Analysis of repoductive seasonality in *Entrepelado* and *Retinto* Iberian pig varieties under intensive management

Melani Martín de Hijas-Villalba[a], Luis Varona[b], Noelia Ibáñez-Escriche[c], Juan Pablo Rosas[d], José Luis Noguera[e], Joaquim Casellas[a,*]

[a]*Grup de Recerca en Millora Genètica Molecular Veterinària, Departament de Ciència Animal i dels Aliments, Universitat Autònoma de Barcelona, 08193 Bellaterra (Barcelona), Spain.* [b]*Departamento de Anatomía Embriología y Genética Animal, Universidad de Zaragoza, 50013 Zaragoza, Spain.* [c]*Departament de Ciència Animal, Universitat Politècnica de València, 46071 Valencia, Spain.* [d]*Programa de Mejora Genética "Castúa", INGA FOOD SA, (Nutreco Group), 06200 Almendralejo, Spain.* [e]*Genètica i Millora Animal, Institut de Recerca i Tecnologia Agroalimentàries, 25198 Lleida, Spain*

* Correspondence to: Departament de Ciència Animal i dels Aliments, Universitat Autònoma de Barcelona, 08193 Bellaterra (Barcelona), Spain

E-mail address: joaquim.casellas@uab.cat

ABSTRACT

To be written...

Keywords: circular mixed model, farrowing distribution, Iberian pig, seasonality

Highlights

- One
- Two
- Three
- Four
- Up to five

1. Introduction

The domestic pig may breed throughout the year with the lowest farrowing rate in autumn (Prunier et al., 1996; Auvigne et al., 2010). This seasonal pattern impairs the swine industry and arises at different environments, production systems, and performance levels (Auvigne et al., 2010). Environmental factors such as heat stress, humidity and photoperiod have been suggested as the main causes of seasonality in pigs, although management, behavior and genetic background cannot be ruled out (Tast et al., 2001; Auvigne et al., 2010).

The Iberian pig is a native Spanish breed with five local varieties typically reared under extensive management systems in the south-west of Spain. They may be seen as an appealing animal model to study reproductive seasonality because of the low rate of genetic change experienced during the last centuries, and the phylogeny closeness to wild boars (Ramírez et al., 2015). Nevertheless, little is known about its seasonal reproductive patterns under current production systems. The recent development of a mixed circular model on the basis of the von Mises distribution (Casellas et al., 2019) has allowed to integrate flexible hierarchical structures accounting for different sources of variation on a circular (*i.e.*, year-round) parametric space. Within this context, the objective of this research was to analyze farrowing parities distribution throughout the year of Iberian sows as well as its environmental and genetic sources of variation.

2. Material and methods

All management procedures under standard farm management from selection nuclei were approved by the Research Ethics Committee of the *Institut de Recerca i Tecnologia Agroalimentàries* (Caldes de Montbui, Spain).

2.1. Farrowing data

Both *Entrepelado* and *Retinto* varieties belong to the Iberian pig breed and they mainly differ in fat deposition (Ibáñez-Escriche et al., 2015), reproductive ability (Noguera et al., 2019) and the coat color in adult individuals which is black and reddish-brown, respectively. Field data was obtained from the *Entrepelado* and *Retinto* selection program of Inga Food SA (Almendralejo, Spain), this actively contributing to the Spain's official Iberian Herdbook (Ministry of Agriculture and Fisheries, Food and Environment, Spain's Government, Madrid, Spain). Sows were kept in two selection farms and one multiplier farm (Extremadura, Spain) under intensive rearing conditions with outdoor paddocks during gestation. The *Entrepelado* variety had 3,200 parities between the years 2010 and 2017 from 739 sows, and the pedigree included 69 sires and 794 dams. On the other hand, data from *Retinto* involved 4,744 parities from 922 sows between 2009 and 2017, and a pedigree involving 89 sires and 975 dams.

2.2. Circular mixed model analysis

Analyses relied on the re-scaled day of farrowing ($\mathbf{y}$) from January, 1st (0) to December, 31st (regular years, $2\pi-2\pi/365$; leap years, $2\pi-2\pi/366$), within the context of a circular parametric space (Casellas et al., 2019). For each Iberian pig variety, the operational model was $\mathbf{y} = \mathbf{Xb} + \mathbf{Z}_1\mathbf{p}_1 + \mathbf{Z}_2\mathbf{p}_2 + \mathbf{Z}_3\mathbf{a} + \mathbf{e}$, with systematic ($\mathbf{b}$), herd-year-season ($\mathbf{p}_1$), permanent sow ($\mathbf{p}_2$), and additive genetic ($\mathbf{a}$) effects; $\mathbf{e}$ stored residuals and $\mathbf{X}$, $\mathbf{Z}_1$, $\mathbf{Z}_2$ and $\mathbf{Z}_3$ were appropriate incidence matrices. Systematic effects accounted for the parity number of the sow (1 to 8, and >8) and the litter size in previous parturition (first parity, <6 piglets, 6 to 10, and >10). The model was developed within a Bayesian context as follows,

$$p(\mathbf{b},\mathbf{p}_1,\mathbf{p}_2,\mathbf{a},\sigma_{p1}^2,\sigma_{p2}^2,\sigma_a^2,\kappa|\mathbf{y}) \propto p(\mathbf{y}|\mathbf{b},\mathbf{p}_1,\mathbf{p}_2,\mathbf{a},\kappa)\ p(\mathbf{b})\ p(\mathbf{p}_1|\sigma_{p1}^2)\ p(\sigma_{p1}^2)$$

$$\times\ p(\mathbf{p}_2|\sigma_{p2}^2)\ p(\sigma_{p2}^2)\ p(\mathbf{a}|\mathbf{A},\sigma_a^2)\ p(\sigma_a^2)\ p(\kappa),$$

where κ was the dispersion-specific parameter within the circular parametric space (see below), **A** was the numerator relationship matrix, and σ_{p1}^2, σ_{p2}^2 and σ_a^2 were herd-year-season, permanent sow and additive genetic variances, respectively. The conditional distribution of **y** was a von Misses process (Fisher, 1993),

$$p(\mathbf{y}|\mathbf{b},\mathbf{p}_1,\mathbf{p}_2,\mathbf{a},\kappa) = \Pi_i \exp(\exp(\kappa) \cos(y_i - (\mathbf{x}_i\mathbf{b} + \mathbf{z}_{1i}\mathbf{p}_1 + \mathbf{z}_{2i}\mathbf{p}_2 + \mathbf{z}_{3i}\mathbf{a}))) / 2\pi I_0(\exp(\kappa)).$$

Note that $\mathbf{x}_i$, $\mathbf{z}_{1i}$, $\mathbf{z}_{2i}$ and $\mathbf{z}_{3i}\mathbf{a}$ were row vectors of incidence inherent to the ith circular record, and $I_0()$ was the modified Bessel function of order 0. A priori distributions for $\mathbf{p}_1$, $\mathbf{p}_2$ and **a** were assumed multivariate normal (**MVN**) as follows, $p(\mathbf{p}_1|\sigma_{p1}^2) = MVN(\mathbf{0},\mathbf{I}\sigma_{p1}^2)$, $p(\mathbf{p}_2|\sigma_{p2}^2) = MVN(\mathbf{0},\mathbf{I}\sigma_{p2}^2)$ and $p(\mathbf{a}|\sigma_a^2) = MVN(\mathbf{0},\mathbf{A}\sigma_a^2)$. A priori distributions for **b**, variance components, and κ were assumed flat between appropriate bounds. Nevertheless, an additional restriction applied to guarantee that $0 \leq \mathbf{Xb} + \mathbf{Z}_1\mathbf{p}_1 + \mathbf{Z}_2\mathbf{p}_2 + \mathbf{Z}_3\mathbf{a} \leq 2\pi$ (Casellas et a., 2019).

Unknown parameters form the joint posterior distribution where sampled by Metropolis-Hastings (Metropolis et al., 1953; **b**, $\mathbf{p}_1$, $\mathbf{p}_2$, **a** and κ) and Gibbs sampling (Gelfand and Smith, 1990; variance components). For each model, three independent Monte Carlo Markov chains where launched with 500,000 sampling iterations after 50,000 burn-in iterations. The length of the burn-in period was assessed by visual inspection on κ.

2.3. Testing for seasonality and other sources of variation

Seasonality presupposes a relevant departure from the wrapped uniform distribution. Within this context, testing for seasonality can be carried out on parameter κ, because the von Mises distribution reduces to a wrapped uniform if $\exp(\kappa) = 0$ (Fisher, 1993). Within this context, the von Mises circular mixed model was compared against a model with $\exp(\kappa) = 0$ and $p(\mathbf{y}|\kappa=0) = \Pi_i\ 1 / 2\pi$. Models were compared through the deviance information criterion

(**DIC**; Spiegelhalter et al., 2002), which equals to $-2\log(1 / 2\pi)$ for the wrapped uniform. The model with lower DIC becomes favored, and a difference of at least 3 to 5 DIC units is typically considered as statistically relevant (Spiegelhalter et al., 2002).

The statistical relevance of systematic effects was evaluated by their posterior distribution and the absence of overlapping when comparing 95% confidence intervals. Random sources of variation were evaluated by the DIC. Once computed DIC under the full model described above, DIC was recalculated after removing each one of $\mathbf{p}_1$, $\mathbf{p}_2$ and $\mathbf{a}$ effects.

3. Results

The raw distribution of farrowing data peaked in March in both Iberian pig varieties and showed a smooth pattern (Figure 1). Analyses revealed negative posterior means for the κ parameter in *Entrepelado* (–7.376) and *Retinto* varieties (–3.393; Table 1), and their sampling paths reached a stationary pattern without collapsing to $-\infty$ (i.e., $\exp(\kappa) = 0$). Indeed, average DIC for the full model reached 11,654 (*Entrepelado* variety) and 17,338 (*Retinto* variety) units, whereas a wrapped uniform model increased DIC to 11,762 and 17,438, respectively.

Operational models included litter size in previous farrowing and parturition number, although influences from previous litter size were discarded in both varieties as 95% confidence intervals overlapped. The parity number had a relevant impact on farrowing distribution (Figure 2) and suggested a delaying pattern up to fourth parturition, which attenuated (or even advanced parturition in *Retinto*) later on. Once weighted systematic effects, farrowing peak was predicted for March, 15th (*Entrepelado*) and April, 8th (*Retinto*) although with wide 95% confidence intervals involving more than two months.

Posterior means for permanent environmental variances ranged between 0.010 and 0.029, whereas additive genetic variance reached slightly higher values around 0.030 (Table

1). The exclusion of $\mathbf{p}_1$ or $\mathbf{p}_2$ effects in any of the two Iberian varieties reduced the DIC in more than 10 units. A similar pattern was revealed for **a** effects in the *Entrepelado* variety, with a reduction of 8.5 DIC units, whereas DIC slightly increased in the *Retinto* variety when removing **a** from the operational model (+0.67 units; results not shown).

4. Discussion

Scientific literature about seasonality in scarce in the pig industry (Prunier et al., 1996; Auvigne et al., 2010), and almost null about Iberian sows (Dobao et al., 1983). To our best knowledge, this is the first attempt to analyze farrowing seasonality in the intensive Iberian pig production system within a circular continuous paradigm. Analyses corroborated the wide Gaussian-like pattern of farrowing data, this being characterized by a von Mises distribution with a small $\exp(\kappa)$ parameter ($1/\exp(\kappa)$ is analogous to variance of the normal distribution; Fisher, 1993). Given the negative estimate obtained for κ (Table 1), both *Entrepelado* and *Retinto* sows must be considered as lowly seasonal, with the farrowing peak located between March and April as consequence of a better reproductive efficiency (i.e., matings) during fall months (decreasing photoperiod and mild temperatures) (Tast et al., 2001; Prunier et al., 1996; Auvigne et al., 2010). Seasonality was corroborated by the DIC statistic, which favored the von Mises model against a wrapped uniform distribution of farrowing data. These results agreed with Dobao et al. (1983) in other Iberian pig varieties, and matched the standard pattern reported for sows in northern hemisphere (Auvigne et al., 2010).

The unique relevant systematic effect was the parity number of the sow. This delayed the farrowing peak for adults sows to early summer, whereas advanced this peak to early spring in the case of gilts and old sows. This could be linked to the lower sensitivity to heat stress of adult sows (Bloemhof et al., 2013), as well as the higher impact of photoperiod in gilts (Kraeling and Webel, 2015). Nevertheless, one must be cautious with the interpretation of these effects on the circular parametric space because (1) they were reported as departures from the population mean although farrowing data widely distributed along the whole year, and (2) posterior means must be viewed as the shortest distance between population mean (μ) and farrowings affected by the ith effect (b_i) although the complementary distance would also be plausible (i.e., $\mu - (2\pi - b_i)$) (Casellas et al., 2019). This did not invalidate the statistical relevance of the effect, but contributes a certain degree of uncertainly about the direction on the circular parametric space.

All random sources of variation were statistically discarded from the analysis of farrowing distribution, with the only exception of the additive genetic background in the *Retinto* variety. The small advantage in terms of DIC did not provide strong evidences about the genetic background for farrowing distribution, and disagreed with previous studies performed in other species like sheep (Casellas et al., 2019). Moreover, σ_a^2 reached a small posterior mean with h^2~0.03. This must discourage future endeavors to modify farrowing distribution by means of genetic selection.

5. Conclusion

Entrepelado and *Retinto* Iberian sows under intensive production systems show a moderate to low degree of seasonality in terms of farrowing distribution, they peaking during spring. This pattern was lowly influenced by systematic and random effects, and only the parity number of the sow consistently influenced both varieties. Relevant genetic variability was only detected in the *Retinto* population, although with very small heritability.

Conflict of interest statement

There are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Acknowledgements

Research supported by projects CGL2016-80155-R and IDI-20170304, and a fellowship granted to M. Martín de Hijas-Villalba (BES-2017-080596) by Spain's *Ministerio de Economía y Competitividad*.

References

Auvigne, V., Leneveu, P., Jehannin, C., Peltoniemi, O., Sallé, E., 2010. Seasonal infertility in sows: A five year field study to analyze the relative roles of heat stress and photoperiod. Theriogenology 74, 60-66.

Bloemhof, S., Mathur, P. K., Knol, E. F., van der Waaij, E. H., 2013. Effect of daily environmental temperature on farrowing rate and total born in dam line sows. J. Anim. Sci. 91, 2667-2679.

Casellas, J., Id-Lahoucine, S., Martín de Hijas-Villalba, M., 2019. Analysis of lambing distribution in the Ripollesa sheep breed. II. Environmental and genetic sources of variation. Animal (in press).

Dobao, M. T., Rodrigañez, J., Silió, L., 1983. Seasonal influence of fecundity and litter size performance characteristics in Iberian pigs. Livest. Prod. Sci. 10, 601-610.

Fisher, N. I., 1993. Statistical analysis of circular data. Cambridge University Press, Cambridge, UK.

Gelfand, A., Smith, A. F. M., 1990. Sampling based approaches to calculating marginal densities. J. Am. Stat. Assoc. 85, 398-409.

Ibáñez-Escriche, N., Magallón, E., Gonzalez, E., Tejeda, J. F., Noguera, J. ., 2016. Genetic parameters and crossbreeding effects of fat deposition and fatty acid profiles in Iberian pig lines. J. Anim. Sci. 94, 28-37.

Kraeling, R. R., Webel, S. K., 2015. Current strategies for reproductive management of gilts and sows in North America. J. Anim. Sci. Biotechnol. 6, 3.

Martinez, A. M., Delgado, J. V., Rodero, A., Vega-Pla, J. L., 2000. Genetic structure of the Iberian pig breed using microstellites. Anim. Genet. 31, 295-301.

Metropolis, N., Rosenbluth, A. W., Rosenbluth, M. N., Teller, A. H., Teller, E., 1953. Equations of state calculations by fast computing machines. J. Chem. Phyis. 21, 1087-1092.

Noguera, J. L., Ibáñez-Escriche, N., Casellas, J., Rosas, J. P., Varona, L., 2019. Genetic prameters and direct, maternal and heterosis effects on litter size in a diallel cross mong three commerical varieties of Iberian pig. Animal (in press).

Prunier, A., Quesnel, H., Messias de Bragança, M., Kermabon, A. Y., 1996. Environmental and seasonal influences on the return to oestrus after weaning in primiparous sows. A review. Livest. Sci. 45, 103-110.

Ramírez, O., Burgos-Paz, W., Casas, E., Ballester, M., Bianco, E., Olalde, I., Santpere, G., Novella, V., Gut, M., Lalueza-Fox, C., Saña, M., Pérez-Enciso, M., 2015. Genome data from sixteenth century pig illuminate modern breed relationships. Heredity 114, 175-184.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., van der Linder, A., 2002. Bayesian measures of model complexity and fit. J. R. Stat. Soc. B 64, 583-639.

Tast, A., Hälli, O., Ahlström, S., Andersson, H., Love, R. J., Peltoniemi, O. A., 2001. Seaasonal alterations in circadian melatonin rhythms of the European wild boar and domestic gilt. J. Pineal Res. 30, 43-49.

Table 1

Summary of herd-year-season (σ_{p1}^2), permanent sow (σ_{p2}^2) and additive genetic (σ_a^2) variances, as well as variance parameter (κ) from analysis of farrowing distribution in *Entrepelado* and *Retinto* Iberian pig varieties.

	Entrepelado variety		*Retinto* variety	
Parameter	Mean[1]	CI95[2]	Mean	CI95
σ_{p1}^2	0.029	0.013 to 0.067	0.012	0.004 to 0.075
σ_{p2}^2	0.010	0.007 to 0.018	0.010	0.003 to 0.027
σ_a^2	0.024	0.009 to 0.039	0.035	0.028 to 0.050
κ	-7.376	-12.298 to -1.583	-3.393	-9.710 to -1.479

[1]Posterior mean; [2]95% confidence interval.

Figure 1. Farrowing distribution on a monthly basis in *Entrepelado* (black) and *Retinto* (grey) Iberian pig varieties.

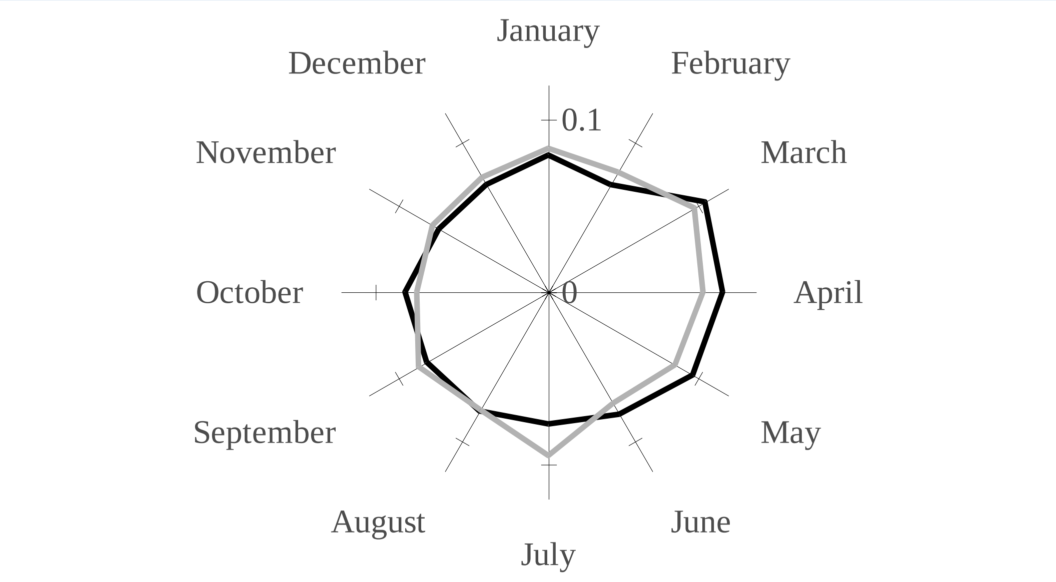
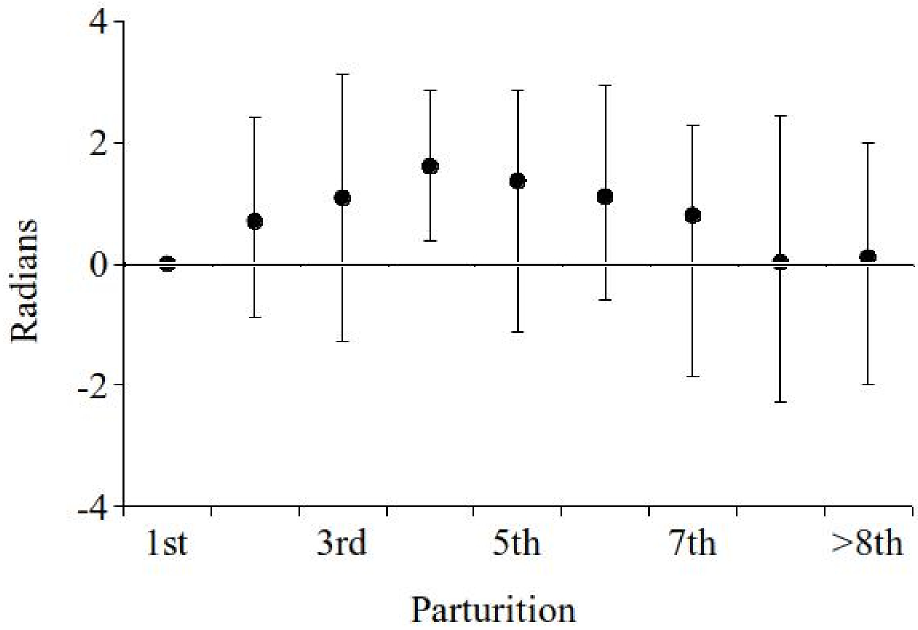


Figure 2. Posterior mean (dot) and 95% confidence intervals (whiskers) for predicted effect of parturition number on farrowing distribution in *Entrepelado* (a) and *Retinto* (b) varieties.

(a)



(b)