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Sow reproductive performance: effect of seminal parameters, season and parity under farm conditions

Hugo Petrocelli[1,*], Carlos Batista[1]

[1]Department Producción Animal y Pasturas, Facultad de Agronomía, Montevideo, Uruguay

*Corresponding author: hugopetrocelli@gmail.com

Abstract

The experiment was carried out in a pig farm to evaluate the reproductive performance under production conditions. The objective of the present study was to evaluate the effect of the seminal parameters (sperm vitality, sperm DNA fragmentation, sperm abnormalities and number of spermatozoa), season (summer, autumn, winter, spring), parity and boar genetic line (male or female genetic line) on the reproductive performance of the sows and gilts. A total of 348 double artificial inseminations (AI) performed with the same ejaculated were evaluated. Farrowing rate (FR), weaning-estrus interval (WEI), weaning-conception interval (WCI), total piglets born (TPB) and piglets born alive (PBA) were recorded. Simple means (standard error) for FR, WEI, WCI, TPB and PBA, were 83.3% (1.90), 4.6 days (0.33), 6.5 days (0.77), 12.3 (0.16) and 11.2 (0.16) respectively. A positive significant correlation (b= 0.150) between FR and sperm vitality was observed. The FR also was affected by season: inseminations performed in summer resulted in the lowest values, and was different from the others seasons. The females in the first two farrowings had lower FR. The male genetic line affected the FR and TPB. TPB and PBA were affected by parity: both were lower in the 2nd farrowing and higher in the 4th-5th farrowing. We conclude that under the conditions of temperate climate parity was the most important factor influencing reproductive performance.

It affected both the farrowing rate and total number of piglets born. Season affected farrowing rate, but not litter size.

Keywords: reproduction performance, pig, sow, boar, environment

1. Introduction

Reproductive output depends on many factors affecting both females and males. There is large variation fertility caused by farm and sow related factors [13]. Unlike other species such as goats and sheep, pigs do not have a highly seasonal reproduction. However, impaired reproductive performance in domestic pigs in late summer and early autumn is a vestige of seasonal breeding in wild boars, from which the domesticated breeds are derived [18]. This seasonal decline in fertility, affects both males [20] and females [1-29].

We know that there is seasonal variation in sow reproductive performance, but there is no consensus regarding the factors causing it, or about their relative importance. Season, temperature, photoperiod, parity, lactation, breed and nutrition [26] are among those most often quoted. Factors such as the parity has an effect on reproductive performance. It was observed a constant increase until the eighth parity, reaching 100% with ninth and more farrowings [24]; in Landrace sows [27] observed a decline in the second parity and then increases, and in Yorkshire sows the increase was continuous until the fifth parity; nevertheless [17] did not observe effect of parity on farrowing rate. The litter size increases with the farrowing number reaching its maximum at the fifth parity and then declines [3]. The weaning first service and weaning conception intervals decrease with the parity number [24-27].

In boar there are effect of seasonal and breed on semen quality and reproductive performance [20]. Sperm quality is extremely important because each boar participates in a large number of matings (or artificial inseminations) throughout the year. Several studies have previously assessed the predictive value of seminal parameters as fertility predictor, using "in vitro" fertilization techniques [23-32] and very few with "in vivo" fertilization [2] with contradictory results [21-23]. Thus, a good evaluation of the quality of the semen of each male is imperative, and the examination should provide a reliable evaluation of the donor.

We hypothesized that sperm quality affects the FR, in addition to the season and parity. Therefore, it is evaluated under farm conditions, the effect of the seminal parameters (sperm vitality, sperm DNA fragmentation, sperm abnormalities and number of spermatozoa in the insemination dose) on the reproductive performance of the sows and gilts; and to examine the annual variation in reproductive performance evaluating the effects of season (summer, autumn, winter, spring), parity (farrowing number) and boar genetic line (male or female genetic line). The traits recorded were farrowing rate (FR), weaning estrus interval (WEI), weaning conception interval (WCI), total piglets born (TPB), and piglets born alive (PBA).

2. Materials and Methods

2.1. Data origin

The experimental work was carried out in a pig farm located in southern Uruguay (SL 34º66' and WL 56º29'). The annual average temperature is 17°C, with seasonal variations. For Summer, Autumn, Winter and Spring respectively: average temperature: 23°C, 18.3°C, 12°C and 17.5°C; maximum temperature: 28°C, 23.5°C, 14°C and 23°C; and minimum temperature: 17°C, 13°C, 6°C and 12°C. The annual rainfall is 1100 mm. Daylight hours vary during the year (e.g. 9 hours 50 minutes in June 21, and 14 hours 28 minutes in December 21) [15].

The experiment was conducted for 12 consecutive months. Within the experimental period seasons were defined as follows: Summer: December 21 to March 20; Autumn: March 21 to June 20; Winter: June 21 to September 20, and Spring: September 21 to December 20. Each boar had at least one ejaculate evaluated in every season. All animals were handled for sampling according to the rules specified by animal welfare commission.

2.2. Animal characteristics and management

A total of 384 double artificial inseminations (experimental unit) performed with the same ejaculated were evaluated. These AI were performed with 115 ejaculates, from eight males. Each ejaculate was used in the first 3 days post-collection, and only those used to inseminate at least three females were evaluated. These AI resulted in 320 farrowings. The number of observations (AI) can be seen in Tables 1 and 2.

Table 1. Number of Observations - Artificial Inseminations (n), Simple Mean, Maximum, Minimum, and Standard Deviation of the Evaluated Variables.

Variable	n	Simple Mean	Maximum	Minimum	Standard deviation
FR[1]	384	83.3	1	0	37.32
TPB[2]	320	12.3	20.0	1.0	2.86
PBA[3]	320	11.2	20.0	1.0	2.79
WEI[4]	165	4.6	11.0	3.0	2.50
WCI[5]	149	6.5	75.0	3.0	9.44

[1]FR: Farrowing Rate;[2]TPB: Total Piglets Born; [3]PBA: Piglets Born Alive;

[4]WEI: Weaning-Estrus Interval; [5]WCI: Weaning Conception Interval.

Table 2. Number Artificial Inseminations by: Season, Parity and Boar Genetic Line.

Season	Parity[1]					Boar Genetic Line	
	1	2	3	4-5	6 and later	ML[2]	FL[3]
Sumer	13	19	14	17	29	84	8
Autumn	8	19	24	10	22	70	13
Winter	10	11	16	34	33	88	16
Spring	20	31	7	16	31	87	18
TOTAL	51	80	61	77	115	329	55

[1]Farrowing Number;

[2]ML = Male Line; [3]FL = Female Line.

The boars were between 1.3 and 2.0 years old at the beginning of the experiment. They were hybrids Pen Ar Lan, five of a terminal male line P76 (ML) and three of the female line Gallia (FL). All the females were produced in the farm and belonged to the same genetic line (FL). The gilts were inseminated with a minimum weight of 120 kg and 7 months of age.

All animals were fed concentrated feed (made on the farm), for pregnant sows, 2 kg in the first 2/3 of gestation and 2.5 kg in the final third; males consumed 2 kg per day. Water consumption was voluntary.

The males were housed in individual pens, and the females were housed in cages throughout gestation and were moved before parturition to farrowing crates. During lactation the sows were housed in cages. The photoperiod was not controlled and the health status was monitored throughout the experiment and animals with problems were not included in the analysis.

The semen was collected using gloved-hand method and discarding the jelly-like fraction of the ejaculate by filtering it through gauze at the time of extraction. The sample was immediately placed in a 37º C water-bath and diluted, using a commercial semen extender (Androstar® Plus, Minitube Abfüll-und Labortechnik Gmbh & Co. KG, Germany). To determine the number of doses per ejaculate, a primary evaluation of the volume (measured with a graduated tube) and a subjective approximation of the motility (with white field microscope) and number of spermatozoa (by colour and appearance of the ejaculate) were performed at the farm. All used ejaculates had a motility between 60 and 80%. Based on this information, the number of doses to be prepared for insemination was calculated. The number of spermatozoa in the doses varied between $2.5x10^9$ and $3.5x10^9$ (Neubauer chamber) and 100 mL. The samples were transferred from the farm to the laboratory using a thermal transport container (with Acetic acid glacial frozen, maintaining the temperature at 16ºC). Once in the laboratory, we evaluated the following characteristics: 1) Sperm Vitality (eosin-nigrosin): SV; 2) Sperm DNA Fragmentation Index: DFI, (Halomax kit; Halotech, Madrid, Spain) technique described by [6]; 3) Total sperm abnormalities: SA (microscope with phase contrast); and 4) Number of Spermatozoa in the Insemination dose: NSI (Neubauer chamber). All of the samples were subjected to DNA dispersion and fluorochrome staining in order to visualize DNA fragmentation of sperm. The processed samples were stained with a fluorochrome, propidium iodide (Sperm-Sus-Halomax® Kit, ChromaCell DNA, Madrid Spain), for viewing on fluorescence microscope (Olympus fluorescence microscope BX41TF, Olympus Corporation, Tokyo, Japan) with a cube of green excitation light. The sperm DNA fragmentation and abnormalities were calculated as the percentage of damaged spermatozoa and sperm vitality percentage of live spermatozoa in the whole sample after counting 200 spermatozoa.

Reproductive performance data included: identification of the sow and the boar, date of insemination and farrowing, piglets born (alive and dead), service failures, weaning-estrus interval, and weaning-conception interval.

2.3. Statistical analysis

The model fitted to the data included the fixed effects of: boar genetic line, boar nested within genetic line, parity and season (insemination season for farrowing rate, or birth season for litter size). Seminal parameters (SV, DFI, SA and NSI) and lactation length (LL) were included as covariates in the model. Motility was not included because it could not be assessed objectively. All ejaculates were used which by subjective observation their motility was greater than 60%.

For parity the sows were grouped in five categories: 1) Gilt: first farrowing, 2) second farrowing, 3) third farrowing, 4) fourth and fifth farrowings and 5) six and later farrowings. The variables analysed were: Farrowing Rate: FR (number of farrowing/number of inseminations); Weaning Estrus Interval: WEI (days between weaning and first estrus); Weaning Conception Interval: WCI (days between weaning and conception day);Total Piglets Born: TPB, and Piglets Born Alive: PBA.

The analyses were performed using the SAS (Statistical Analysis System, V 9.0). FR was analysed using Genmod procedure, a binomial analysis were conducted (chi-square test). Pearson correlation between FR and the seminal parameters, WEI, and WCI were conducted. The other variables were performed using Mixed procedure, the means were compared using Tukey's test at a 5% level of significance.

For FR the fixed model was:

$Yijklm = \mu + GLi + Bij + Pk + Sl + Eijklm$

Where: μ = population mean,

GLi = effect of the ith boar genetic line,

Bij = effect of the jth boar within the ith genetic line,

Pk = kth parity number,

Sl = effect of the lth season,

Eijklm = experimental error.

For litter size (TPB and PBA) the model also include the seminal parameters (SV, DFI, SA and NSI) as covariate.

For WEI and WCI male variables (boar and genetic line) were not included in the model, and the covariate included were lactation length (LL).

All the interactions were included. Interactions with $p>0.15$ were removed from the model.

3. Results

The levels of significance of the different variables and covariates studied can be seen in Table 3.

Table 3. Analysis of Variance, Final Model (significant interactions)of FR, TPB, PBA,WEI and WCI: Tests of Fixed Effects and Covariate.

	Pr>ChiSq	Pr> F			
Fixed Effects	FR[1]	TPB[2]	PBA[3]	WEI[4]	WCI[5]
GL[6]	0.0061	0.043	0.170	---	---
Boar (GL)[7]	0.6837	0.878	0.942	---	---
Parity	0.0005	0.006	0.060	0.388	0.958
Season	0.0001	0.615	0.722	0.167	0.882
GLxS[8]	0.0229	---	---	---	---
Covariate[9]					
SV	---	0.532	0.431	---	---
DFI	---	0.311	0.375	---	---
SA	---	0.861	0.705	---	---
NSI	---	0.222	0.316	---	---
LL	---	---	---	0.248	0.230

[1]FR: Farrowing Rate;[2]TPB: Total Piglets Born;

[3]PBA: Piglets Born Alive;[4]WEI: Weaning-Estrus Interval;

[5]WCI: Weaning Conception Interval.

[6]GL: Boar Genetic Line

[7]Boar (GL): Boar nested in Genetic Line;

[8]GLxS: interaction Genetic Line*Season

[9]Covariate:

SV: Sperm Vitality;

DFI: DNA Fragmentation Index;

SA: Sperm Abnormalities;

NSI: Number of spermatozoa in the Inseminate dose;

LL: Lactation Length.

Annual average for FR was 83.3%, for TPB and PBA were 12.3 ± 0.16 and 11.2 ± 0.16 piglets respectively; for WEI and WCI 4.6 ± 0.33 and 6.5 ± 0.77 days respectively; for LL = 22.2 ± 0.11 days did not vary throughout the year.

The SV was the only seminal parameters that showed a significant correlation (p=0.003) with FR, r=0.1495 (not reported but derived from analysis shown in Table 3). The other seminal parameters had no significant effect with any of the variables studied.

Season had a significant effect on FR, whereas TPB, PBA, WEI and WCI were not affected (Table 4).

Parity was the factor with the greatest effect on FR and TPB, but it did not affect PBA,WEI and WCI (Table 5). Although the PBA was not significant at 5%, it showed a near level (p = 0.060, see Table 3).

Table 4. Effect of the Season of IA and Boar Genetic Line on Reproductive Performance, Least Squares Means (± SE).

Season	FR (%)[1]	TPB[2]	PBA[3]	WEI (days)[4]	WCI (days)[5]
Summer	46.1(6.80)[b]	12.1(0.44)	11.3(0.43)	4.6(0.49)	5.8(1.54)
Autumn	93.7(6.55)[a]	12.7(0.48)	11.7(0.48)	4.1(0.63)	7.7(1.94)
Winter	82.0(5.79)[a]	12.7(0.41)	11.4(0.41)	4.5(0.52)	6.6(1.57)
Spring	83.2(4.86)[a]	12.5(0.37)	11.1(0.37)	5.9(0.59)	6.6(1.79)
Boar Genetic Line					
ML[6]	85.7(2.33)[a]	12.0(0.19)[b]	11.0(0.19)	---	---
FL[7]	66.8(5.84)[b]	13.1(0.52)[a]	11.8(0.52)	---	---

[1]FR: Farrowing Rate; [2]TPB: Total Piglets Born; [3]PBA: Piglets Born Alive;

[6]ML: Male Line; [7]FL: Female Line

[4]WEI: Weaning-Estrus Interval; [5]WCI: Weaning Conception Interval.

[a,b] Values within a column with different superscripts differ significantly at *P*<0.05.

Table 5. Effect of the Parity on Reproductive Performance, Least Squares Means (± SE).

Parity[1]	FR (%)[2]	TPB[3]	PBA[4]	WEI (days)[5]	WCI (days)[6]
1st (gilts)	67.1(5.82)^{c}	12.0(0.54)^{bc}	10.9(0.54) ^{b}	3.7(0.76)	7.8(2.29)
2nd	68.1(4.84)^{c}	11.6(0.44) ^{c}	10.8(0.44) ^{b}	4.7(0.59)	6.7(1.86)
3rd	77.9(5.51)^{bc}	12.7(0.46)^{ab}	11.8(0.46)^{ab}	5.7(0.64)	5.5(2.00)
4th - 5th	82.9(4.85) ^{ab}	13.5(0.40) ^{a}	12.1(0.40) ^{a}	5.1(0.71)	7.1(2.17)
6th and later	85.2(4.14) ^{a}	12.8(0.36)^{ab}	11.2(0.36) ^{b}	4.8(0.43)	6.4(1.32)

[1]Farrowing Number;

[2]FR: Farrowing Rate; [3]TPB: Total Piglets Born; [4]PBA: Piglets Born Alive;

[5]WEI: Weaning-Estrus Interval; [6]WCI: Weaning Conception Interval.

[a,b] Values within a column with different superscripts differ significantly at *P*<0.05.

For FR, significant interactions between season and GL (Table 6) were observed. In summer the lowest values of FR were observed, differing from the rest of the stations for the FL males and of autumn and winter for the ML males. Summer and autumn the GL presented significant differences, the FL boars were more affected than the ML boars. In winter and spring they showed no differences.

Table 6. Interaction Between Boar Genetic Line and Season for Farrowing Rate, Least Squares Means (± SE).

Boar Genetic Line	Season			
	Summer	Autumn	Winter	Spring
ML[1]	$_{b}$71.3(4.0)^{x}	$_{a}$100.0(5.4)^{x}	$_{a}$87.0(4.7)	$_{b}$81.5(4.5)
FL[2]	$_{b}$20.8(12.9)^{y}	$_{a}$84.4(11.3)^{y}	$_{a}$ 77.0 9.8)	$_{a}$84.8(8.6)

1ML: Male Line; 2FL: Female Line

[a,b] Values within a rows with different superscripts differ significantly at *P*<0.05.

[x, y] Values within a column with different superscripts differ significantly at *P*<0.05

Despite the relatively low number of observations, the effect of genetic male line was included in the model because it gives greater accuracy. The FL showed a lower FR than the ML, but the TPB was higher in the FL line. There was no effect on the PBA.

4. Discussion

The farrowing rate was affected the quality of the semen, season, parity and genetic line of the male.

Of all the seminal parameters studied, SV was the only one that presented a positive relationship with FR; DFI, AT and NSI did not showed significant relationship. Other researchers also found no correlation between morphological abnormalities and FR [9-21]. Same researchers observed a positive correlation of normal sperm with farrowing rate [32], nevertheless; others found negative correlation between DFI and FR [6]. The differences may be due to different working conditions. In addition, it should be considered that when working on under farm conditions, it is difficult to observe relationships between seminal parameters and fertility, which may be due to the high number of spermatozoa in AI doses.

Despite having evaluated only a year, the effect of the season was included in the models since in previous work carried out in the same farm, the seasonal effect on the FR [19] and the seminal parameters [20] were demonstrated.

Our results agree with those reported by [24] who observed the best conception rates in females mated in the autumn and poorest in summer inseminations. It also agrees with others researchers who found a decrease in FR with inseminations performed in summer [1-16-22] or in summer and early autumn [29].

In our study, weekly or monthly variation in FR was not evaluated, so we did not observe what happened in early autumn. Despite not having evaluated the photoperiod, the decrease in FR occurs in summer and it increased in autumn, seasons in which the photoperiod decreases. Results that could be indicating that, as was hypothesized by several researchers [e.g. 16], that the main effect is the temperature and not the photoperiod. In addition, it should be taken into account, in this experiment, that the males are in a thermally controlled environment, the effect of temperature has greater influence on the females than on males.

The most frequent reason for farrowing failure in summer months is irregular rebreeding, 25 to 35 days after IA [25]. The exact biological reason for an increase in the breeding failure in the summer has not yet been clearly understood. Sometimes it has been associated with an increase in embryonic deaths following service in summer and (or) a variation in the secretion of several hormones, although this is contradictory [25]. Some researchers mention hormonal

imbalances as an explanation of the decline in fertility during the summer. According to [29], the increased temperature inhibits prolactin release from the hypophysis, which is necessary for enhancement of secretory activity of corpora lutea around 30th day of gestation. This also causes pregnancy loss and irregular rebreeding. Reference [30] found variation in melatonin and gonadotropins secretion. By contrast, other authors found no effect [12].

The young sows, gilts and the 2nd farrowing sows, showed a lower FR than the older females (four or later farrowings). These results partially agree with those observed by [17], who found a lower FR in primiparous than in multiparous sows. By contrast, [14] did not find a significant parity effect. One possible explanation for this is that gilts were still growing, were inseminated when they were 7-8 months old, and those of second farrowing when they were approximately one year old, therefore their rebreeding will be affected. This may be due to two facts involving an increase in their metabolic requirements: that they have not fully completed their growth, and the preceding lactation, they suckled a litter [3-27].

Only the effect of the genetic line of the male was evaluated since the females are all of the same line (FL). The boar genetic line affects the FR. This finding is consistent with that of many researchers who observed differences between pig breeds for reproductive performance [28-31]. There is no other information regarding the performance of the genetic lines studied in this experiment. No explanation was found for the fact that the inseminations carried out with LM males resulted in a greater FR than those inseminations with LF males.

We observed an interaction between boar genetic line and season, the males belonged to the female line showed a lower FR, and were more affected in summer than de male line boars. No papers were found that evaluated these genetic types. We could hypothesize, that these males selected for reproductive parameters are more affected than those selected for daily gain and conversion efficiency.

Although TPB is affected by the boar genetic line, no correlations were observed between seminal parameters and litter size at birth. These results were consistent with those observed by other researchers who also did not observe correlation of the seminal parameters with litter size [8-23]. However, it contradicts what was observed by [5] a who found negative correlation between DFI and TPB.

The effect of the season on litter size at birth was not in agreement with some other reports. We found no effect of season, agreeing with the observations by [23-29]. By contrast, some researchers report an effect of season on litter size [26] but others found no effect [14].

Reference [25] indicate that these variable results can be attributed to the fact that litter size is influenced by the interaction of numerous genetic and non-genetic factors, and by different conditions and research methods.

As reported by several researchers, we also observed an effect of parity on litter size, younger sows gave rise to smaller litters than adults (four or later farrowings). Our results are consistent with those observed by [10] for whom TPB was lower in the second farrowing, followed by litter size in the first, third and fourth farrowings. Reference [26] also reported an increase in litter size from first to fourth-fifth parities, followed by a decrease in sixth to eighth parities. The increase in litter size with increasing parity, can be explained by an increase in ovulation rate, uterine capacity [9], and age of the sow [4].

There were significant differences between boar genetic lines. LF showed increased TPB, greater than the LM. These results agree with studies conducted in Uruguay [7] and in USA [9] who found variations in uterine capacity in lines selected for litter size. No significant differences were observed in PBA. This result was not in agreement with reports by other researchers who found differences between parities [10] and between months [19].

The WEI and WCI were not affected by any of the variables evaluated. This is consistent with observations by [14]. This is not in agreement with results from several researchers who reported differences between primiparous and adult sows, and observed a longer intervals in primiparous sows [11-24]. A reason for not observing differences may be the low number of data used.

5. Conclusions

Reproductive variables were affected by female attributes and sperm viability. On the male side, there was a relation between sperm vitality and farrowing rate, which highlights the effect of semen quality on reproductive performance. Regarding females, we conclude that under the conditions of the present study (temperate climate) sow parity was the most important factor influencing reproductive performance. It affected both the farrowing rate and total number of piglets born. Season affected farrowing rate, but not litter size.

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References

[1] Auvigne, V., Leneveu, P., Jehannin, C., Peltoniemi, O. and Sallé, E, "Seasonal infertility in sows: a five years field study to analyze the relative roles of heat stress and photoperiod," *Theriogenology*, 74 (1). 60–66. Jul.2010.

[2] Boe-Hansen, G.B., Christensen, P., Vibjerg, D., Nielsen, N.B.F. and Hedeboe, A.M, "Sperm chromatin structure integrity in liquid stored boar semen and its relationships with field fertility," *Theriogenology*, 69 (6). 728-736. Apr.2008.

[3] Buxadé C, *Ganado porcino*, Mundi-Prensa, Madrid, 1984.

[4] Culbertson, M.S., Mabry, J.W., Bertrand, J.K. and Nelson, A.H, "Breed-Specific Adjustment Factors for Reproductive Traits in Duroc, Hampshire, Landrace, and Yorkshire Swine," *Journal of Animal Science*, 75. 2362–2367. Sep.1997

[5] Didion, B.A., Kasperson, K.M., Wixon, R.L. and Evenson, D.P, "Boar Fertility and Sperm Chromatin Structure Status: A Retrospective Report," *Journal of Andrology*, 30 (6). 655-660. Nov-Dec.2009.

[6] Enciso, M., López-Fernández, C., Fernández, J.L., García, P., Gosálbez, A. and Gosálvez, J, "A new method to analyze boar sperm DNA fragmentation under bright-field or fluorescence microscopy," *Theriogenology*, 65 (2). 308–316. Jan.2006.

[7] Farías, L, 1999. *Evaluación de la productividad de lechones por cerdas de dos líneas genéticas: Resultados preliminares*. Tesis Grado, Universidad de la República-Facultad de Agronomía, Montevideo, Uruguay, 1999. [E-book] Available: http://biblioteca.fagro.edu.uy/iah/textostesis/1999/2838far.pdf.

[8] Gadea, J., Sellés, E. and Marco, M.A, "The predictive value of porcine seminal parameters on fertility outcome under commercial conditions," *Reproduction of Domestical Animals*, 39 (5). 303-308. Oct.2004.

[9] Gama, L.L. and Johnson, R.K, "Changes in ovulation rate, uterine capacity, uterine dimensions, and parity effects with selection for litter size in swine," *Journal of Animal Science*, 71 (3). 608–617. Mar.1993.

[10] Gómez-Medina, M., Segura-Correa, J.C. and Rodríguez-Buenfil, J.C, "Efecto de año, bimestre y número de parto de la cerda en el tamaño y peso de la camada al nacer y al destete en una granja comercial," *Revista Biomédica*, 10 (1). 23–28. 1999.

[11] Guedes, R.M.C. and Nogueira, R.H.G, "The influence of parity order and body condition and serum hormones on weaning-to-estrus interval of sow," *Animal Reproduction Science*, 67 (1-2). 91-99. Jul.2001.

[12] Hälli, O., Peltoniemi, O.A.T., Tast, A., Virolainen, J.V., Munsterhjelm, C., Valros, A. and Heinonen, M, "Photoperiod and luteinizing hormone secretion in domestic and wild pigs," *Animal Reproduction Science*, 103 (1-2). 99–106. Jan.2008.

[13] Hanenberg, E.H.A.T., Knol, E.F. and Merks, J.W.M, "Estimates of genetic parameters for reproduction traits at different parities in Dutch Landrace pigs," *Livestock Production Science*, 69 (2). 179–186. May.2001.

[14] Hughes, P.E, "Effects of parity, season and boar contact on the reproductive performance of weaned sows," *Livestock Production Science*, 54 (2). 151–157. May.1998.

[15] INIA GRAS, *Banco datos agroclimático*. 2015. Available: http://www.inia.uy/gras/Clima/Banco-datos-agroclimatico .

[16] LeMoine, A, *Meteorological effects on seasonal infertility in pigs. PhD thesis, University of Leeds,* Faculty of Biological Sciences, UK, 2013. [E-book] Available: http://etheses.whiterose.ac.uk/5059/1/Anna%20LeMoine%20thesis%20March%202013.pdf.

[17] Martinat-Botté, F., Dagorn, J., Terqui, M. and Dando, P, "Effect of confinement, climatic conditions and litter parity on the seasonal variations of the fertility rate and prolificacy," *Anaïs Recherche Vétérinaire*, 15 (2). 165-172. 1984.

[18] Mauget, R. and Boissin, J, "Seasonal Changes in Testis Weight and Testosterone Concentration in the European Wild Boar (Sus scrofa L.)," *Animal Reproduction Science*, 13. 67-74. 1987.

[19] Motta, A, *Evaluación de los efectos de la estación y del tipo de servicio sobre la eficiencia reproductiva en una granja porcina del sur del país*. Facultad de Agronomía, Universidad de la República, Montevideo, 1991, Tesis de Grado, T. 2132.

[20] Petrocelli. H., Batista, C. and Gosálvez, J, "Season variation in sperm characteristics of boar in southern Uruguay," *Revista Brasileira de Zootecnía*, 44 (1). 1-7. 2015.

[21] Popwell, J.M. and Flowers, W.L, "Variability in relationships between semen quality and estimates of in vivo and in vitro fertility in boars," *Animal Reproduction Science*, 81 (1-2). 97–113. Mar.2004.

[22] Quesnel, H., Boulot, S. and Le Cozler, Y, "Les variations saisonnières des performances de reproduction chez la truie," *INRA, Productions Animales*, 18 (2). 101-110. Mai.2005.

[23] Ruiz-Sánchez, A.L., O'Donoghue, R., Novak, S., Dyck, M.K., Cosgrove, J.R., Dixon, W.T. and Foxcroft, G.R, "The predictive value of routine semen evaluation and IVF technology for determining relative boar fertility," *Theriogenology*, 66 (4). 736–748. Sep.2006.

[24] Schwarz, T., Nowicki, J. and Tuz, R, "Reproductive performance of Polish Large White sows in intensive production - Effect of parity and season," *Annals of Animal Science*, 9 (3). 269–277. 2009.

[25] Stančić, B., Božić, A., Stančić, I., Radović, I. and Dagin, S, "Sow seasonal infertility. *Contemporary Agriculture/Savremena Poljoprivreda*, 60 (1-2). 195-203. 2011.

[26] Suriyasomboon, A., Lundeheim, N., Kunavongkrit, A. and Einarsson, "Effect of temperature and humidity on reproductive performance of crossbred sows in Thailand," *Theriogenology*, 65 (3). 606–28. Feb.2006.

[27] Tantasuparuk, W., Lundeheim, N., Dalin, A.M., Kunavongkrit, A. and Einarsson, S. "Reproductive performance of purebred Landrace and Yorkshire sows in Thailand with special reference to seasonal influence and parity number," *Theriogenology*, 54 (3). 481–496. Aug.2000.

[28] Tantasuparuk, W., Techakumphu, M. and Dornin, S, "Relationships between ovulation rate and litter size in purebred Landrace and Yorkshire gilts," *Theriogenology*, 63 (4). 1142–8. Mar.2005.

[29] Tast, A., Peltoniemi, O.A.T., Virolainen, J.V. and Love, R.J, "Early disruption of pregnancy as a manifestation of seasonal infertility in pigs," *Animal Reproduction Science*, 74 (1-2). 75–86. Nov.2002.

[30] Thiéry, J.C., Chemineau, P., Hernandez, X., Migaud, M. and Malpaux, B, "Neuroendocrine interactions and seasonality," *Domestic Animal Endocrinology*, 23 (1-2). 87-100. Jul.2002.

[31] Wolf, J, "Heritabilities and genetic correlations for litter size and semen traits in Czech Large White and Landrace pigs," *Journal of Animal Science*,88. 2893–903. 2010.

[32] Xu, X., Pommier, S., Arbov, T., Hutchings, B., Sotto, W. and Foxcroft, G.R, "In vitro maturation and fertilization techniques for assessment of semen quality and boar fertility," *Journal of Animal Science*,76. 3079–3089. 1998.