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# Prediction of growth performance parameters in the growing and free-range finishing phases of the Iberian pig via meta-analysis

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## Abstract

*Aim of study:* To describe and predict mathematically the growth parameters of Iberian pigs.

*Area of study:* Iberian *dehesa* agroforestry system. Southwest of Iberian Peninsula.

*Material and methods:* A quantitative and systematic review was carried out to find all studies with valid data of growth and finishing in the Iberian swine breed published up to May 2020. For the analysis of the data, a mathematical fitting model was obtained and a function was postulated to describe the relation between the variables age and body weight.

*Main results:* 112 publications were found, and after applying several quality filters, 18 with age and weight matched data were used. The database was composed of 76 different tests and 22,558 animals. The clasical growth phases were independently evaluated for data analysis.It was necessary to separate the finishing trials into three groups according to the starting age. Seven mathematical models were obtained for lactation,post-weaning, and *montanera* finishing. However, no valid test data were found during the growth and prefinishing phases. Besides that, a single model was obtained combining lactation and post-weaning, and another surface model including the variables age and weight to compare average daily weight gain in *montanera* finishing phase.

*Research highlights:* After systematic review of the studies that provide information on the growth of Iberian pigs, and a quantitative analysis, some mathematical linear and nonlinear models have been developed for the prediction of the production ratios at different phases.

**Additional key words:** average daily weight gain; *montanera*; *dehesa*.

**Abbreviatons used:** ABW (average body weight); ADWG (average daily weight gain); BW (body weight); IMF (intramuscular fat); RMSE (root mean square error).

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# Introduction

The Iberian pig is an emblematic and autochthonous racial group from Spain and Portugal. Its cured products are well known for their high organoleptic quality due to its traditional finishing system based on a natural diet of acorns and grass grazed (Lopez-Bote, 1998), as well as for their fattening tendency. This breed, like other native breeds, is known for its rusticity and ability to adapt to its natural environment, which is the *dehesa* agroecosystem (Rodríguez-Estévez et al., 2009). The *dehesa* is a human-made ecosystem located in the Southwest of the Iberian Peninsula: it is like a savannah with natural grasslands, scattered oak trees (*Quercus* sp.) and very few shrub layer (Rodríguez-Estévez et al., 2012). The *montanera* or pannage (acorn mast) is the season when pigs can forage acorns (Lopez-Bote et al., 2001). These fruits mainly fall down from October to December and can remain on the ground for several weeks to be eaten by pigs from October to February.

From the beginning of the 21st century, the Iberian pig production system has been intensified and its census has highly increased, expanding its production out of the traditional breeding area. At present two models of Iberian pig raising coexist, the traditional system linked to the *dehesa* and the pure Iberian breed and an intensive system to produce crossbreed Iberian pigs (Iberian sows mated by Duroc boars), the most frequency model today (RIBER, 2021). The second system is an adaptation of the worldwide intensive swine production, while the traditional system lacks growth modelling to predict the performance of Iberian breed growing and free-range finishing performance.

The present study aims to calculate growth rates and predictive curves for Iberian pigs raised and finishing according to the breed traditional system by means of a meta-analysis evaluating and including every study published about this topic.

# Material and methods

## Systematic bibliographic review

The primary dataset used in the present work comes from a previous study by Sánchez-Esquiliche & Rodríguez-Estévez (2011), which has been completed with new references from 2011 until May 2020. For this purpose, a quantitative and systematic review has been carried out to obtain data to performance a meta-analysis (Vázquez, 1990). The data came from different sources: books, books of abstracts, national and international journals, technical magazines, monographs of the Iberian breed, doctoral theses and master degree projects; all of these focused on productive data about growth the growing and finishing phase of the Iberian pigs (Vázquez, 1990).

## Data collection

The following information was collected from all the valid references: number of animals measured (n), average daily weight gain (ADWG), matched age-body weight (BW) data for the traditional growth phases: lactation (birth to weaned), nursery (weaned to 23 kg), growing

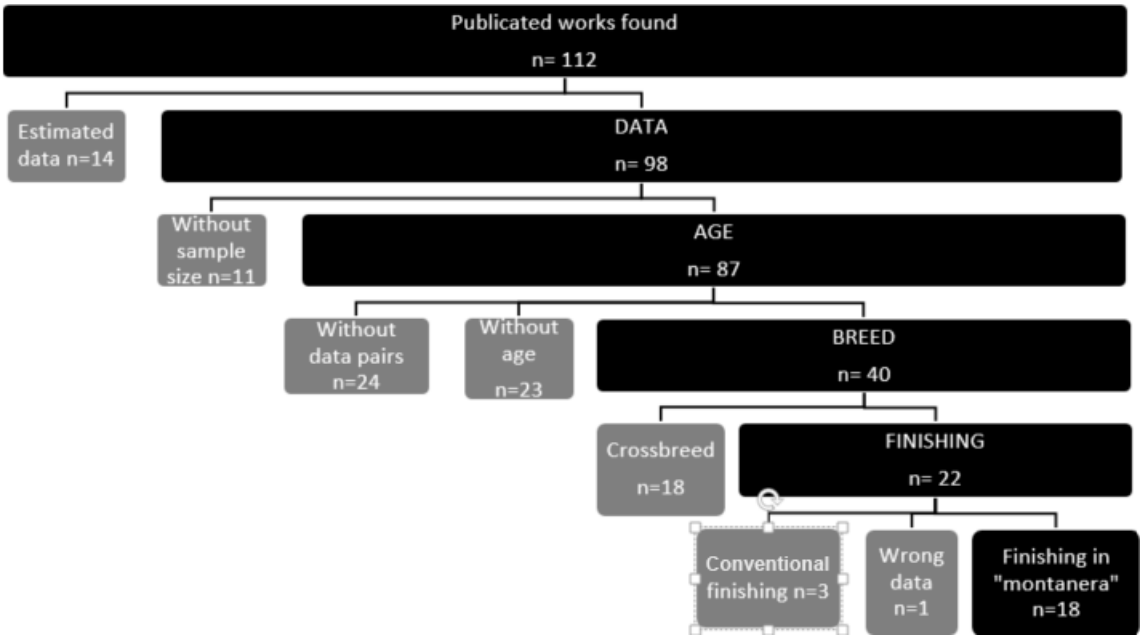


**Figure 1.** Triage of studies with the application of the inclusion criteria applied

(23.0 to 57.5 kg), pre-finishing (57.5 to 103.5 kg) and finishing (103.5 kg to slaughter) were selected.

Following the methodology proposed by Jensen et al. (2002), the experimental unit used was the "trial" within each work. Trials are the different tests carried out within a "study", therefore, a reference or study can include one or more trials with different factors (e.g. age or diet).

### Criteria for inclusion of studies

Each study was reviewed and evaluated to decide if its data were valid for their inclusion in the database. So, in order to avoid inaccuracies, errors and/or biases some quality criterions were followed (Jensen et al., 2002) and the reasons to exclude a study were: some data came from estimations; sample size was not indicated; unpaired data; lack of information about the age of the animals; cross-breed pigs; finishing with balanced feed and not in *montanera* system; and presumably wrong data.

Furthermore, in those cases in which different finishing models were compared, only the data from the finishing trials in *montanera* were included.

### Mathematical fitting models

The mathematical model was obtained by the curve fitting of the data. Then, a function was postulated to describe the relation between the variables age and BW in the different phases. The least squares method was used for the fitting to minimize the root mean square error (RMSE).

Linear and nonlinear models have been obtained; however, for a RMSE given the simplest mathematical function has been selected, and therefore a linear function is proposed. In addition, the square of the correlation between the variables was obtained to know the percentage of the response explained variance by each variable. The software used to perform these analyses has been Wolfram Mathematica 12.3 (Wolfram Research, 2021).

## Results and discussion

### Literature review

A summary of the studies found in the literature review is shown in Table S1 [suppl] (112 references); the oldest found corresponds to Aparicio-Macarro (1977) and the most recent one corresponds to Vázquez-Gómez et al. (2020). Within these references, the finishing is the most studied phase (74 references), while lactation is the least studied one (27 references). Most of the references give information on only one phase (60/112), while 12 references study the pigs whole life.

### Database for analysis (descriptive statistics)

Figure 1 shows the triage of papers with the application of the inclusion criteria above mentioned. Finally, 18 works (16.07%) about growing and finishing Iberian pigs in *montanera* system have been selected and included for this meta-analysis. What is more, for the weight-age data from Castellano et al. (2013 and 2014) only a study has been included, because both studies correspond to the same experience.

Therefore, after applying the restriction criteria to the publications, 76 trials from 18 studies were used to complete the database, these including 22,558 animals.

There is a lack of data for Iberian pigs between 120 and 240 days old, which corresponds to the growing and pre-finishing phases. The reason for this information gap could be due to the complexity of these phases, when a strong feed restriction is necessary to maintain slow growth rate to obtain pigs of adequate body composition and weight before the final free-range finishing period or *montanera* (López-Bote et al., 2001). This feed restriction leads to a wide variety of management procedures to optimize the first phases, from intensive to extensive systems, with different types of growth modulation (Rodríguez-Estévez et al., 2011).

### Overall weight-age analysis

Although several models have been calculated with all the data (76 trials), only the simplest one is presented:

$$f(x) = -1.7738513 + 0.346855x$$
$$(\text{RMSE}= 12.66,\ r^2 = 0.98,\ x \in [0, 537]) \quad \text{[Model 1]}$$

where f(x) is weight (kg) and x is age (days).

However, this model is not good for the values near the end points of the interval, with bad fit and large RMSE. In order to improve this, the interval was divided according to the following categories: lactation phase, nursery phase and *montanera* finishing phase (Table 2).

### Lactation phase

Firstly, a mathematical model to predict growth rate as a function of weight and age is necessary. For the analysis of this lactation phase, there were available data from piglets weighed at birth and weaned between 21 and 60 days (9814 piglets from 23 trials within 8 studies). Here it is important to indicate that the traditional lactation length of this breed is 60 days.

This is the simplest fitting model to predict the lactation growth rate (Fig. 2):

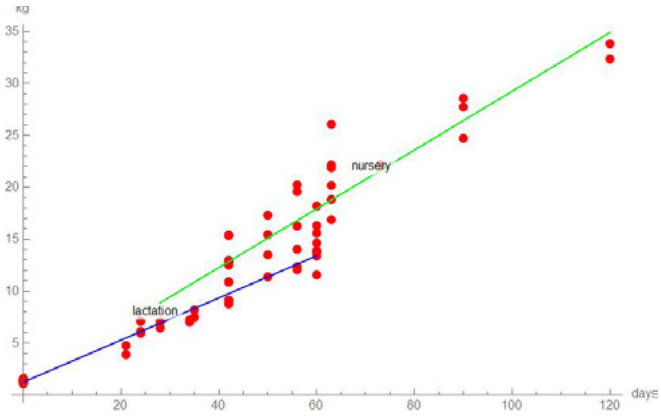


**Figure 2.** Lactation and nursery age-weight data and mathematical models f(x) = 1.24929 + 0.2025 x for x ∈ [0, 60], and f(x) = 0.95456 + 0.28285 x for x ∈ [28, 120] respectively. x: Age in days.

$$f(x) = 1.24929 + 0.2025\ x$$
$$(RMSE= 0.787,\ r^2 = 0.974,\ x \in [0, 60] \qquad [Model\ 2]$$

where f(x) is weight (kg) and x is age (days).

The average birth BW in the database was 1.36 kg (Table 2), and the fitting model 2 estimated 1.2419 kg. Ayuso et al. (2016) reported a birth weight of purebred Iberian piglets of 1.21 kg, while the birth weight of crossbred Iberian piglets ranged from 1.75 to 1.77 kg (Soto-Caballé, 2006; Ayuso et al., 2016). The maximum weight (1.60 kg) found for purebred animals in this database is reported by Forero et al. (2001), and it is still lower than the average BW in crossbred piglets of the studies previously shown. Soto-Caballé (2006) reported an average weaning BW at 38 days of 8.41 kg in Iberian × Duroc crossbred pigs, which is lower than the BW of 8.94 kg obtained for purebred Iberian pigs at 38 days old with model 2. In this line, Ayuso et al. (2016) reported a lower birth weight of Iberian piglets compared to crossbred piglets and a higher postnatal growth of purebred Iberian pigs in the first weeks.

The ADWG during lactation from 0 to 60 days old obtained with the model 2 is 0.203 kg day$^{-1}$. Aguinaga et al. (2010) obtained 0.165 kg day$^{-1}$ in piglets weaned at 34 days and without having received any pre-starter feed (fed only with maternal milk); which could be the reason for that lower ADWG. On the other hand, Aparicio-Macarro (1987) found 0.225 kg day$^{-1}$ for a weaning age of 60 days in a very traditional system, probably with poorer sow diet but with additional feed for piglets at the end of this period. The ADWG found in the present study was higher than the obtained by Vázquez-Gómez et al. (2020), with Iberian × Duroc crossbred piglets weaned at 24 days with an ADWG from 0.132 to 0.201 kg day$^{-1}$, which is also consistent with the higher postnatal growth of purebred Iberian pigs previously reported by Ayuso et al. (2016).

## Nursery phase

There were available data from 9,085 piglets from 19 trials for the analysis of the nursery phase, with an average initial age from 28 to 71 days and average initial weights from 6.45 to 22.2 kg BW, average final age from 50 to 120 days old and average final weight between 11.4 and 33.8 kg and from (Table 2).

The best model to calculate the growth rate at the nursery stage is (Fig. 2):

$$f(x) = 0.95456 + 0.28285\ x$$
$$(RMSE= 2.4388,\ r^2= 0.852;\ \ x \in [28, 120]) \qquad [Model\ 3]$$

where f(x) is weight (kg) and x is age (days).

According to this model, the ADWG is 0.283 kg day$^{-1}$, compared to the average of 0.317 kg day$^{-1}$ resulting from the studies included at this database.

Sánchez-Esquiliche & Rodríguez-Estévez (2011) indicated that a target of 18.2 kg could be set for crossbred Duroc × Iberian piglets at 61.7 days old; which is close to the estimation of 18.4 kg BW with model 3. Vázquez-Gómez et al. (2020) showed from 20.6 to 24.7 kg of BW at 71 days in crossbred piglets; while this model 3 estimated 21.03 kg at that age. Thus, it is shown that the weight of Iberian piglets and Duroc × Iberian crossbred piglets around the 3-month of life was similar.

## Model for combining the estimations of lactation and nursery

A new model [4] was calculated to evaluate the weight-age for lactation and nursery phases as a whole, from birth to 120 days:

$$f(x) = 0.726235 + 0.2680132\ x$$
$$(RMSE= 2.32,\ r^2= 0.896;\ x \in [0, 120]) \qquad [Model\ 4]$$

where f(x) is weight (kg) and x is age (days).

At weaning time there were many changes and challenges for the piglets, such is solid diet instead of milk, litter grouping or separation from their mothers. Therefore, it is necessary to know the age at weaning to use one of these previous models [2] or [3]. However, for the first 120 days of life, the model [4] could be applied even if the age at weaning is unknown, because this model simplifies the growth modelling; although, it does not improve the accuracy of the two previous ones (RMSE was 0.787, 2.4388 and 2.32 for models [2], [3] and [4], respectively).

## *Montanera* finishing phase

For the analysis of the traditional free-range finishing system based on just grazing natural resources (acorns and grass), there were available data from 3,659 pigs from 34 trials within 11 studies, with data from pigs that were 240

**Table 1.** Number of animals (N) and main characteristics in the trials used for the model in each phase and finishing age group in the case of finishing (*montanera*).

| Characteristics [a] | Growth stages | | | Finishing age group [b] | | | |
|---|---|---|---|---|---|---|---|
| | Total [1] | Lactation [2] | Nursery [3] | Total [5] | α [6] | β [7] | γ [8] |
| N | 22558 | 9814 | 9085 | 3659 | 218 | 2390 | 1075 |
| Trials | 76 | 23 | 19 | 34 | 9 | 17 | 8 |
| Average initial age (days) | 171 | 0 | 43.0 | 356 | 283 | 364 | 418 |
| Minimum initial age (days) | 0 | 0 | 28 | 240 | 240 | 341 | 413 |
| Maximum initial age (days) | 429 | 0 | 73 | 429 | 323 | 390 | 429 |
| Initial ABW (kg) | 54.3 | 1.36 | 13.3 | 113 | 103 | 117 | 117 |
| Minimum initial BW (kg) | 1.11 | 1.11 | 6.45 | 77.4 | 77.4 | 97.9 | 103 |
| Maximum initial BW (kg) | 140.3 | 1.6 | 22.15 | 140.3 | 119.5 | 140 | 135 |
| Average final age (days) | 228 | 43.2 | 69.1 | 441 | 369 | 460 | 485 |
| Minimum final age (days) | 21 | 21 | 50 | 351 | 351 | 438 | 473 |
| Maximum final age (days) | 537 | 60 | 120 | 537 | 383 | 510 | 537 |
| Final ABW (kg) | 80.3 | 9.89 | 21.1 | 161 | 145 | 168 | 164 |
| Minimum final BW (kg) | 3.9 | 3.9 | 11.4 | 114 | 114 | 150 | 154 |
| Maximum final ABW (kg) | 191 | 15.6 | 33.8 | 191 | 158 | 191 | 174 |
| Average period length (days) | 57.3 | 43.2 | 23.1 | 85.9 | 85.3 | 95.2 | 66.8 |
| Minimum period length (days) | 8 | 21 | 8 | 58 | 60 | 60 | 58 |
| Maximum period length (days) | 120 | 60 | 60 | 120 | 120 | 120 | 117 |
| Average weight gain (kg) | 26.0 | 8.54 | 7.77 | 48 | 42.3 | 51.5 | 46.9 |
| Minimum weight gain (kg) | 0.50 | 2.79 | 0.50 | 31.7 | 31.7 | 33.2 | 32.3 |
| Maximum weight gain (kg) | 62.0 | 14.4 | 20.0 | 62.0 | 62.0 | 61.3 | 57.7 |
| ADWG (kg $day^{-1}$) | 0.404 | 0.194 | 0.317 | 0.594 | 0.548 | 0.553 | 0.734 |
| Minimum ADWG (kg $day^{-1}$) | 0.063 | 0.132 | 0.063 | 0.271 | 0.271 | 0.369 | 0.442 |
| Maximum ADWG (kg $day^{-1}$) | 1.000 | 0.260 | 0.510 | 1.000 | 0.790 | 0.871 | 1.000 |

[a]ABW: average body. BW: body weight. ADWG: average daily weight gain. [b] α [6]: Model for animals until 330 days old. at the beginning of the finishing period. β [7]: Model for animals between 331 to 396 days old at the beginning of the finishing period. γ [8]: Model for animals older than 387 days old at the beginning of the finishing period.

to 537 days old, with BW from 77.38 to 191.3 kg. At the beginning of the finishing phase, the average BW obtained was 114.2 (from 77.38 to 140.3) kg with 356.9 (from 240 to 429) days old (Table 2); and at the end of this phase, pigs were on average 438.80 (from 351 to 537) days old and weighed 162.58 (from 114.25 to 191.3) kg of average body weight (ABW).

A cloud of dots (Fig. 3) was obtained in the finishing age-weight and the mathematical model [5] is:

$$f(x) = 10.947763 + 0.31643\ x$$
$$(RMSE= 18.45,\ r^2= 0.75;\ x \in [240, 537]) \quad \text{[Model 5]}$$

where f(x) is weight (kg) and x is age (days).

Finishing phase in *montanera* does not begin until there are enough acorns to forage only natural resources in a free-range grazing system (Rodríguez-Estévez et al., 2009) and, meanwhile, the pigs are fed restrictively. *Montanera* starting depends on weather conditions (first autumn rains) and availability of ripen acorns (mast) on the ground for the pigs foraging from October to February.

According to these meta-analysis data, 100-kg BW pigs were obtained between 250 and 425 days old, and 150-kg BW animals ranged from 350 to 525 days old (Fig. 3). This fact demonstrates that the growth rate of free-range fattened Iberian pigs does not only depend on their age, but also on the previous restricted feeding pattern. The pig age to start this finishing period is not fixed because it is determined by the availability of acorns in the ground; therefore, there is a large dispersion for the starting age, with extreme values like 240 to 429 days old and from 77.38 to 140.3 kg BW of initial weight in the reported studies.

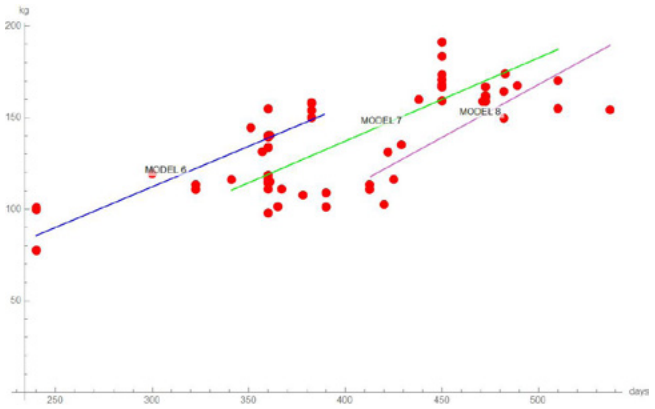


**Figure 3.** Mathematical models [6], [7] and [8] of age-dependent (days) finishing phase at beginning: f(x) = -20.71961233 + 0.44324x for x ∈ [240, 323], f(x) = -44.5744436 +0.45446x for x ∈ [341, 390], and f(x) = -120.84149 +0.577866x for x ∈ [413, 429] respectively. x: age in days, f(x): weight in kg

Thus, there is an important age difference at the beginning of the *montanera.* Daza et al. (2007) stratified a group of pigs with a mean of 101.2 kg BW into three groups according to their age at the start of this finishing period. In line to this last cited work, the database obtained in the current work was classified according to the age of the animals at the start of this phase and three mathematical models were obtained for three age intervals (Table 1): 9 trials and 218 animals with a starting age under 334 days [group α and model 6], 17 trials with 2390 pigs and an age of 365±30 days [group β and model 7], and 1075 animals from 8 trials with an age over 396 days [group γ and model 8].

When this stratification was carried out, the mathematical models obtained for each age group had less RMSE than the model that does not consider the age of stratification at the beginning of the finishing period. For these age intervals, the ABW at the beginning of this finishing phase was 102.6, 116.9 and 116.7 kg for α, β and γ age groups, respectively.

It has been already mentioned that the start of free-range finishing is determined by the availability of acorns to be grazed and not by the age of the pigs (from 283.3 to 418.3 days of initial age at the start of finishing phase in this meta-analysis). The initial BW is driven by growth modulation with food restriction in the pre- finishing stages (Freitas, 1998). In this study, initial BW of β and γ groups were similar; however, in the finishing phase a substantial greater ADWG was found in γ group compared with the β group (0.553 and 0.734 kg $d^{-1}$ for β and γ respectively), probably because, although the animals of both groups were of similar BW, their body fat/protein composition was different. This increase in ADWG is generally accompanied by an improvement in carcass quality characteristics, like an increase in the intramuscular fat (IMF) content. Indeed, Daza et al. (2007) or Rodríguez-Sánchez et al. (2010) compared animals of different ages at the start of this finishing period and found a lower meat quality at lower ages, additionally ADWG also decreased. However, Latorre et al. (2004) analysed commercial pigs (Pietrain × Large White sires mated with Landrace × Large White dams) and concluded that an increase in slaughter weight between 113 to 133 kg did not produce significate changes in IMF.

On the other hand, Oka & Iwamoto (2007) found that a feed restriction and re-alimentation of cattle caused a higher fat deposition and higher marbling scores than when cattle is fed ad libitum. The feed restriction is a common practice during the growing phase of the Iberian pigs to get a minimum increase weight and prepare these for *montanera*. In adition, a fast growth in this free-range grazing phase increases fat deposition because protein deposition is restricted by the low supply of protein by acorns (Lopez-Bote et al., 2001; Nieto et al., 2002), and the genetic

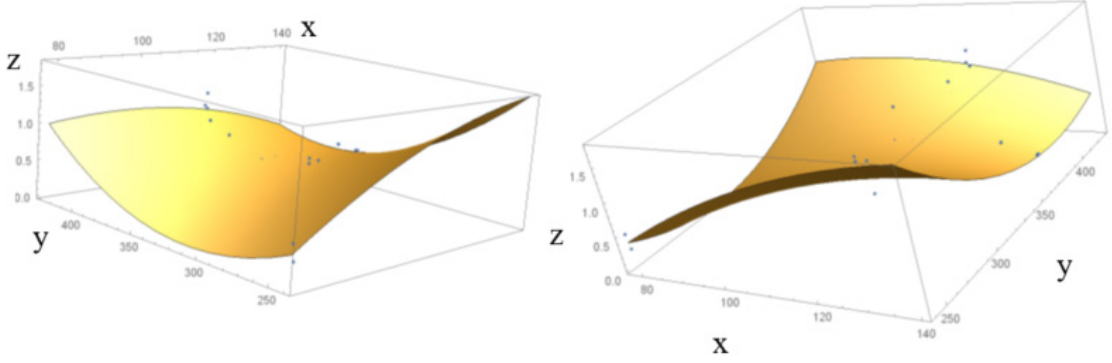


**Figure 4.** Surface mathematical model f(x,y) = − 0.6199 + 0.1135x − 0.031y – 0.0002$x^2$ − 0.0001xy + 6.85 $10^{-5}$ $y^2$, where x and y represent the age and weight, respectively, to predict the average daily weight gain (ADWG, kg $day^{-1}$) (z) in *montanera* from the initial weight and age.

limit for protein deposition in Iberian pigs (Nieto et al., 2012).

Therefore, it could be important to predict weight and age at slaughter when analysing the productive yields in finishing and the quality characteristics of the carcass of the Iberian free-range pigs. To facilitate these analyses, a surface model was applied to the database obtained in the present work, where the ADWG has been evaluated with respect to the age and weight of the pig at the beginning of the finishing period. Considering the age and weight of the pigs at the start of the finishing period a two-variable model was calculated to predict the ADWG during this period of finishing (Fig. 4).

$$f(x,y) = -0.6199 + 0.1135x - 0.031y - 0.0002x^2 - 0.0001xy + 6.85 \cdot 10^{-5} y^2 \text{ (RMSE = 0.1249)} \quad \text{[Model 9]}$$

where x = age, and y = weight.

With this mathematical model, it would be possible to obtain an estimate of ADWG and the date or age at which these pigs could be sent to slaughterhouse and their target weight.

# Conclusions

The nine models calculated helped to make predictions and benchmarks in each phase of this local breed. Among them, two mathematical models ([2] and [3]) were obtained to evaluate productive objectives in early growth (lactation and nursery) phases of Iberian pig. For the *montanera* phase it was necessary to divide the database into different age groups to compare, in a discrete way, ADWG as a function of the starting age, or a surface model with two independent variables for continuous comparison. The finishing models ([6], [7], [8] and [9]) help to predict the slaughter weight and age by knowing the BW and age at the beginning of the finishing phase, being the mature acorn the main limiting factor when deciding the stocking rate of the animals in the *dehesa*.

# Authors' contributions

**Conceptualization:** V. Rodríguez-Estévez, F. Sánchez-Esquiliche
**Data curation:** F. Sánchez-Esquiliche, C. Ferreira, A. Muniesa, V. Rodríguez-Estévez
**Formal analysis:** C. Ferreira, A. Muniesa
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**Investigation:** F. Sánchez-Esquiliche, C. Ferreira, A. Muniesa, V. Rodríguez-Estévez
**Methodology:** C. Ferreira, F. Sánchez-Esquiliche, A. Muniesa
**Project administration:** F. Sánchez-Esquiliche
**Resources:** Not applicable
**Software:** C. Ferreira
**Supervision:** C. Ferreira, A. Muniesa
**Validation:** F. Sánchez-Esquiliche
**Visualization:** C. Ferreira, A. Muniesa
**Writing – original draft:** C. Ferreira, A. Muniesa
**Writing – review & editing:** F. Sánchez-Esquiliche, C. Ferreira, A. Muniesa, V. Rodríguez-Estévez

# References

Aguinaga M, Gómez Carballar F, Nieto R, Aguilera J, 2010. Utilization of milk amino acids by the suckling Iberian piglet. J Anim Physiol Anim Nutr 95(6): 771-780. https://doi.org/10.1111/j.1439-0396.2010.01108.x

Aparicio-Macarro JB, 1977. Ceba de cerdo Iberico. vii) Ganancia en peso vivo en régimen de pastoreo (montanera) suplementado con harina de soja. Control del depósito de grasa dorsal. Arch Zootec 26: 97-110.

Aparicio-Macarro J, 1987. El cerdo Ibérico. Premio de investigación editado por Sánchez Romero Carvajal Jabugo SA Huelva, 122.

Ayuso M, Fernández A, Núñez Y, Benitez R, Isabel B, Fernandez AI, et al., 2016. Developmental stage, muscle and genetic type modify muscle transcriptome in pigs: effects on gene expression and regulatory factors involved in growth and metabolism. PloS One 11(12): e0167858. https://doi.org/10.1371/journal.pone.0167858

Castellano R, Aguinaga MA, Nieto R, Aguilera JF, Haro A, Seiquer I, 2013. Utilization of milk minerals by Iberian suckling piglets. Span J Agric Res 11(2): 417-426. https://doi.org/10.5424/sjar/2013112-3415

Castellano R, Aguinaga M, Nieto R, Aguilera J, Haro A, Seiquer I, 2014. Effects of intermittent suckling on body composition of Iberian piglets weaned at 35 days of age. Animal 8(5): 714. https://doi.org/10.1017/S1751731114000184

Daza A, Lopez-Bote C, Olivares A, Menoyo D, Ruiz J, 2007. Age at the beginning of the fattening period of Iberian pigs under free-range conditions affects growth, carcass characteristics and the fatty acid profile of lipids. Anim Feed Sci Technol 139(1-2): 81-91. https://doi.org/10.1016/j.anifeedsci.2007.01.003

Forero F, Venegas M, Cumbreras M, Ferrer R, 2001. Manchado de Jabugo: caracteres productivos y reproductivos. Porci (España) 61: 81-87.

Freitas A, 1998. Influência do nível e regime alimentar em pré-acabamento sobre o crescimento e desenvolvimento do porco Alentejano e suas repercussões sobre o acabamento em montanheira e com alimento comercial. PhD Thesis, Universidade de Évora.

Jensen C, Ersbøll AK, Nielsen JP, 2002. A meta-analysis comparing the effect of vaccines against Mycoplasma hyopneumoniae on daily weight gain in pigs. Prev Vet Med 54(3): 265-278. https://doi.org/10.1016/S0167-5877(02)00005-3

Latorre M, Lázaro R, Valencia D, Medel P, Mateos G, 2004. The effects of gender and slaughter weight on the growth performance, carcass traits, and meat quality characteristics of heavy pigs. J Anim Sci 82(2): 526-533. https://doi.org/10.2527/2004.822526x

Lopez-Bote CJ, 1998. Sustained utilization of the Iberian pig breed. Meat Sci 49: S17-S27. https://doi.org/10.1016/S0309-1740(98)00072-2

Lopez-Bote C, Rey A, Isabel B, 2001. Alimentación del cerdo Ibérico en la dehesa. Porcino Ibérico: aspectos claves; Buxadé C, Daza A (eds). Ed Mundi-Prensa, Madrid, pp: 215-246.

Nieto R, Rivera M, García MA, Aguilera J, 2002. Amino acid availability and energy value of acorn in the Iberian pig. Livest Prod Sci 77(2-3): 227-239. https://doi.org/10.1016/S0301-6226(02)00040-4

Nieto R, Lara L, Barea R, García-Valverde R, Aguinaga M, Conde-Aguilera JA, Aguilera J, 2012. Response analysis of the Iberian pig growing from birth to 150 kg body weight to changes in protein and energy supply. J Anim Sci 90(11): 3809-3820. https://doi.org/10.2527/jas.2011-5027

Oka A, Iwamoto E, 2007. Effects of restricted feeding of concentrate during the early fattening period on growth, carcass characteristics and fat necrosis of Japanese Black steers. Bulletin of the Hyogo Prefectural Technology Center for Agriculture, Forestry and Fisheries. Animal Husbandry Section (Japan) 53: 57-62.

RIBER, 2021. Registro informativo de organismos independientes de control del ibérico. RIBER. https://www.mapa.gob.es/es/alimentacion/temas/control-calidad/mesa-iberico/riber-publico/ [Sept 14, 2021].

Rodríguez-Estévez V, García A, Peña F, Gómez A, 2009. Foraging of Iberian pigs grazing natural pasture in the dehesa. Livest Sci 120: 135-143. https://doi.org/10.1016/j.livsci.2008.05.006

Rodríguez-Estévez V, Sánchez-Rodríguez M, García AR, Gómez-Castro AG, 2011. Average daily weight gain of Iberian fattening pigs when grazing natural resources. Livest Sci 137(1-3): 292-295. https://doi.org/10.1016/j.livsci.2010.11.015

Rodríguez-Estévez V, Sánchez-Rodríguez M, Arce C, García AR, Perea JM, Gómez-Castro AG, 2012. Consumption of acorns by finishing Iberian pigs and their function in the conservation of the dehesa agroecosystem. In: Agroforestry for biodiversity and ecosystem services. Science and Practice, InTech. 1-22. https://doi.org/10.5772/34877

Rodríguez-Sánchez J, Ripoll G, Latorre M, 2010. The influence of age at the beginning of Montanera period on meat characteristics and fat quality of outdoor Iberian pigs. Animal 4(2): 289-294. https://doi.org/10.1017/S1751731109991029

Sánchez-Esquiliche F, Rodríguez-Estévez V, 2011. Meta-análisis de los resultados productivos de las fases de crecimiento y cebo del cerdo Ibérico. Trabajo de fin de Máster en Zootecnia y Gestión Sostenible. Universidad de Córdoba, Spain.

Soto-Cavallé, 2006. Valoración en prueba de campo de la eficacia metafiláctica de Baycoxr 5% respecto de la coccidiais en lechones de raza ibérica por isospora suis. Solo Cerdo Ibérico 15: 74-83.

Vázquez C, 1990. Revisiones cuantitativas de la literatura: El meta-análisis. Evaluación Psicológica 6: 261-288.

Vázquez-Gómez M, García-Contreras C, Astiz S, Torres-Rovira L, Fernández-Moya E, Olivares Á, Isabel B, 2020. Piglet birthweight and sex affect growth performance and fatty acid composition in fatty pigs. Anim Prod Sci 60(4): 573-583. https://doi.org/10.1071/AN18254

Wolfram Research, 2021. Mathematica, vers 12.3. Wolfram Research, Inc., Champaign, IL, USA.