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EFFECT OF BEING HALF-BROTHERS OVER PIGS' BODY WEIGHT VARIABILITY AT SLAUGTHERING

Final degree project – Agricultural engineering

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EFFECT OF BEING HALF-BROTHERS OVER PIG' BODY WEIGHT VARIABILITY AT SLAUGHTERING

RESUM

Objectiu: Determinar l'efecte genètic (mitjos germans/es), del pes i del gènere sobre la variabilitat de pes de sacrifici de porcs sotmesos a les mateixes condicions d'alimentació i maneig.

Metodologia: Es van seleccionar un total de 406 garrins d'una base de dades de 1304 animals, i es van emparellar en funció de 3 factors: mateixa mare, mateix pes de naixement i mateix gènere. A continuació es van establir tres categories en funció del pes a naixement: Grup Lleuger, Grup Mig i Grup Pesat. Es va seguir la mateixa metodologia per establir grups de pes al dia 21 (deslletament) i al dia 64 (final de transició). Finalment, les parelles van dividir-se en dos grups en funció de la diferència de pes entre animals de la mateixa parella al dia 163 (final de fase d'engreix).

Resultats: Els animals amb un major pes al naixement van mostrar un creixement significativament superior als altres dos grups d'animals (P<0,05).

Les categories de pes viu al naixement i al deslletament no van tenir cap efecte significatiu sobre la diferencia de pes a sacrifici (P>0,10). D'altra banda, el pes viu a final de fase de transició sí que va mostrar tenir una tendència sobre aquesta mateixa variable (P<0,10).

El grup de parelles amb un pes més alt al final de de transició van tenir un creixement més homogeni a durant la fase d'engreix que els altres dos grups (P<0,05).

Finalment, els darrers anàlisis van demostrar que l'efecte de ser mitjos-germans/es respecte la variabilitat de pes al moment de sacrifici és petit (només el 20% de les parelles assoleixen un pes de sacrifici molt semblant), i que la diferència de pes al final de fase de transició és determinant per la diferència de pes en el moment de sacrifici (P<0,05).

Conclusions: Es conclou que l'efecte de ser mitjos germans sobre la diferència de pes a sacrifici és petit, sense que existeixi cap relació amb el pes de naixement o el gènere dels animals. En la fase de transició és on es produeix una diferència de pes entre animals aparellats que resultarà determinant per la diferència de pes a sacrifici. La ingestió d'aliment, així com el seu aprofitament, són els factors més importants per entendre la variabilitat de pes a sacrifici entre mitjos germans/es.

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RESUMEN

Objetivo: Determinar el efecto genético (medios hermanos/as), del peso y del género sobre la variabilidad del peso de sacrificio de cerdos sometidos a las mismas condiciones de alimentación i manejo.

Metodología: Se seleccionaron un total de 406 lechones de una base de datos de 1304 animales, y se emparejaron en función de 3 factores: misma madre, igual peso de nacimiento i mismo género. A continuación se establecieron tres categorías de animales en función del peso a nacimiento: Grupo Ligero, Grupo Medio y Grupo Pesado. La misma metodología fue utilizada para establecer grupos de peso a día 21 (destete) y a día 64 (fin de la transición). Finalmente, las parejas se dividieron en dos grupos en función de la diferencia de peso, entre animales de la misma pareja, a día 163 (final fase de engorde)

Resultados: Los animales con un mayor peso de nacimiento resultaron crecer más que los otros dos grupos de animales (P<0,05).

Las categorías de peso vivo a nacimiento y a destete no tuvieron ningún efecto significativo sobre la diferencia de peso, entre animales emparejados, a final de fase de engorde (P>0,10). Por otro lado, el factor peso corporal a final de fase de transición sí que demostró tener una tendencia por la misma variable respuesta (P<0,10).

El grupo de parejas con un mayor peso corporal a final de fase de transición resultaron tener un crecimiento más homogéneo durante la fase de engorde que los otros dos grupos (P<0,05).

Finalmente, los últimos análisis demostraron que el efecto de ser medios hermanos/as respecto la variabilidad de peso en el momento de sacrificio es pequeño (sólo el 20% de las parejas alcanzan un peso de sacrificio muy parecido), y que la diferencia de peso a final de fase de transición es significativa por la diferencia de peso en el momento de sacrificio (P<0,05).

Conclusiones: Se concluye que el efecto de ser medios hermanos respecto a la diferencia de peso a sacrificio es pequeña, sin que exista ninguna relación con el peso de nacimiento o el género de los animales. En la fase de transición es donde se produce una diferencia de peso entre animales emparejados que resultara determinante por la diferencia de peso a sacrificio. La ingestión de alimento, así como su aprovechamiento, son los factores más importantes por entender la variabilidad de peso a sacrificio entre medios hermanos/as.

EFFECT OF BEING HALF-BROTHERS OVER PIG' BODY WEIGHT VARIABILITY AT SLAUGHTERING

ABSTRACT

Objective: To determine the genetic effect (half-brothers/sisters), body weight and gender on the BW variability at the end of fattening phase between pigs subjected to the same feed and management conditions.

Methods: 406 piglets were selected from a database of 1304. Piglets were paired according to 3 factors: same mother, equal birth weight and same gender. Next, three categories of animals were established according to the birth body weight category: Light Group, Medium Group and Heavy Group. The same methodology was used to set the groups of weight at day 21 (weaning) and day 64 (end of growing phase). Finally, pairs were divided in two groups according to the body weight difference, between paired animals, at day 163 (end of fattening phase)

Results: Heavy piglets at birth day had higher growth compared with the other two groups of animals ($P<0,05$). Birth body weight and body weight at weaning categories had no significant effect on weight difference between paired animals at the end of fattening phase ($P>0,10$). On the other hand, the body weight category at the end of nursery period showed a tendency for the same variable ($P<0,10$).

Heavy animals at the end of nursery period followed a more homogenous growth during fattening phase than the other two groups ($P<0,05$).

Finally, the last analyses showed that the effect of being half-brothers on body weight variability at slaughtering is low (only 20% of the pairs reach a very close body weight at the slaughter moment), and that weight difference at the beginning of fattening phase was significant for weight difference at slaughtering ($P<0,05$).

Conclusions: It was concluded that the effect of being half-brothers/sisters on weight difference at slaughtering is low, and it does not exist any relationship between this variable and the birth body weight or the gender. The weight difference produced during nursery period is going to be determinant for the final weight difference at the end of fattening phase. Feed ingestion, as well as absorption metabolic efficiency, appeared to be the most important factors to understand the body weight variability at slaughtering between half-brothers/sisters.

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SYMBOLS AND ACRONYMS

ADG: Average Daily Gain (g)

BW: Body Weight (kg)

BBW: Birth Body Weight (kg)

BBW category: Groups of animals set according to BBW

BW category 21: Groups of animals set according to BW at day 21

BW category 64: Groups of animals set according to BW at day 64

CV: Coefficient of variation (%)

CR: Conversion Ratio

DD105: Difference of days to achieve 105 kg between paired animals

d: day

GD: Growth Difference (g)

GR: Growth Rate (g)

NE: Net Energy (kcal)

WD: Weight Difference (kg)

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"Learn everything you can, anytime you can, from anyone you can; there will always come a time when you will be grateful you did" – Sarah Caldwell

1. INTRODUCTION

1.1 Current situation of Spanish pig sector

Spanish productive system differs from most of the European Union (EU) countries. The last decades, a familiar production based on small farms and companies has evolved into an effective vertical integration system. The bet to this type of production could help to understand why Spain is so efficient in pig production, being nowadays the EU country with a largest number of sows and, together with Denmark, lowest production cost (Davis, 2017). Moreover, while other EU countries are stabilizing their herds, Spain keeps growing (FAO, 2020). In very broad terms, vertical integration system is the process of connecting different sub-systems (components) into a larger system controlled by a single entity (Lehtonen, 2018). From economic point of view, vertical integration occurs when a company acquires another company that operates in a production process of the same industry, either before or after in the supply chain. This strategy allows the company to increase profits from newly acquired operations by selling its products to final consumers. Moreover, it also increases the efficiencies in the production costs and cuts down on delays in delivery and transportation. These companies that control the whole production process, from the feed industry until the slaughterhouse, have detected important inefficiencies in the production system. With the old segmented way of production, these inefficiencies were unadvertised, but now, some concerns such as body weight variability at slaughtering are gaining importance among producers (Tarver, 2019).

1.2 Body weight variability, a handicap for swine industry

New strategies of the companies searching an increase of efficiency, plus the raising awareness about biosecurity, had provoked that closed cycle farms, with continuous-flow systems, have evolved into all-in all-out systems. Among the different handicaps that had emerged during this evolution, the intrinsic growth variability of swine production has become one of the biggest concerns between producers (Huang and Miller, 2004; López-Vergé *et al.*, 2018; Patience *et al.*, 2004).

Producers often talk in terms of weight average, although at the slaughterhouse animals are evaluated as individuals. Some of them will fall under or over the desired weight range, both carrying economic penalties. If variability between animals of the same batch is reduced, these penalties can also be reduced, increasing the price obtained per kg of meat sold (Towers, 2016) and reducing shadow costs of production. Thus, it is not surprising that the last years a lot of research around this topic, trying to find new techniques to increase the body weight homogeneity at slaughtering, has been done (O'Quinn *et al.*, 2001; Wang *et al.*, 2016; Cadéro *et al.*, 2018; López-Vergé *et al.*, 2018). Part of this variability effect is reduced by arranging the slaughtering of the animals based on their body weight. However, this solution is insufficient especially for lightest animals. Moreover, it leads to an underuse of the facilities and a consequent increase of the production cost (SIP Consultors, 2019).

1.3 Genetics and body weight variability in swine industry

There are many different factors that can induce body weight (BW) variability, including genetic factors. Many animal traits, and not only the mean but also the variation around that mean, are under genetic control (Sell-Kubiak *et al.*, 2015). There is also clear evidence that satiety in humans is influenced by the genome, and that differences on this part of the genome have a direct effect on the weight of the individuals (Llewellyn *et al.*, 2014). In this sense, it will not be ludicrous to think that the phenotypic variability observed in pigs' BW is caused, or at least influenced, by an unknown genotypic structure that controls voluntary feed ingestion. At the same time, there are a lot of different hypothesis around other factors such as gender, birth body weight (BBW) and gut's microbiota effect (Campos *et al.*, 2012; Archer *et al.*, 2003; Quesnel *et al.*, 2008).

Therefore, it seems clear that there is not a unique cause for BW variability, it is more likely a holistic topic. One of the factors which is thought to be determinant is gender. There is no doubt that it exits an important difference in feed conversion between males and females (Sheikh *et al.*, 2017). Females have a significantly higher conversion ratio than males as a consequence of higher feed intake. At the end, the two genders normally achieve a similar daily gain. This effect is especially seen at the end of fattening phase when animals achieve puberty and sexual hormones start acting (Vázquez-Gómez *et al.*, 2020).

1.4 Management and body weight variability

In pig production exists an intrinsic BW variability linked to the animals' biology. At the same time it is also proved that management techniques applied by the farmer have huge influence over this factor (Schinckel *et al.*, 2007).

The first step for promoting BW homogeneity between littermates occurs during insemination. Sow nutrition around this moment is crucial to increase the homogeneity of oocysts' and conceptuses' development, reducing BW variability between littermates at birth (Yuan *et al.*, 2015).

Lactation period is also very important for BW variability between littermates. Piglets have a clear hierarchy and all the piglets suckle always the same teat. Piglets suckling the sow's front teats grow faster than those suckling the inguinal teats because of differences on milk production quantity (Fraser and Jones, 1975; Rendón del Águila *et al.*, 2017). Moreover, a consumption of 250 g of colostrum per animal during the first 24 h after birth is recommended to achieve good health status, but also to ensure a normal pre- and post- weaning growth (Quesnel *et al.*, 2012). Rendón del Águila *et al.*, (2017) concluded that piglets with low BBW spend more time to ensure their suckling teat, reducing the amount of colostrum intake and increasing their vulnerability to diseases. It also supposes a higher risk for their posterior development.

Immediately after weaning, anorexia and the low feed intake are responsible for villous atrophy and reduced growth rate (GR) in newly-weaned pigs. To achieve an homogeneous growth of the batch during post-weaning period, it will be crucial to promote piglet's feed intake as soon as possible, avoiding the number of fall back piglets (Dong and Pluske, 2007). Some technics such as sorting pigs by weight after weaning have become very popular among farmers. But a number of studies (*e.g*. Wolter *et al.*, 2002) have shown that this practice only reduces variation at time of sorting, and that they have no effect if there is no individualized treatment among different groups of animals. In other words, there is no benefit in sorting pigs to reduce variation if then all groups are treated in the same way (reviewed from Wright, 2017). López-Vergé *et al.* (2018) concluded that pigs allotted to more feeder spaces tended to have lower BW variability during the growing and finishing phases of production. The same study suggested that specific feeding strategies for light piglets, at the start of the growing period, reduced the variability of the population at slaughter.

From a practical point of view, it might be highly interesting to know the group of animals more susceptible to have higher weight variability and in which productive phase this phenomenon becomes irreversible. In this case, and knowing that management is especially important for reducing BW variability, farmer could focus on the most vulnerable group of pigs, especially the lightest ones, applying individualized techniques to promote homogeneity within animals.

1.5 Relation between increasing prolificacy and body weight variability

The last decades it has been an increasing tendency among producers to wager for hyperprolific sows. Selection for prolificacy has led to an important increase of litter size at birth and a consequent reduction of piglets' BBW (Huby *et al.*, 2003). At the same time, despite the low heritability, some studies reflect a clear increase of BBW variability between littermates (Maignel *et al.*, 1998).

Quiniou *et al.*, (2002) studied the consequences of the increasing BBW variation between piglets and its subsequent performance. After the research, they concluded a positive relation between BBW variability and the number of inviable piglets. The main reason may be that a considerable proportion of growth performance after birth may be pre-programmed during foetal development in the uterus (Town *et al.*, 2004). Therefore, it is clear that sows with very heterogeneous BBW piglets reinforce the competition between littermates, increasing the number of non-viable animals and growth differences between them (Huby *et al.*, 2003).

1.6 Previous work

Eventually, it must be stated that there is no previous research done about the specific topic of this study. Although there are a lot of studies about BW variability in pigs (*e.g.* Huang & Miller, 2004; López-Vergé *et al.*, 2018), none of them approached the subject from this perspective. It is clear that it will be impossible for a project of this magnitude to conclude the reasons that induce BW variability between piglets with very similar initial conditions and same management/environment, but it has to be used and understood as a set point for further research on this field.

2. HYPOTHESIS AND GOALS

There is proved evidence that piglets with low BBW have higher tendency to develop impaired growth. The difficulties of piglets' adaptation during weaning period are also well documented. In addition, there are also clear growth differences between males and females, especially at the end of fattening phase. For these reasons, plus all the research done beforehand, the initial hypothesis of the research program were:

- Animals with low birth body weight will be more susceptible to future weight variability.
- Provided a piglet live weight at birth, the variation of growth produced during lactation and nursery phase will be determinant to the final variability of weight between animals.
- At the end of the fattening period gender also may affect body weight variability.

In this sense, with the will of understanding better the cause of weight variability in sow production, the main objectives of this study are the following:

- To study the effect of being half-brothers or sisters, born from the same sow, over the variability of body weight at slaughtering.
- To determine how initial body weight category (heavy, medium and light) influences growth variability on pigs.
- To study which productive phase (lactation, nursery, growing-finishing) is more determinant for body weight differences found between half-brothers or sisters at slaughtering.

3. METHODOLGY: MATERIALS AND METHODS

3.1 Materials

First of all, it must be said that the information for this project was recorded in a previous research program carried out by Dr. Sergi López Vergé, and supervised by Dr. Josep Gasa Gasó and Dr. David Solà Oriol, named "Estudio y gestión de la variabilidad de peso vivo a lo largo del ciclo del porcino en condiciones comerciales". SNIBA group, and Dr. Sergi López Vergé in particular, contributed in the current project by sharing the information of their previous study. This information was used in order to continue with the research of the objective topic from a different point of view. Obviously the original information was digested and processed for achieving the specific objectives of the current project.

The observational study, conducted under the approval of the Animal Ethics Committee of the Universitat Autònoma de Barcelona, was done in Catalonia (Spain) under commercial conditions in which pigs were monitored from birth to slaughter. All the information belonging to the sow was also recorded. So the current research program is strictly observational and based on an existing database that was not processed for its purpose.

The information source for this project was a database with information about 1,304 males and females pigs [Pitetrain x (Landrace x Large White)] from 110 litters born from 26/09/2015 until 09/10/2015. It was the batch selected for the researchers to carry out the initial project mentioned before. All animals were acquired from a unique commercial farm of 500 Landrace × Large White sows (Hypor, Hendrix-Genetics, Netherlands) that follows a 4-wk batch management production system. Piglets were weaned at 21.4 ± 2.2 days of age, on average, and moved to one nursery unit with four rooms of 24 pens with 23 to 24 animals per pen. The nursery was equipped with central heating and forced ventilation. Thereafter, the animals of the population were moved to their corresponding external growing–finishing farm. In that period, the different groups of pigs were not maintained in order to not interfere in the routine of the farms. Instead, pigs were again distributed in their respective farms according to sex and approximate BW (according to the experience of the stock workers). All animals were fed *ad libitum* with a pelleted diet.

3.2 Methods

An initial digestion and transformation of the original database was necessary to have all the necessary information for the current project. The variables used during the analysis can be seen in **Table 1**.

Table 1. *Individual and pair information of the population used for the project (after database digestion)*

	Variable	Observations
Individual information	Animal identification	A number was assigned to each animal to monitor its evolution. Used as random factor in individual analysis.
	Sow number	Identification of the sow. It was really important to know which animals were half-brothers/sisters. Used as random factor in pair analysis.
	Day	Day of data recording (counting from the day animal was born). Used as factor.
	Gender	Male/Female. Variable used as a factor to predict the objective variables.
	Body weight	Live body weight of pigs was measured on d 0, 21, 64, 125 and 163. Necessary to set up body weight categories at d 0, 21 and 64. Used in the project to check the normal distribution of the population and as a response variable (kg).
	Growth rate	Growth rate was measured on d 0, 21, 64, 125 and 163. Used in the project to check the normal distribution of the population and as a response variable (g).
	Days to achieve 105 kg	Time that an animal spent to achieve an objective weight of 105 kg. It was calculated through a specific prediction model for each animal. Used in the project as a response variable (days).
Pair information	Pair identification	A number was assigned to each pair
	Body weight category	Pairs of animals were distributed in 3 groups according to their body weight at d 0, 21 and 64. The methodology used is explained afterwards. Used in the project as a factor.
	Body weight difference	Weight difference between paired animals was calculated for d 0, 21, 64, 125 and 163. This information was used in the project as a response variable (kg).
	Growth rate difference	Growth difference between paired animals was calculated for days 0, 21, 64, 125 and 163. This information was used in the project as a response variable (g)

Pair information	Difference of in days to achieve 105 kg	Difference of time that animals of same pair spent to achieve an objective body weight of 105 kg. Used in the project as a response variable (days)

The methodology used during the research program was the following:

1. **Selection of piglets for the study**. Adopted piglets, animals with visible clinic diseases and the ones which died before 163-d old were discarded. No more restrictions in other factors, such as a BBW minimum or litter BBW homogeneity, were stablished.
2. **Piglets pairing**. Selected piglets were paired according to the following criteria: 50% brothers and sisters (only sow information was available as sows were inseminated artificially with semen pool doses), same gender and maximum variation of 60 g of BBW. This criteria was set according to the most restrictive difference that allowed sufficient data to conduct the further statistical analysis, representing a variance lower than 5% of the BBW average. In case that more than two piglets accomplished these conditions, the two animals with closest BBW were grouped. A total of 408 piglets, that formed 204 pairs, accomplished these conditions and were used for the analysis.
3. **Effect of the productive phase.** To see the effect that different productive phases had on the final BW variability, BW categories were set at birth (d 0), at weaning (d 21) and at the end of nursery phase (d 64). In further points it is explained how it was done.
4. **Creation of groups according to the mean BBW of the pair (BBW categories)**. Pairs were divided into 3 categories according to the weight: 51 pairs with lowest BBW (Light group), 51 of medium BBW (Medium group) and 51 with highest BBW (Heavy group). 25 pairs between Light and Medium groups and 26 pairs between Medium and High groups were discarded. This criteria was selected to intensify the possible effect of BBW.
5. **Selection of pairs according to weight at weaning day (d 21) and at the entrance to fattening phase (d 64).** Pairs that differed more than 389 g at d 21 and 1.417 kg at d 64 were discarded (independently d 21 from 64). This criteria was set by extrapolating 100 g* of variation at d 0 to the average weight of the population at d 21 and 64. Forty-five pairs were selected for d 21 and 42 pairs for d 64.

* The first option was to repeat the same criteria than point 2, extrapolating 60 g to the BW average of d 21 and 64. However, variance of weight between pairs increased during the first stages of life, so this criteria was too restrictive and no sufficient data was available for carrying out statistical analysis. For this reason, it was decided to put a more tolerable cut point. The

criteria for selecting pairs remained below 7% of the average BW of the population for the different stages.

6. **Creation of groups according to BW at d 21 and d 64 using the mean BW of the pair (Groups at 21 and Groups at 64)**. Pairs were divided according the same criteria of point 4. For d 21 the distribution of the categories was: 11 pairs with lowest BW (Light group), 11 of medium BW (Medium group) and 11 with highest BW (Heavy group). 6 pairs between Light and Medium groups and 6 pairs between Medium and High groups were discarded. For d 64 the distribution of the categories was: 10 pairs with lower BW (Light group), 10 of medium BW (Medium group) and 10 with higher BW (Heavy group). 6 pairs between Light and Medium groups and 6 pairs between Medium and High groups were discarded.
7. **Creation of groups according to WD at d 163.** Pairs were divided, according to the weight difference (WD) between the two animals at d 163, into two categories: Pairs with same BW / Pairs with different BW. The limit between the two categories was 3.95 kg, the equivalent to extrapolate 60 g of BBW to the mean BW of the population at d 163.

3.3 Statistics

Variables "Individual body weight (BW)", "Individual growth (GR)", "Weight difference (WD)", "Growth difference (GD)", "Days to achieve 105 kg" and "Difference of days to achieve 105 kg (DD105)" were analysed using a linear mixed model for repeated measures, using the nlme package (Pinheiro *et al.*, 2020) of R software version 4.00 (R Core Team 2020). Initially, the statistical model contained the fixed effects of the group (1, 2 and 3), gender (male and female) and days of life (0, 21, 64, 125 and 163), the interaction group x day, group x gender, day x gender and the residual error. The random effect was introduced for the animal in individual analyses and for the sow in pair difference analyses. Then, different covariance structure modelling was tested (*i.e.*, compound symmetry, unstructured with constant variance and unstructured with different variances). The best for each response variable was selected following the theoretic information approach based on Akaike's Information Criterion (AIC). Therefore, the models with the lowest AIC value were selected (Burnham and Anderson 2002). Finally, for analysis between Pairs with different BW and pairs with same BW, the same model was used but with these two groups. Differences between means were determined and significance was declared at P<0.05 and tendency at P < 0.10.

4. RESULTS

4.1 Characterization of the population

First of all, it must be said that no significant difference was observed in BW or growth rate (GR) between males and females (*P* > 0.10*)*, so all the pairs were treated together.

Another important aspect to take into consideration is that the parity of the dam was not considered for selecting the animals. The sow parity of the dam was the following:

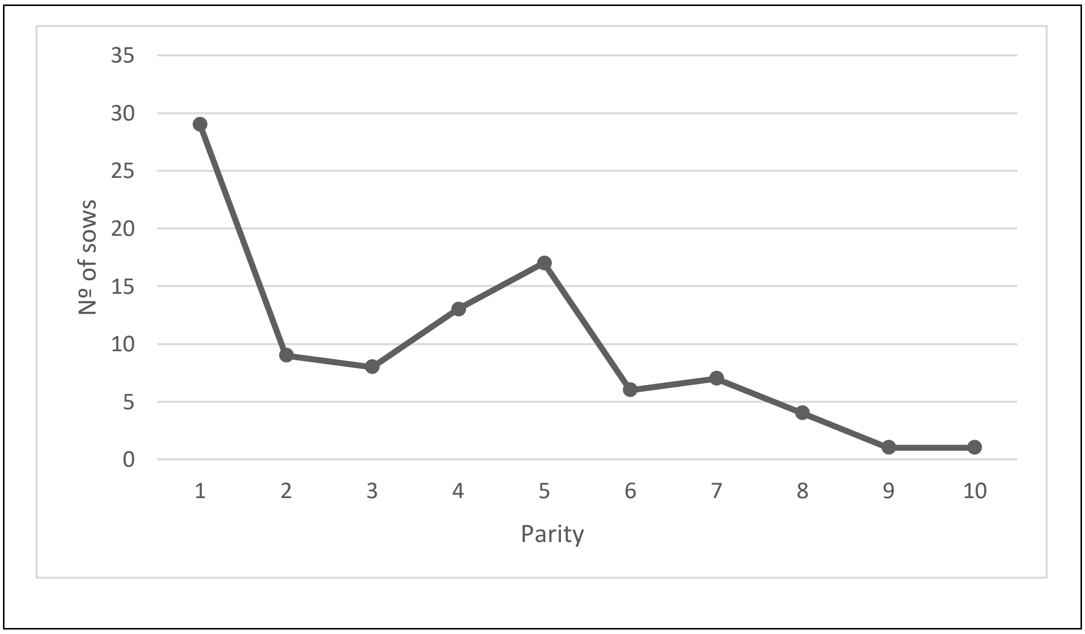

Figure 1. *Parity distribution of the sows used for the current study.*

The BBW of the selected population was 1.47 ± 0.31 kg, which is very similar to the average of commercial farms (Quesnel *et al.*, 2008; López-Vergé *et al*., 2018; Fix *et al*., 2010). To get a visual overview of the population some histograms of the BW and GR were made. **Figure 1** displays the BW distribution of the analysed population for d 0, 21, 64 and 163. At d 0 the distribution of the population was displaced to the left, which means that low BBW prevailed. For d 21 and 64, the graphics showed a really normal distribution of the population. Finally, at d 163, the distribution of the same population was more displaced to the right, prevailing the number of heavy BW pigs.

Figure 2 shows the GR evolution of the population. Similar to the BW evolution, at the end of lactation period the distribution of the population was displaced to the left, which means that there were more piglets with a low GR. During nursery, the distribution was really normal, and at growing-fattening phase the distribution was again displaced to the right, so pigs with high GR prevail among pigs with low GR. In addition, the CV of the population's growth during lactation (25.0%) and nursery (22.9 %) was much higher than during growing-fattening period (11.1 %).

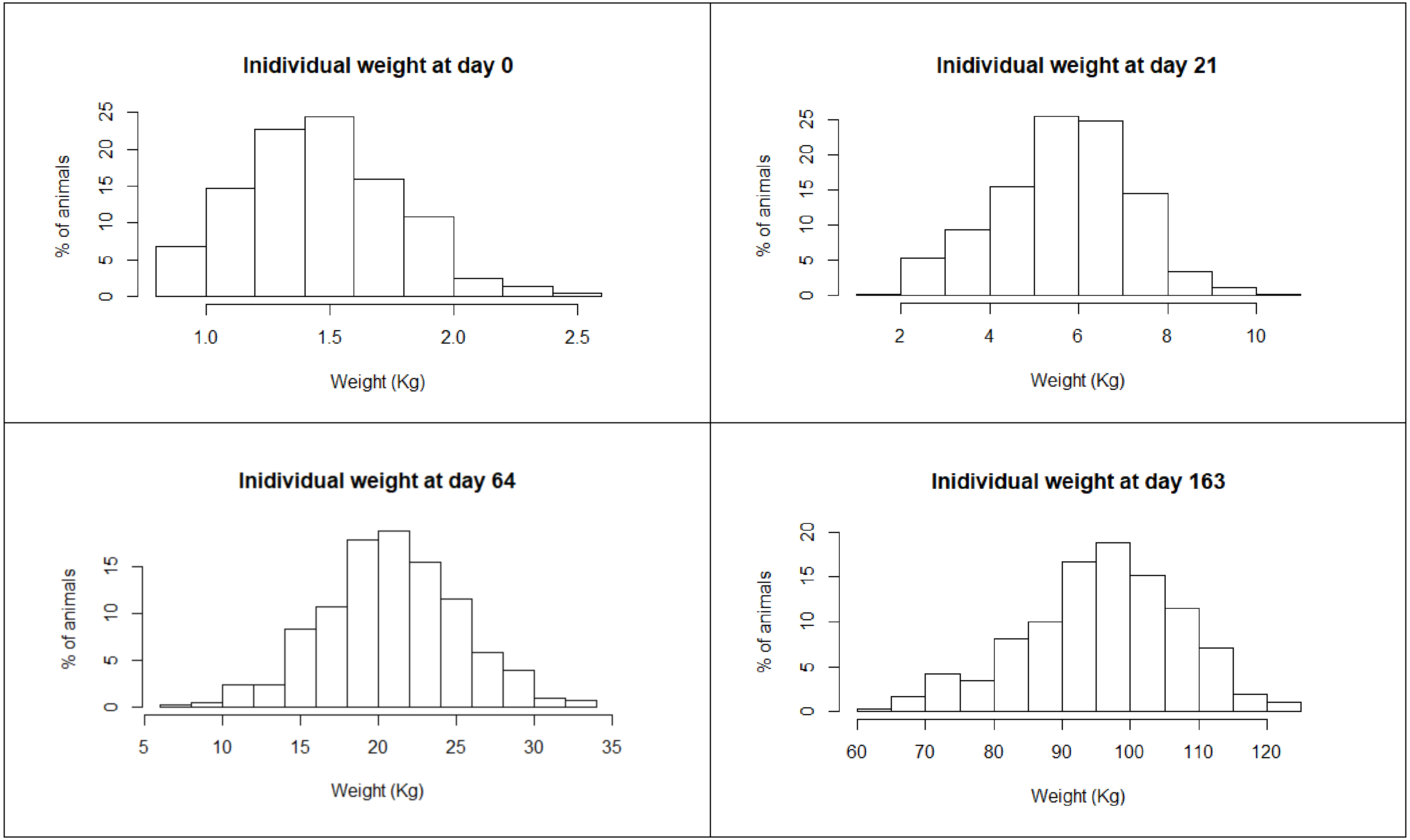

Figure 2. *Evolution of individual body weight of the pigs from day 0 until 163*

Note: Number of histogram breaks calculated through Sturges formula

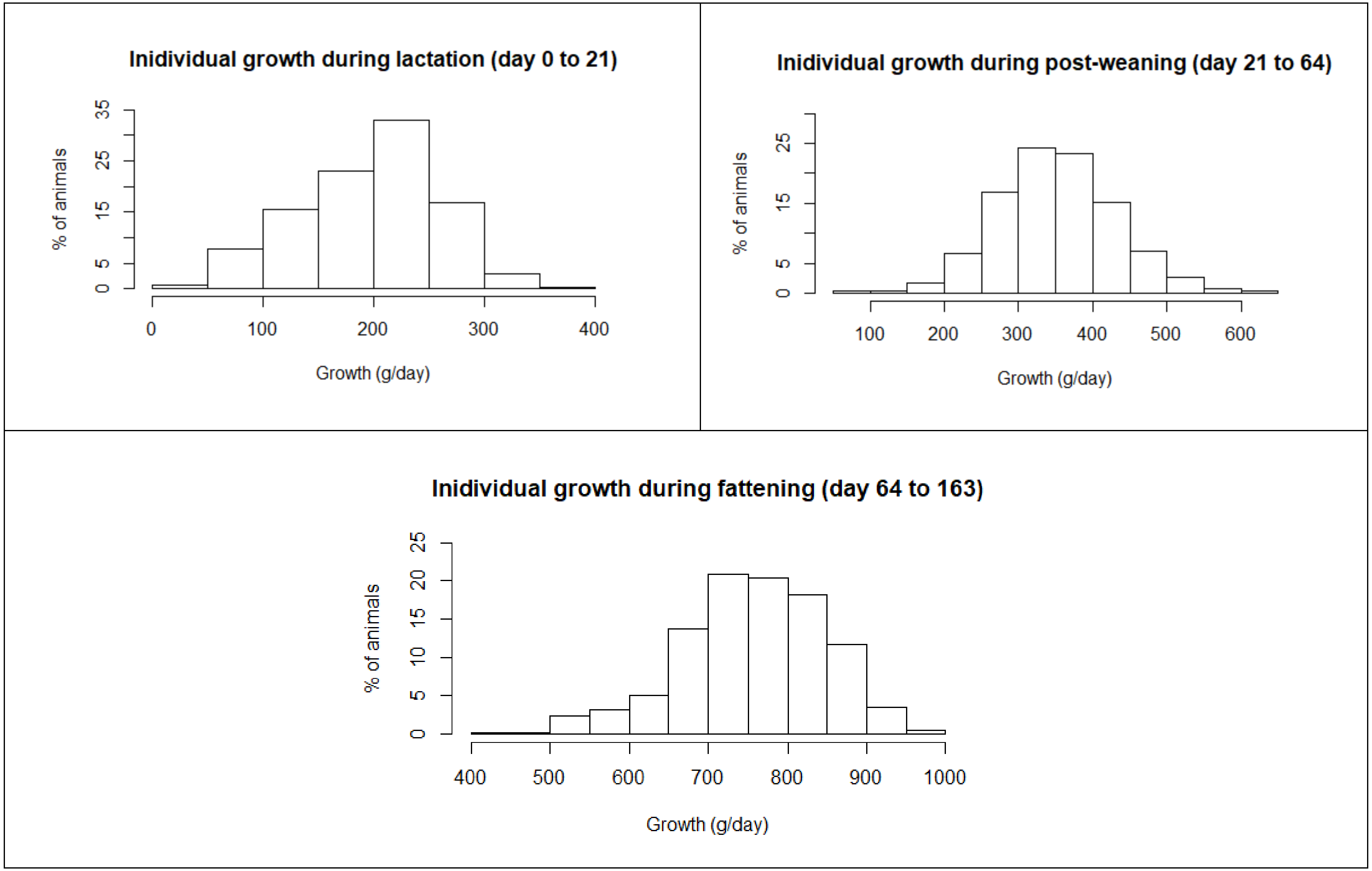

Figure 3. *Evolution of the pigs' growth from day 0 until 163.*

Note: Number of histogram breaks calculated through Sturges formula

4.2 Differences of body weight and growth rate according to birth body weight category

Animals were ranked according their BBW. Their BW was analysed in 5 different moments and, as it can be reflected in **Table 2**, the effect of BBW appeared to be significant (*P<0.001*). At the end of fattening phase, there is no significant difference between Light and Medium groups, although the difference between these two groups and the heavy group remains significant.

Table 2. *Evolution population's body weight divided by birth body weight category (Light: n=102; Medium: n=102; Heavy: n=102)*

	Birth body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Body weight, kg					
Day 0	1.08 [c]	1.46 [b]	1.88 [a]	0.94	<0.001*
Day 21	5.20 [b]	5.71 [b]	6.51 [a]	1.50	0.012*
Day 64	18.72 [c]	20.67 [b]	23.50 [a]	1.50	<0.001*
Day 125	62.67 [c]	65.80 [b]	71.97 [a]	1.50	<0.001*
Day 163	91.90 [b]	94.83 [b]	101.97 [a]	1.50	<0.001*
Average	35.91 [c]	37.69 [b]	41.16 [a]	0.67	<0.001*

[a,b,c] Means with different letters in values of the same row are significantly difference (P<0.05).

Day effect: P-value <0.001

Gender effect: P-value= 0.447

The previous result seen in **Table 2** can be explained with the analysis shown in **Table 3**. There it can be seen that BW category influences the GR of the animal (*P*<0.001). The two variables present a positive relation, being the heavier animals at birth the ones with a higher GR. These differences are especially induced during lactation (*P*<0.001) and weaning (*P*=0.024). At fattening phase, no significant differences of GR between BBW categories were observed (*P=0.179).*

Table 3. *Evolution of population's growth rate divided by birth body weight category (Light: n=102; Medium: n=102; Heavy: n=102)*

	Birth body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Growth, g					
DG days 0-21	172.5 [c]	200.0 [b]	223.9 [a]	10.81	<0.001*
DG days 21-64	314.3 [b]	347.9 [ab]	395.2 [a]	13.04	0.024*
DG days 64-163	739.2 [a]	749.2 [a]	792.6 [a]	13.04	0.179
Average	408.6 [c]	432.4 [b]	470.6 [a]	7.64	<.001*

[a,b,c] Means with different letters in values of the same row are significantly difference (P<0.05).

Day effect: P-value <0.001

Gender effect: P-value=0.656

Interaction between group and day show a tendency (P= 0.061)

4.3 Analyses of weight difference and growth difference according to birth body weight category

For better understanding the BW variability, two variables were analysed: WD and GD. In this case, some contradictory results were obtained. The results of WD are presented in **Table 4** and the results of GD in **Table 5**.

Although BBW category did not show any significant effect on WD (*P*=0.823*)*, it had a significant effect on GD (*P*=0.014). Pairs of light BBW category followed a more similar GR than pairs of heavy BBW category (75.4 g vs 100.4 g), while medium BBW category animals did not have any significant differences with the other two groups (93.2 g). The difference between Groups 1 and 3 was generated in the last part of the fattening phase because on other phases no BBW category effect was shown (*P*>0.05). The other variable included in the model, which was the gender, did not have a significant effect for neither of the two variables (*P*>0.05).

Table 4. *Evolution of weight difference between paired animals divided by birth body weight (Light: n=51; Medium: n=51; Heavy: n=51)*

	Birth body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Weight difference, kg					
Day 0	0.06	0.08	0.07	0.97	0.887
Day 21	1.07	1.14	1.20	1.29	0.915
Day 64	3.56	3.53	3.27	1.29	0.829
Day 125	8.49	8.37	8.26	1.29	0.844
Day 163	10.50	11.94	12.34	1.29	0.334
Average	4.75	5.01	5.03	0.94	0.823

a,b,c Means with different letters in values of the same row are significantly difference (P<0.05).
Day effect: P-value <0.001
Gender effect: P-value= 0.177

Table 5. *Evolution of growth difference between paired animals divided by birth body weight (Light: n=51; Medium: n=51; Heavy n=51)*

	Body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Growth difference, g					
Days 0-21	47.7 ^{a}	52.1 ^{a}	63.3 ^{a}	16.5	0.352
Days 22-64	68.4 ^{a}	71.4 ^{a}	68.9 ^{a}	22.8	0.515
Days 65-125	97.8 ^{a}	111.5 ^{a}	104.5 ^{a}	22.8	0.675
Days 126-163	87.4 ^{c}	137.9 ^{b}	164.7 ^{a}	22.8	0.007*
Average	75.4 ^{b}	93.2 ^{ab}	100.4 ^{a}	11.7	0.014*

a,b,c Means with different letters in values of the same row are significantly different (P<0.05).
Day effect: P-value <0.001
Gender effect: P-value= 0.180
There is a significant Interaction (P-value= 0.020) between the categories group and day (Group x Day)

4.4 Analysis of weight difference and growth difference according to body weight category at day 21 and at day 64

To see the BW effect from a different point of view, the same analysis was repeated but with the groups of pairs made at day 21 and at day 64. The results of WD are presented in **Table 6** and GD results in **Table 7.**

For *BW category 21* no significant differences were observed, neither for WD (*P*=0.826) nor GD (*P*=0.585). However, this changes for *BW category 64*. Although the group effect on WD only shows a tendency (*P*=0.075), the analysis of GD is a clear sign (*P*=0.024) that pairs of Group 2 have a higher variability of GR than the other groups. For the last part of the fattening phase, heavy group pairs follow an incredibly homogenous growth compared with Light and Medium groups. As it happened with the analysis of BBW category, gender continues without showing significant difference for any of the analysed variables (*P*>0.05).

Table 6. *Evolution of weight difference (WD) between paired animals divided by body weight category 21 (Light: n=11; Medium: n=11; Heavy: n=11) and BW category 64 (Light: n=10; Medium: n=10; Heavy: n=10)*

	Body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Weight difference, kg (groups at d 21)					
WD 21	0.63	0.91	0.20	2.42	0.515
WD 64	2.05	3.99	2.90	2.84	0.886
WD 125	7.53	8.12	8.70	2.84	0.740
WD 163	11.31	9.61	12.56	2.84	0.259
Average	5.38	5.97	6.40	1.70	0.826
Weight difference, kg (groups at day 64)					
WD 64	0.31	0.78	1.20	2.44	0.720
WD 125	4.31	9.30	5.56	2.82	0.114
WD 163	9.22	13.97	7.33	2.82	0.134
Average	4.61	8.02	4.70	1.71	0.075 ·

[a,b,c] Means with different letters in values of the same row are significantly difference (P<0.05).

Day effect <0.0001 for groups at day 21

Gender effect: P-value= 0.401 for groups at day 21

Day effect <0.0001 for groups at day 64

Gender effect: P-value= 0.487 for groups at day 64

Table 7. *Evolution of growth difference (GD) between paired animals divided by body weight category at day 21 (Light: n=11; Medium: n=11; Heavy: n=11) and day 64 (Light: n=10; Medium: n=10; Heavy: n=10)*

	Body weight category				Group effect
Item	Light	Medium	Heavy	SEM	P-value
Growth difference, g (groups at d 21)					
GD days 21-64	66.6	79.1	70.5	39.39	0.751
GD days 64-125	106.7	78.6	114.6	54.76	0.461
GD days 125-163	144.7	95.5	129.9	54.76	0.264
Average	106.0	84.4	105.0	27.85	0.585
Growth difference, g (groups at d 64)					
GD days 64-125	77.9 [a]	139.8 [a]	86.1 [a]	37.78	0.103
GD days 125-163	162.5 [a]	172.9 [a]	55.6 [b]	45.53	0.017*
Average	120.2 [ab]	156.3 [a]	70.9 [b]	26.48	0.024*

[a,b,c] *Means with different letters in values of the same row are significantly difference (P*<0.05).

Day effect: P-value= 0.080 (groups at d 21)

Gender effect: P-value= 0.996 (groups at d 21)

Day effect P-value = 0.129 (groups at d 64)

Gender effect: P-value= 0.631 (groups at d 64)

There is a tendency on the interaction between group and day for groups at d 64 (P=0.056)

4.5 Do paired animals present significant weight difference at the end of fattening phase?

To answer this question, an as it can be seen in **Table 8**, the studied pairs were separated in two categories according to their WD at d 163. On this analysis, only 20% of the studied pairs present a similar BW at the end of fattening phase. The Unsorted group is the one with a higher percentage of pairs with same BW at slaughtering (29%) followed by Medium group (22%). Light and Heavy group only have a 7% of pairs each one.

Table 8. *Difference of body weight (BW) between paired animals at d 163.*

	Body weight category				
Item	Light	Medium	Heavy	Unsorted	Total
Total number of pairs	51	51	51	51	204
Nº of pairs with same BW	7	11	7	15	40
Nº of pairs with different BW	44	40	44	36	164
Pairs with equal BW, %	14	22	14	29	20

From the total of 40 pairs of pigs that have the same BW at d 163, 21 were females and 19 males.

Figure 4 was done to see the effect of BW variability from another point of view. Analysed individuals spend 176 ± 18 days to achieve an objective BW of 105 kg. The mean difference between paired animals to achieve the objective BW was 18 ± 13 days. Heavy group with a day difference between paired animals (DD105) of 17 days was the one with a lower difference. Heavy group was followed by Light group (17 days) and finally Medium group (19 days). No significant difference in DD105 between groups was observed (*P*=0.935).

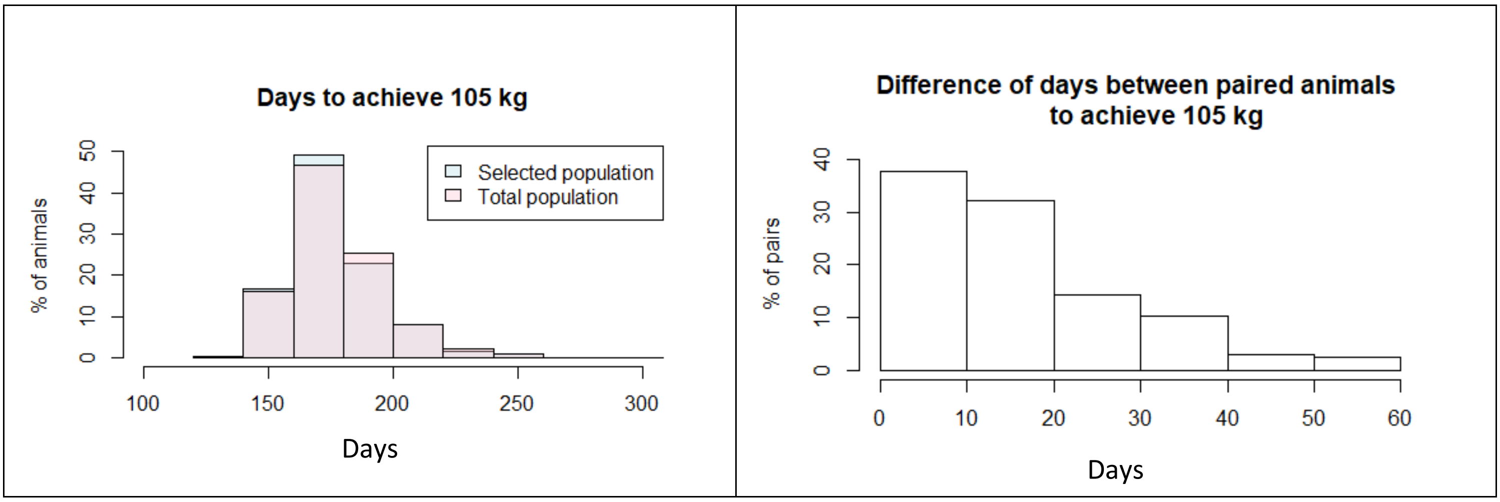

Figure 4. *Histograms with the characterization of the population for the factor: days to achieve 105 kg.*

4.6 Key moment for weight difference

As it was clearly seen in previous parts, there is no doubt that, although paired animals present really similar initial conditions, a high percentage of them achieve a different BW at the end of fattening phase. However, an important aspect to take a look is when the BW variability between paired animals becomes irreversible. To do so from a visual form, **Figure 5** shows the evolution of WD between paired animals grouped according to the WD at d 163.

It can be seen that during lactation the evolution of the two groups is practically the same (*P=0.806*). However, at the end of nursery phase significant differences on WD appear between the two groups (*P=0.027*), remaining significant until the end of the fattening phase. Obviously the huge difference observed at day 163 is induced by the form that the two groups were separated. However, with this analysis it can be determined that the WD produced during nursery phase is already determinant for posterior BW differences.

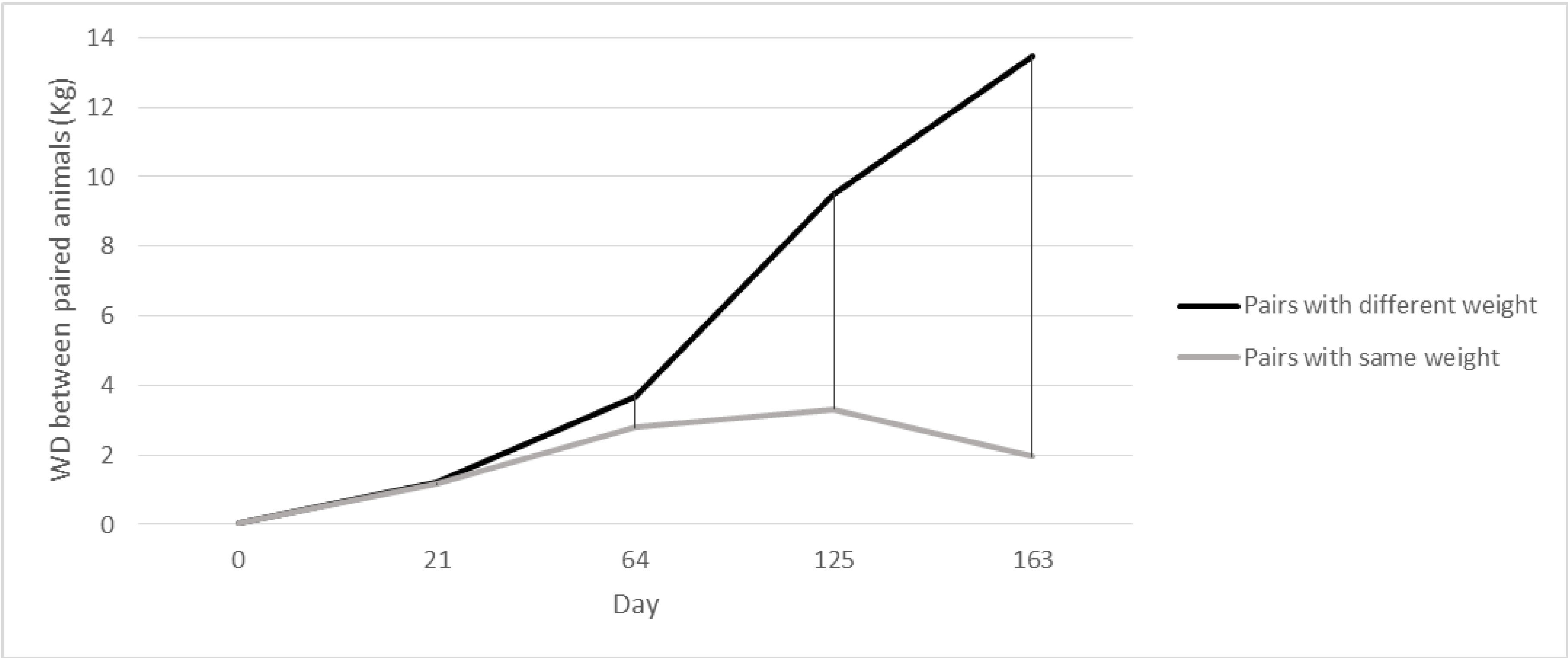

Figure 5. *Evolution of weight difference with pairs sorted according to weight difference group at d 163*

5. DISCUSSION

It has been highly proved that in polytocous species, such as pigs, animals with low birth body weight (BBW) correlate with low growth rate (GR) during posterior development (Vázquez-Gómez *et al*., 2020). From a biological point of view, this fact is explained because of the number of muscle fibres that differentiate during prenatal myogenesis, which will be determinant for the further GR of the animal (Rehfeldt and Kuhn, 2006). As Fix *et al*, (2010) concluded, pigs with low BBW begin life smaller, present a lower GR, and as a result are lighter throughout all their life. This impact is clearly seen in the current project with important differences of GR according to BBW category (*P<0.001*). However, this fact has been already demonstrated by different researchers (Rehfeldt and Kuhn 2006; Rehfeldt *et al*., 2008; Fix *et al.*, 2010), and the main objective of this research work was to reflect the effect of being half-brothers/sisters in pigs' body weight (BW) variability.

5.1 Genetic effect on ingestion and body weight variability

Mrode and Kennedy (1993) conducted a study in which they showed that factors such as average daily gain (ADG) or conversion ratio (CR) had a heritability of 0.43 and 0.30, respectively. In the same vein, He *et al.*, (2017) published a research paper in which they concluded that pigs presented large differences on gene expression in multiple aspects of glucose metabolism: glucose transport, gluconeogenesis and glycolysis. With this basis, it seems that genetics play a key role in feed ingestion and feed efficiency, which at the end are two main aspects that determine the animal growth.

The results of the current project determined that the difference of time that paired animals spent to achieve an objective weight of 105 kg was 18 d, and that only 20% of the pairs achieved the end of the fattening phase with a really close BW. If genetics were the only factor affecting BW variability, this difference of time between paired animals might be much lower. This means, that there are some factors that have a heavier impact on BW variability than genetics.

As it can be seen in **Figure 5**, GD between paired animals is clearly related with the difference of days that the two animals spent to achieve an objective weight of 105 kg. This correlation suggests that the difference of time to achieve an objective slaughter weight is clearly related with the individual GR, which depends on the quantity of ingested feed but also on the efficiency through the process of absorbing nutrients. Glucose is a universal fuel for mammals' cell type and it may enter from outside of the body or be released from intracellular stores (glycogen). During glycolysis, glucose is broken down in the cytosol forming pyruvate. Then Acetyl-CoA, obtained from pyruvate, initiates the Krebs cycle. Finally, oxidative phosphorylation occurs on the inner mitochondrial membrane to turn NADH and $FADH_2$ into ATP. All this process produces between 32 and 38 ATPs that are used for body maintenance and, in young animals, for growth (DiTullio and Dell'Angelica, 2018). After the results obtained during this project, it clearly seems that the difference of growth between half-brothers/sisters is more related to the quantity of ingested feed rather than the efficiency of feed digestion. To understand better this effect, in future studies might be necessary to control the consumption and growth of the pigs individually.

This difference of about 18 d to achieve an objective weight supposes an important loss of efficiency for the company. If we translate this impact into economic terms, a difference of 18 days supposes an increase of 1.32 € per pig the production cost (SIP Consultors 2019). In an extremely competitive sector such as pig industry, it seems essential to find the factors that are generating such a difference to find solutions.

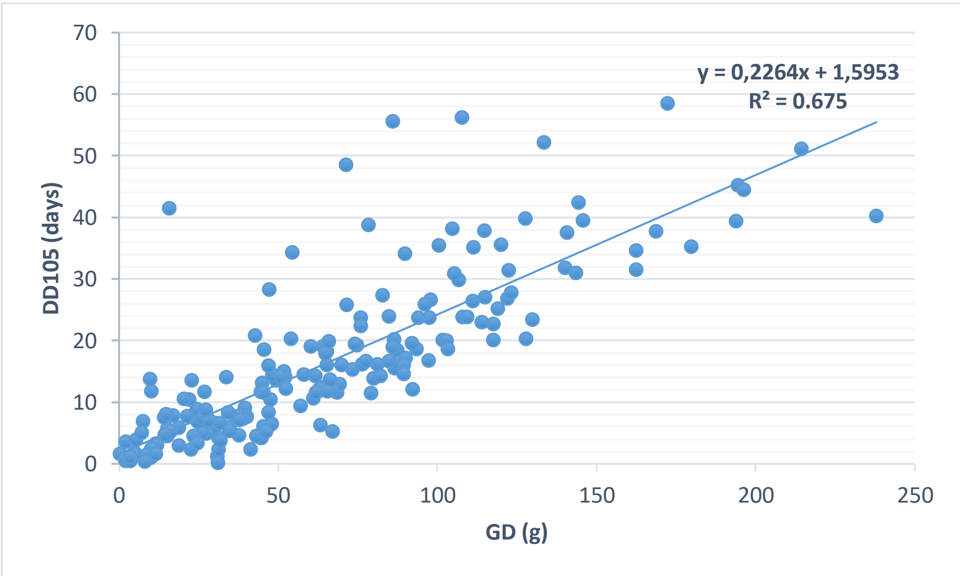

Figure 6. *Relation between growth difference (GD) and difference of days to achieve an objective weight of 105 kg*

5.2 Effect of different productive phases on final weight differences

Some of the consulted literature (Rehfeldt and Kuhn 2006; Fix *et al.*, 2010) before conducting the analyses triggered the formulation of the following hypothesis: *"Animals with low birth body weight will be more susceptible to future weight variability"*. After doing the statistical analyses, it can be concluded that BBW has no effect on the weight difference (WD) between paired animals (*P*>0.10). Although all the growth and viability difficulties that low BBW piglets experience during their development (Rehfeldt and Kuhn, 2006; Rehfeldt *et al.*, 2008; Vizcaíno *et al.*, 2017), there is no evidence that low BBW increases WD between piglets under the same nutritional and management conditions. In a global tendency towards hyperprolific genetics, this factor means that in principle a reduction of low BBW might not be the cause of increasing variability, the main problem resides in the increase of BBW variability.

Traditional pig production system can be easily divided into 3 phases: lactation, nursery and growing-finishing (Baxter, 1984). Focusing on ingestion, which is the parameter with higher impact on WD, nutrients found in the milk suckled by piglets during lactation are highly absorbable (Stoll *et al.*, 1998). The other factor linked to nutrition that could affect WD is the quantity of ingested feed. López-Vergé *et al*., (2018) concluded that light piglets, subjected to specific feeding strategies during nursery, can increase their growth rate and partially catch up with their heavier counterparts. According to the cited literature, our study reflected that at the end of lactation period neither BW *(P=0.515)* nor WD (*P=0.826)* had significant effect for final WD between paired animals.

The process of weaning produces a lot of stress to the piglets due to physiological, environmental and social changes (Campbell *et al*., 2013). On the other hand, early weaned piglets, under commercial farming conditions, still have an immature digestive tract. When diet is changed from milk into grain, different nutrients and conditions can harm villi cells. This issue, a part of triggering health problems, reduces the absorption capability of the intestinal tract, affecting piglet's growth (Lindemann *et al.*, 1986). These differences on quantity and absorbance of ingested feed could mean a difference of growth between paired animals. In the current study, at the end of nursery period BW showed a tendency (*P=0.075)* over final WD between paired animals. Moreover, as it was hypothesized at the beginning of the research, the WD produced during nursery reflects a significant effect on the WD at the end of the fattening phase (*P=0.027*). Piglets capable of adapting rapidly to the new conditions/diet after weaning will have a more homogenous growth afterwards.

Eventually, the growing-finishing phase is when pigs present a higher feed intake (English *et al.*, 1992). In this case, the effect of ingestion on WD should be more accentuate (Figure 4). During this period, the gastrointestinal tract of viable pigs is completely developed and adapted to the grain diet (Lindemann *et al.*, 1986). This is why during this phase there are less differences on the capability of absorbing nutrients between individuals. The high quantity of ingested feed and the proximity to slaughtering provokes that growing-finishing period is when differences of GR between paired animals have a higher influence over the final WD. In addition, it is also important to take into consideration that during the fattening phase the gain composition changes. Due to biological reasons, as the animal gets elder it starts depositing more fat tissue in comparison with muscle tissue (Dunshea and D'Souza, 2003). It has been demonstrated that this component has an important genetic influence (Chen *et al.*, 2008).

6. CONCLUSIONS

It is concluded that:

1. The effect of being-half-brothers/sisters on body weight homogeneity at the end of fattening phase is low. An 80% of the analysed pairs showed a different body weight at d 163, with an average difference of time to achieve 105 kg, between paired animals, of 18 days. This difference of weight at the end of fattening phase it is induced from the nursery phase.

2. Neither gender nor birth body weight seem to affect final weight difference between paired animals. None of these two variables showed significant effect on weight difference. The increasing problem of weight variability does not seem to be linked to low birth body weight.

3. Weight variability is a holistic aspect influenced by several factors. The current study suggests the importance of individual ingestion. The quantity of ingested feed and the capability of absorbing and metabolizing nutrients may play a key role, together with the growth tissue composition, mainly during the fattening phase.

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