-2 days) could be related to incomplete uterine involution and hormonal imbalance affecting follicular development and ovulation. According to Castagna et al[23] the reduced fertility associated with a short WEI could also be due to a greater incidence of ovarian cysts in sows with a WEI lesser than 3 days. A greater rate of return to estrus in females with ovarian cysts was reported in comparison to sows without cysts. According to Lucy et al[24], the interval to estrus post-weaning depends on the stage of ovarian follicular development.

Overall, an increased FR was recorded in females with a WEI of 3-6 days which in turn decreased in females with WEI of 7 to 12 days and increased again in females with WEI of 13 to 20 days in both the parity classes. This is comparable with the reports of Poleze et al[4], who observed an increase in FR in females with WEI of 3-5 days and 13-21 days and decreased values of FR in females with a WEI of 6-8 days and 9-12 days. According to Soede et al[22], the decrease in LS and FR with an increase in WEI from 3 to 7-12 days can be explained by a lower ovulation rate and lower embryo survival due to disturbed follicular development during or after lactation and or by poor fertilization rates due to a suboptimal timing of insemination.

WEI between 3-8 days has been associated with a reduced interval between the onset of estrus and ovulation, emphasizing that females with longer WEI would have a shorter interval between the onset of estrus and ovulation.[20] It was so reported that this may have affected the time of insemination in relation to the time of ovulation leading to an increased chance that the first artificial intelligence (AI) would be postovulatory in females with longer WEI. Similar circumstances could probably have contributed to the lower reproductive performance of sows with WEI of 7-12 days in the present study. According to Belstra et al[25], farm-specific factors can influence the range over which WEI has an inverse relationship with the duration of estrus and the onset of estrus-to-ovulation interval.

Trans-abdominal US examination of the ovaries facilitated monitoring of the growth of follicles and ovulation. A number of follicles with a diameter ranging from 3 to 10 mm were detected during the entire post-weaning period on both the ovaries. These findings were in accordance with the reports of Lucy et al[24] and Yilma.[7] In pigs, ovulation occurs near the end of the estrus period and it may last for several hours.[20] Previous investigations have revealed that sows ovulate 39-40 hours following spontaneous estrus and 40-42 hours after the administration of hCG.[26] Similarly, Laurincik et al[27] reported that maximum ovulation rate could be achieved between 44-48 hours after administering an injection of hCG (which primarily has an LH-like effect). In the present study, ovulation occurred 48.8 (±8.25) hours after the beginning of estrus. The mean length of ovulation in post-weaning sows was 4.82 (±1.69) hours, ranging between 2-6 hours. The length of ovulation obtained in the present study was comparable with the observation of Brüssow et al[26] and Soede et al.[28]

CONCLUSION

The current study revealed that the reproductive performance indicators, FR and ls were affected in sows with WEI of 1-2 and 7-12 days post-weaning. Ultrasound examination of the ovaries enabled the detection and monitoring of pre-ovulatory follicles and ovulation process during the climax of estrus.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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