Simulation Modelling To Provide Insights Into The Optimization Of Delivery Weights Of Finisher Pigs

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Abstract: A simulation model was developed to model the optimization problem of finishing pig delivery weights. The model was developed following a participatory problem analysis of the decision problem, to align the model as much as possible with the needs and expectations of the stakeholders. It's functioning was tested by simulating different management strategies (i.e. finishing different sex combinations), in which differences in animal performance provoke different optima at the level of the animal and of a pig place per unit of time. The model's results align with the findings of past studies modelling the delivery weight decision problem.

1. Introduction

Decisions on slaughter weight and timing of slaughter might be as old as pigs production itself. Hence, these questions have repeatedly been studied by researchers in the past. It has been a side result of studies focusing on profit maximisation per unit of time from batch production (Heady et al., 1976; Kawaguchi and Kennedy, 1989), and it received more attention in studies by (Chavas et al., 1985; Jolly et al., 1980; Boland et al., 1993; Niemi, 2006; Boys et al., 2007 Niemi et al., 2010; Kristensen et al., 2012). The research questions on optimal slaughter weight mainly focused on 1) differences in optimal delivery weight and optimal feeding decisions provoked by animal performance,2) optimal slaughter weight under various market circumstances and 3) losses from suboptimal delivery of finisher pigs for the farmer when pig herds are heterogeneous. While these historic studies answered these questions starting from different premises and assumptions on the technical and economic context in which the slaughter decisions were to be made, some general insights into the questions ,outlined above, could be derived.

Still, renewed requests come from the industry to investigate the optimal delivery weight problem. This revival might be due to several reasons. First, the decision context is dynamic in time and spatially situated. For example, pricing schemes can differ between different regions and have changed with time. Similarly, spatial-temporal dynamics in market conditions might require the information to be updated. Moreover, the production process has changed; genotypes have been further improved by genetic selection and alternatives for surgical castrated males, in the form of intact and GnRH-vaccinated males are being used increasingly as a response to welfare concerns.

Secondly, some issues for practical use of optimization models arise. Optimizing delivery weight is a relatively complex problem and as for all hard-science based optimisation models, the application of these model in practise is troublesome (Martin, 2015). This phenomenon is not an exclusive feature of pig production or the delivery weight optimization problem, since similar implementation problems have been reported for example by Groenendaal et al. (2004), developing a model to support replacement decisions on dairy farms. Historical optimisation models might not have reached the intended decision makers. In the past, computational capacity of computers (Glen, 1983), might have been a burden. Nowadays this issue should be greatly overcome. Still, the theoretical and mathematical complexity (Tanure et al., 2013), combined with a reliance on large informational needs and parameters which are difficult to estimate on farms (Black, 2014), still pose burdens on practical implementation of optimisation models. Lastly, the historic optimization models might have included too much decision variables, over which farmers do not have (full) control or information to be able to include these variables in their decision set. This might have limited the applicability of these model's in a practical context.

To acquire a clear understanding of the practical decision context a participatory problem analysis (see Leen et al., 2017) of the delivery weight decision was executed. In this process stakeholders were involved in reframing the decision problem, i.e. listing the crucial factors and processes to be modelled and the questions to be solved. This analysis put forward that the priority of the consulted stakeholders did not concern increasing the level of detail and model sophistication to further improve the accuracy of the model's results but most important was to provide a relatively simple model that allows a farmer to use the limited on-farm data he disposes of to obtain farm-specific insights into the delivery weight optimization problem. This reaction is not weird, given the context in which these Flemish stakeholders are currently operating (see further for a situation of the production context).

The industry members demanded insight into i) the evolution of losses due to suboptimal delivery in addition to the mere optimization results, ii) the effect of sex and differences in animal performance on the optimal delivery results and iii) the value of having separate delivery moments for different sexes in the same batch (split-harvesting). However, the experts did put more emphasis on the learning potential of the model simulations for the farmers than on the normative value of the model producing the simulations (Leen et al., 2017). While the proposed model outlook aligned with the historical studies, they urged to limit the model complexity to enhance the conceptual accessibility and applicability and prevent the user of being discouraged to use the model. Therefore, the objective of this study was to provide insights into questions raised by stakeholders concerning the optimization of finisher pig delivery weights at the tactical decision level. For this aim, a simulation model was developed, in line with the expectations and needs of the pig production stakeholders.

2. Material & Methods

Situating the Flemish finisher pig production

In this section, the Flemish finisher pig production is roughly depicted to illustrate the context that has to be simulated by the slaughter weight model. In Flanders, 81% of finisher pigs are produced on specialized pig farms with equal shares for both farrow-to-finish and finisher farms. The majority of farms feed their finisher pigs with purchased compound feed in a two or three phase feeding regime, which is applied to better match the nutrient supply with nutrient requirements by the pigs. Typically, finisher pigs are fed *ad libitum*, because the predominantly used Piétrain sire is known for its lower appetite compared to other terminal sire breeds. The feeding regime in terms of feed content and timing of transitions from one feed to another are predetermined and not subject to integrated optimization with the slaughter decision during the production cycle as for example in the studies by Chavas et al. (1985) and Niemi (2006).

Data collection on production performance indicators during pig finishing is limited. Weighing scales are used on some farms, but these are usually not automated, so weighing is mainly limited to the entry and departure from the finishing facility. On few farms, feed input is monitored at pen level and usually only compartment but often no monitoring is done. In this depicted context we assume pig farmers not to have perfect control over growth and carcass quality during production.

Exact figures on how many finishers pigs are being sold following a carcass merit system or on a live weight basis are not available, but the share following the carcass merit system is estimated to be at least 38 percent. The carcass value of this share is being determined with AUTOFOM III (Carometec Food Technology, Herlev, Denmark) measurements. A carcass quality index (**MBI**) is determined based on the lean meat percentage and the conformation of the pig's carcass. Premiums or discounts are being paid per kg of carcass weight according to the quality class in which the carcass is categorised. Additionally, premiums or discounts per kg of carcass weight are linked with desirable or undesirable carcass weights.

The simulation model: brief overview

The simulation model approaches the decision problem at the tactical level, to provide information on the optimal amount of feeder piglets required over a longer period. Consequently, the model uses long term average prices for in- and outputs. Since, pig production is a continuous batch operation, the optimization needs to be executed per unit of time and not at batch level, but should account for the opportunity cost of replacement (**OR**). This means that the trade-off between the finishing duration of a batch and the annual throughput of a stable place needs to be considered. Therefore, fluxes of in- and outputs are calculated for each day in the production cycle per finishing pig place per year based on empirical growth and feed intake models. From these figures, costs and revenues per pig place per year are calculated and the optimal finishing duration and delivery weight is determined as the point at which gross margin per finishing pig place is maximized. Gross margin is defined as the difference between revenues on the one hand and the sum of feed costs, costs for purchase or production of feeder piglets, operational costs per production cycle (invariable with the pig's weight) and costs for manure disposal on the other hand.

Models used

Based on an evaluation of several empiric growth and feed intake models for accuracy and calibration possibilities (manuscript under review), the growth model proposed by Bridges et al. (1986) (equation 1), modelling live weight (W) as a function of age, and the daily feed intake (DFI) model by Giesen *et al.* (1988) (equation 3) were selected to model the basic biological processes of pig production. With a limited amount of observations, these basic models allow for describing animal growth and feed intake and consequently the evolution in feed efficiency. Because of the differences in animal performance between sexes, separate curves are established for gilts (**GI**) and another sex being either intact boars (**BO**), barrows (**BA**) or GnRH-vaccinated boars (**GnRH-BO**).

Analyses of the slaughter results of the carcass quality index, based on meat percentage and carcass conformation, showed little evolution in the quality index with increasing carcass weight (data not published), which is explained by a counterbalance of an improving carcass conformation and a slightly worsening lean meat percentage with increasing carcass weight. Far more variation in the carcass quality index was explained by sex. Consequently, the model treats carcass quality as invariant with carcass weight, but average carcass quality per sex is inserted as a model input. Similarly, dressing percentage is fixed per sex and considered as a model input.

$$W_{i,sex} = W_{m,sex}\left(1 - e^{m_{sex} \times Age_i^{a_{sex}}}\right) \quad (1)$$

$$Average\ daily\ growth\ (ADG_{i,sex}) = a_{sex} \times m_{sex} \times Age^{(a_{sex}-1)} \times W_{m,sex} \times e^{m_{sex} \times Age_i^{a_{sex}}} \quad (2)$$

with $W_{m,sex}$ the mature body weight, m_{sex}, the exponential growth decay constant and a_{sex} the kinetic order constant, with values determined for each sex separately. The index i denotes the number of the day in the finishing period.

$$Daily\ feed\ intake\ (DFI_{i,sex}) = d_{sex} \times e^{\left(-f_{sex} * Age_i - \frac{g_{sex}}{Age_i}\right)} \quad (3)$$

$$Cumulative\ feed\ intake\ (CFI_{i,sex}) = \sum_1^i d_{sex} \times e^{\left(-f_{sex} * Age_i - \frac{g_{sex}}{Age_i}\right)} \quad (4)$$

with d_{sex}, f_{sex}, g_{sex} the parameters in the DFI model adapted from Giesen et al. (1988) and i the index for days in finishing.

The evolution in total mortality is modelled starting from the assumption that the probability of a pig dying remains the same throughout the production cycle. The daily probability of dying ($Pb_{daily\ mortality}$) is then determined from equation 5. The evolution in total mortality is described by equation 6. Consequently this evolution in total mortality is used to correct both the live weight production (equation 7), carcass weight production (equation 9) and cumulative (equation 11) and daily feed intake (equation 12) for mortality according to Van Meensel et al. (2010).

$$Pb_{daily\ mortality} = 1 - \sqrt[Finishing\ duration]{(1 - Total\ mortality\%)} \quad (5)$$

$$Total\ mortality_i = \sum_1^i (Pb_{daily\ mortality} \times \left(1 - Pb_{daily\ mortality}\right)^{(i-1)}) \quad (6)$$

$$Net\ live\ weight\ production_{i,sex} = W_{i,sex} \times (1 - Total\ mortality_i) \quad (7)$$

$$Carcass\ weight_{i,sex} = W_{i,sex} \times Dressing\ percentage_{sex} \quad (8)$$

$$Net\ carcass\ weight_{i,sex} = Net\ live\ weight\ production_i \times Dressing\ percentage_{sex} \quad (9)$$

$$Days\ present_i = \sum_1^i (\left(1 - Pb_{daily\ mortality}\right)^{(i)}) \quad (10)$$

$$Net\ CFI_i = CFI_i \times (\frac{\text{Days present}_i}{i}) \quad (11)$$

$$Net\ DFI_i = Net\ CFI_{i+1} - Net\ CFI_i \quad (12)$$

With i the index for days in the finishing period.
Volumetric manure production is modelled as from the dry matter intake and dry matter digestibility, the dry matter concentration of slurry and the volumetric weight of slurry (equation 13).

$$Volumetric\ slurry\ production\ \left(VMP_{i,sex}\right) = net\ CFI_{i,sex} \times DM_{feed} \times DMD_{feed} \times DM_{slurry} \times \rho_{slurry} \quad (13)$$

with DM_{feed} , the dry matter content of feed, DMD_{feed} the dry matter digestibility of feed, DM_{slurry} the dry matter content of slurry and ρ_{slurry} the density of slurry and i the index for days in finishing.

Modelling inputs, outputs, revenues and costs for the finishing stage

For the gross margin model, it is assumed that two different sexes are housed in the same compartment in equal shares. For this reason, first, the gross margin (GM) between revenues, feed costs, feeder piglet costs, manure disposal costs and other fixed cost per production cycle, is calculated per pig for each sex. Revenue per pig on day i is calculated from its carcass weight and corresponding weight and quality corrected unit price (equation 14). The payment grid with a detailed description of the premiums and discounts based on carcass weight and quality is added in appendix I.

$$Revenue_{pig,i} = Net\ carcass\ weight_{i,sex} \times P_{pig}\left(base\ price, P_{cw}(carcass\ weight_{i,sex}), P_{cq}(carcass\ index_{sex})\right) \quad (14)$$

with P_{cw} , P_{cq} respectively the premium or discount depending on the carcass weight and carcass quality.

$$Feed_{i,sex} = P_{f1} \times \sum_{W_{i,sex}}^{40} DFI_{i,sex} + P_{f2} \times \sum_{W_{i,sex=40}}^{70} DFI_{i,sex} + P_{f3} \times \sum_{W_{i,sex=70}}^{W_{i,sex}} DFI_{i,sex} \quad (15)$$

with $P_{f1,2,3}$ the unit prices of feed in the corresponding feeding phase with changes of feeding phase at 40 and 70 kg of body weight.

$$Slurry\ disposal_{i,sex} = P_{SD} \times \sum_{1}^{i} VMP_{i,sex} \quad (16)$$

with P_{SD} the unit price per m³ of slurry to be disposed

$$Batch = P_{feeder\ piglet} + P_{production\ cycle} \quad (17)$$

with $P_{feeder\ piglet}$ the cost per feeder piglet and $P_{production\ cycle}$ the amount of fixed expenses per production cycle.

$$GM_{i,sex} = Revenue_{pig,i} - Feed_{i,sex} - Slurry\ disposal_{i,sex} - Batch \quad (18)$$

Consecutively an aggregated gross margin per pig place can be calculated, assuming a strict execution of an all-in/all-out (**AIAO**) production regime (equation 19a).

$$GM_{pig\ place,,aiao,i} = 0.5 \times GM_{i,sex1} + 0.5 \times GM_{i,sex2} \quad (19a)$$

$$GM_{pig\ place,split,i} = 0.5 \times \max_{1\to i}(GM_{i,sex1}) + 0.5 \times \max_{1\to i}(GM_{i,sex2}) \quad (19b)$$

Equations 19a and 19b do not yet account for the opportunity cost of replacement. This is included in equation 20 by multiplying with the number of possible production cycles (R_i), which depends on the finishing duration (i) and the idle time (T_{idle}) between consecutive cycles.

$$GM_{pig\ place/year,i} = GM_{pig\ place,strategy,i} \times R_i \ \ with\ R_i = \frac{365}{(i+T_{idle})} \quad (20)$$

Data sources and scenarios

Animal profiles were constructed from an animal performance trial described in Van den Broeke *et al.* (2016), for each sexe. Growth and feed intake curves were constructed by non-linear regression, using an ordinary least squares estimation procedure on serial body weight and feed intake recordings. Parameters for the Bridges and Giesen model are listed in Table 1. A graphical comparison of the differences in technical performance between the sexes is included in appendix II. Results are reported for the optimum at animal level, neglecting OCR and for the combinations of GI with BO, BA and GnRH-BO assuming AIAO and Split-harvesting.

Table 1 Animal performance indicators and fitted model parameters per sex

Type	ADG[a] (g)	Growth inflexion point		FCR[a] (kg/kg)	MBI[b]	*Wf*	*-e^m*	*a*	*f*	*g*	*h*
		Weight (kg)	Age (d)			Bridges growth model			Giesen feed intake model		
Bo	874	66.0	122	2.33	3.35	149.4	-12.05	2.39	500	0.019	377.8
Ba	850	63.5	116	2.54	3.63	147.3	-11.48	2.29	336.0	0.017	338.5
Gi	760	63	124	2.52	3.06	235.7	-10.69	1.98	23.8	0.007	141.6
GnRH-Bo	836	92	155	2.35	3.82	152.7	-10.98	2.15	8.4	0.002	197.4

[A] Average daily growth (ADG) and feed conversion ratio (FCR) are reported for a standardized weight trajectory between 25-110 kg. [b]MBI: carcass quality index (the lower the better), averages per sex from slaughter house results in the animal trial

An economic scenario was defined with average prices for finisher pigs, feeder piglets and feed over the 5-year period between 2012 and 2016 (Table 2). Additionally, cost for GnRH-vaccination was estimated to be 3 euro per animal and manure disposal costs were set at 17 euro/m³ of slurry. Some extra costs, like stable cleaning, bedding material, etc., are invariant with finishing duration but are fixed per production cycle. These costs are incorporated in $P_{batch.}$. For the analysis it is assumed that the unit prices for feeding phase 1 (F1) and phase 3 (F3), relate to phase 2 (F2) as 108% and 82% respectively.

Table 2 Economic parameters used in the analysis

Scenario	Finisher pig	Feeder piglet	Feed	F1	F2	F3	GnRH-vaccin	Manure disposal	Fixed cost per cycle
	€/kg carcass	€/piglet	€/ton	€/ton	€/ton	€/ton	€/pig	€/m³	€/batch
Base	1.20	41.00	258	279	258	237	3.00	17.00	3.50

3. Results and discussion

The evolution in gross margin per animal with increasing finishing duration is marked by sharp discontinuities for each sex (figure 1),which correspond to the weight ranges with price premiums for (un)desirable carcass weights. For all sexes the highest premium (+0.06 €/kg) is allotted to carcasses between 85 and 95 kg. The optimal delivery moments are always located in this weight range with the maximal price premium. There are differences in gross margin per animal between the different sexes, which are due to differences in technical performance. However, we do not claim these technical results to be universal for the sexes used in the analysis, because they are based only on one trial. The gilts grew slower and consequently it took longer before they entered the maximal weight premium range (**MWPR**) compared to the other sexes. Additionally, the gilts in the animal trial showed a comparable cumulative feed conversion to that of the barrows, but their marginal feed efficiency aggravated more with increasing finishing duration. This aggravating feed efficiency (Figure AII) resulted in the optimal slaughter weight of gilts being lower than the upper limit of the maximal weight premium. (**UMWP**). This contrasts with the other sexes, for which the optima without OCR aligned with the UMWP. The differences in maximal GM between gilts and boars and GnRH-boars are also due to differences in feed efficiency. The marginal feed efficiency allowed the Boars and GnRH-boars to be fattened until the UMWP is reached, thus a heavier carcass could be sold and its production required less feed. With boars showing a slightly higher GM than the GnRH-boars (Table 3). Due to their sustained higher marginal growth and least aggravating marginal feed efficiency, the GnRH-boars showed the steepest evolution in GM per animal as a function of finishing duration, but at the same time the shortest time window in the range to obtain the maximal weight premium.

Table 3 Simulation results of the sex combinations Gilts with Boars, Barrows and GnRH-Boars, assuming no opportunity cost of replacement (OCR), All-in/all-out (with OCR) and split-harvest (with OCR)

		Gross margin per pig (€)	Optimal delivery weight (kg)	Finishing duration (d)[b]	Production cycles per year	Gross margin per pig place[c] (€/PPY)	Average gross margin per pig place[c,d] (€/PPY)
No OCR	GI	8.38	117	130	-	-	-

	BO	11.74	123	124	-	-	-
	BA	8.59	120	119	-	-	-
	GnRH-BO	11.67	123	120			
AIAO[a]	GI×BO	7.97	110	117	2.94	23.46	28.21
	BO	11.2	119	117	2.94	32.96	
	GI×BA	7.76	108	114	3.02	23.41	24.43
	BA	8.43	117	114	3.02	25.44	
	GI×GnRH-BO	8.14	112	120	2.87	23.39	28.46
	GnRH-BO	11.67	123	120	2.87	33.53	
Split-harvest[a]	GI×BO	7.97	110	117	2.94	23.46	28.21
	BO	11.2	119	117	2.94	32.96	
	GI×BA	7.76	108	114	3.02	23.41	24.43
	BA	8.43	117	114	3.02	25.44	
	GI×GnRH-BO	8.14	112	120	2.87	23.39	28.46
	GnRH-BO	11.67	123	120	2.87	33.53	

[a]: Opportunity cost of replacement taken into account, [b] idle time between cycles not included, [c]: PPY: per pig place per year, [d]: gross margin per pig place per year averaged over the values per sex, assuming equal shares of the two sexes.

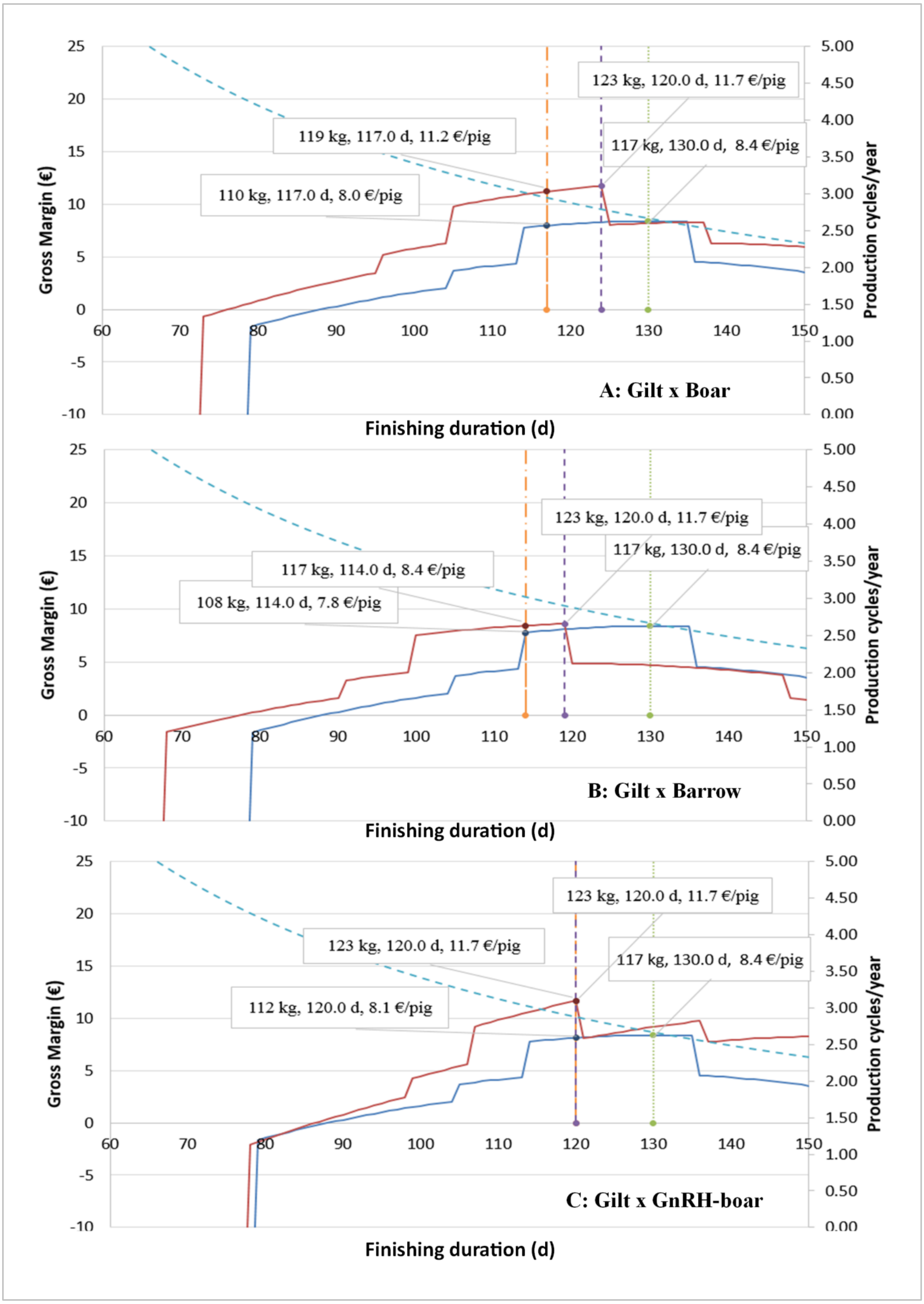


Figure 1: Evolutions in gross margin per sexual type: Gilt (full blue line), Male sexual type (full red line). The green dashed line: the optimal finishing duration for gilts without opportunity cost of replacement, purple dashed line: optimal finishing duration for the male sexual type, orange dashed line: optimal finishing duration under All-in/all-out accounting for opportunity cost of replacement, which is derived from the evolution in number of production cycles (blue dashed line) on right vertical axis.

When accounting for OCR and assuming AIAO, all sexes except the GnRH-boars were slaughtered before their optimum at the animal level (no OCR) (Figure 1). This can be explained by the fact that the reduction in number of production cycles (the dashed blue line in Figure 1), provoked by an increase in finishing duration, lowers the gross margin per pig place more than the increase in gross margin per animal that is attained from prolonging the finishing duration. Here, the differences between sexes in the marginal GM per animal and amplitude of the GM per animal explain the results. Under AIAO the slope of the GM per pig place per year can be written as:

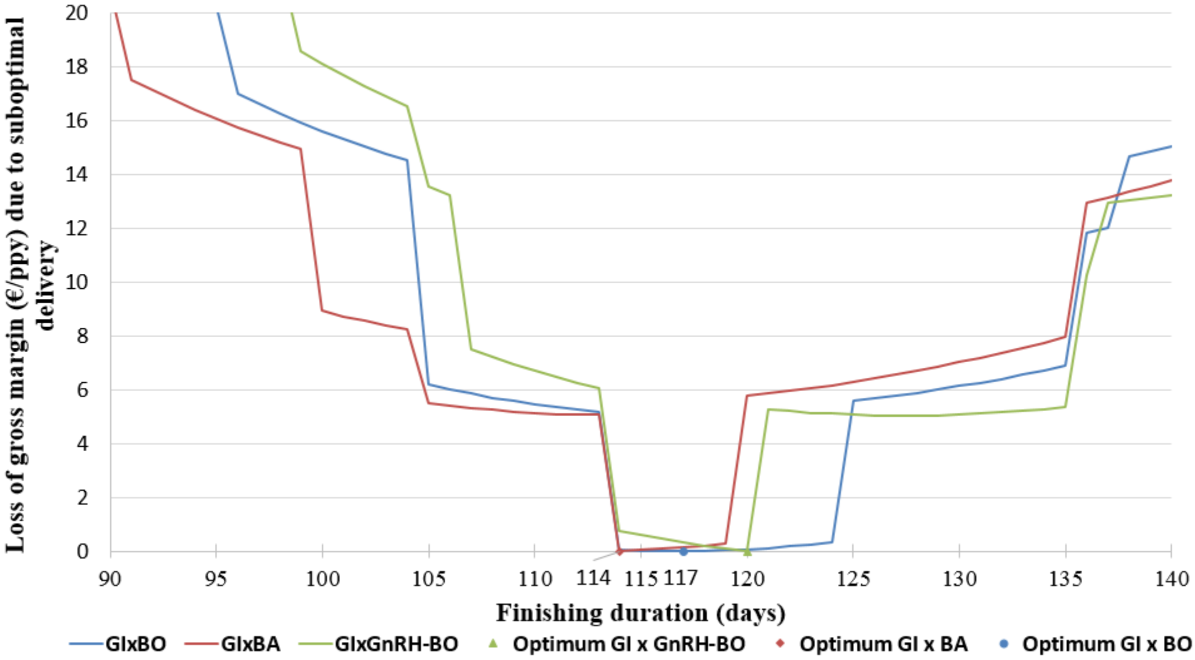
$\frac{dGM_{ppy}}{di} = \frac{dR}{di} \times 0.5\ \left(GM_{gilts}(i) + GM_{male}(i)\right) + R(i) \times 0.5 \left(\frac{dGM_{gilts}}{di} + \frac{dGM_{male}}{di}\right)$ in the optimum this can be rewritten as:

$$-\frac{dR}{di} \times 0.5\ \left(GM_{gilts}(i) + GM_{male}(i)\right) = R(i) \times 0.5 \left(\frac{dGM_{gilts}}{di} + \frac{dGM_{male}}{di}\right)$$

For a certain finishing duration i, the higher the values of GM_{gilts} and GM_{male} , the steeper the marginal GM_{gilts} and GM_{male} must be to counterbalance the reduction (*dR/di* <0) in production cycles per year. The difference in optimal finishing duration between the GixBo combination and the GIxBa can thus be explained by the greater marginal GM of the boars compared to the barrows. The steeper marginal GM curve of the boars allows the finishing duration to be 5 days longer compared to the GixBa situation. 114 days of finishing is just enough time for the gilts to enter the MWPR. Shortening the finishing duration further would result in a high loss of gross margin per gilt and is not beneficial. For a similar reason, the finishing duration for the GIxGnRH-bo combination is fixed at the UMWP increasing the finishing duration would result in a reduction of production cycles and a larger loss in GM per GNrH-bo compared to the gain in GM per gilt. This is in agreement with the findings of Chavas et al. (1985).

The results show no additional value of practicing split-harvesting, i.e. having separate deliveries for the different sexes. This can be explained in part by the positive slope of the GM per animal in the MWPR for all the sexes and in part by the time window in which both gilts and the other sex in the combination are simultaneously in the MWPR. First, split-harvesting can be seen as buying additional time for the slowest growing sex (i.e. the gilts), to gain extra gross margin per animal. Since the results under AIAO showed that keeping the barrows and boars to their optimum at animal level was not economically beneficial, it is logical that buying more time for the gilts to gain in GM per animal is even worse. In the GixGnRH-BO combination, the GnRH-BO do attain their maximal GM per animal, and still split-harvesting was not beneficial. Here again the explanation is found in the little positive slope of the marginal GM of the gilts,which does not outweigh the reduction in production cycles per year. If for the GixGnRH-BO combination the differences in animal performance would have been bigger, split harvesting would have been beneficial, because the timewindow in which both sexes are in the MWPR would disappear (results not shown). In this situation, practising AIAO would result in large losses in GM per pigplace per year because either Gilts suffer large discounts from prematurity or GnRH-boars for being to heavy. This agrees to the findings of Boys *et al.* (2007). Moreover, the results underestimate the value of split harvesting, because the approach of using the average technical curves per sex does only cover the variability between the "average" animal of each sex. Including stochasticity in the animal models, to better approximate the total variability between pigs might result in individual GM-curves per animal that make split-harvesting economically beneficial. When the proposed model will include this stochasticity, it will be able to deliver insights in the possible gains in gross margin per pig place from reducing so called sorting losses. However, the question remains whether these gains in gross margin outweigh the investment and operating costs of the sorting technology.

The importance of optimal timing of delivery depends also on the combination of sexes (Figure 2). The graph shows the losses in gross margin per pig place due to suboptimal delivery under an AIAO regime and accounting for OCR. The optima can be found at the crossing of the x-axis. The relatively flat plateaus near the optimum correspond to the time windows in which both sexes in the combination are simultaneously in the MWPR, and allow for a certain error margin in the decision. These plateaus, correspond to the flat pay-off curves, which are universal to economic production models with continuous decision variables according to (Pannell, 2006). However, in this example the payment grid artificially creates several consecutive plateaus. The difference in overlap between the sex combination is clear. This overlap is the greatest for the GixBO-combination and the smallest for the GixBA-combination. For the GixBO-combination, the losses from suboptimal delivery are limited when slaughtering either too light or too heavy. In contrast, since the optimum for the GixBA-combination lies at the lower limit of the MWPR, the losses from suboptimal delivery due to overweight are minimal compared to the losses from premature delivery. The slopes of these curves are logically also depending on the marginal gross margin of the animals which depend on their technical performance. The situation for the GixGnRH-BO combination is the reverse of the GixBA, since it's optimum lies at the UMWP, overdue delivery costs much more than premature delivery. However, this sex combination shows the greatest slope in the MWPR, and thus benefits most from optimal delivery.



By using different animal performance curves in the sex combinations, it was possible to

Figure 2. Comparison of the losses in gross margin per pig place per year due to suboptimal marketing under AIAO for the different sex combinations

investigate the simulation model's reaction to these differences in determining the optimal finishing duration, delivery weight and gross margins. Further, sensitivity analysis is needed, including prices and animal profiles to investigate the universality of the results on sex combinations.

4. Conclusion

The proposed simulation model, produces results that are in line with the mechanism that have been reported in the past by other studies on the optimal delivery weight problem. The opportunity cost of replacement needs to be accounted for in a continuous batch operation. The current analysis corroborates the difference in optima between optimization at batch level or per unit of time. Different profiles of animal performance explain the differences in optima. Moreover, their combination (i.e. different sexes) affects the optimization as well, which can be important for the farm manager. No additional value from practising split-harvesting was detected in the current results. However, a more accurate analysis of this question requires more herd-variability to be included in the animal performance models.

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6. Appendix I: Carcass Merit Scheme

Table AI Price premiums and discounts per kg carcass

Gilts, Barrows, GnRH-Boars		Boars	
Carcass weight limits (kg)	Premium/Discount (€/kg carcass)	Carcass weight limits (kg)	Premium/Discount (€/kg carcass)
<50	-0.52	<50	-0.52
50-60	0.37	50-60	0.37
60-65	-0.22	60-65	-0.22
65-80	0	65-80	0
80-85	0.02	80-85	0.02
85-95	0.06	85-95	0.06
95-105	0.02	95-100	0.02
105-115	0	100-105	0
115-125	-0.05	105-115	-0.05
>125	-0.32	115-125	-0.075
		>125	-0.32

Table AII Price premium scheme based on Quality indices, used in the analysis

Premium class	**Quality index**	**Premium (€/kg cacass)**	**Premium class**	**Quality index**	**Premium (€/kg cacass)**
1	0-1.9	+0.155	9	4.1-4.4	+0.04
2	1.9-2.2	+0.145	10	4.4-4.7	0
3	2.2-2.5	+0.135	11	4.7-4.99	-0.04
4	2.5-2.8	+0.125	12	5.0-5.4	-0.09
5	2.8-3.1	+0.115	13	5.4-5.69	-0.14
6	3.1-3.4	+0.105	14	5.7-5.99	-0.19
7	3.4-3.75	+0.09	15	>=6	-0.24
8	3.75-4.1	+0.07			

Appendix II: Comparison of animal performance between sexual types

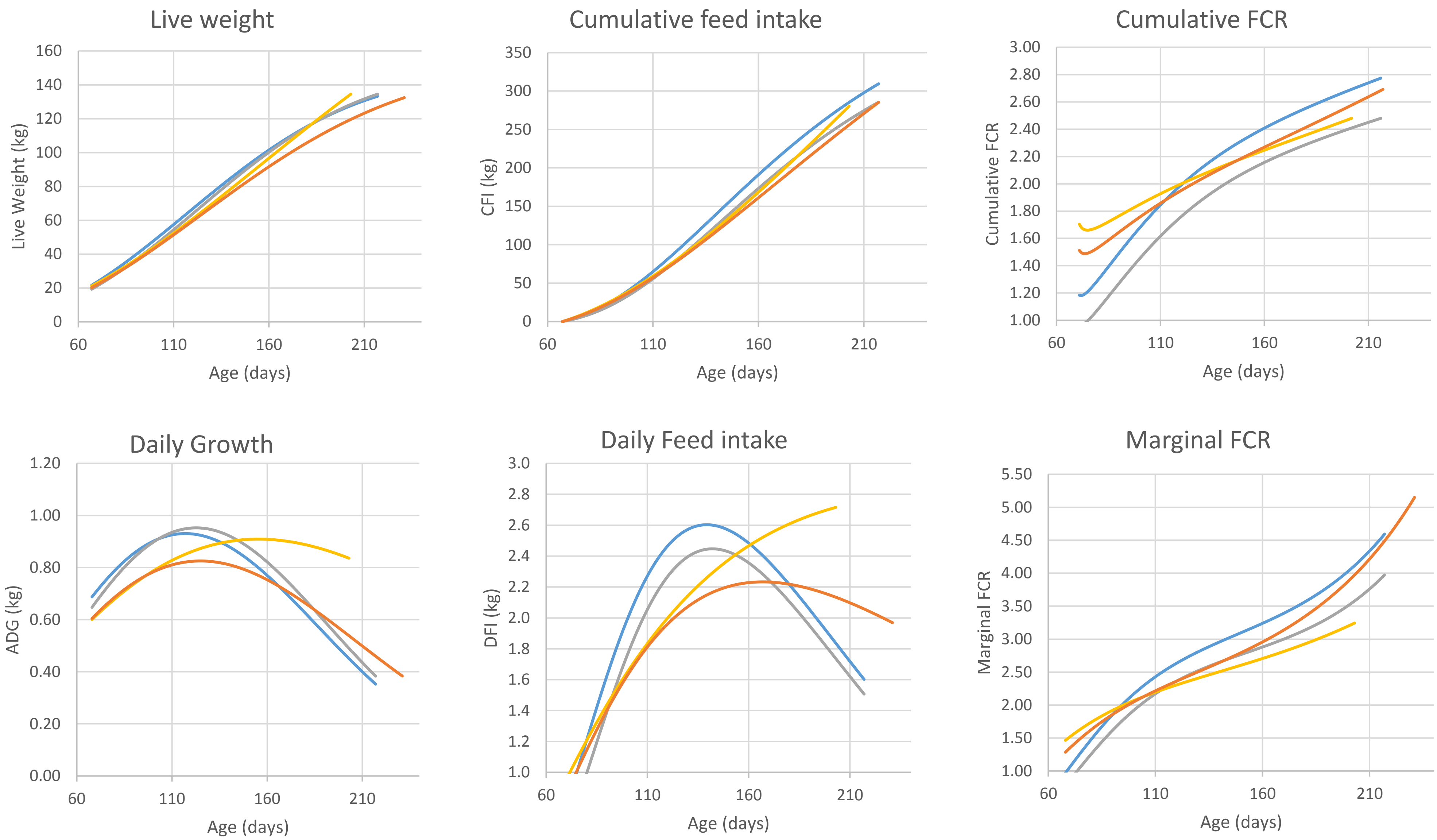

Figure AII: Evolution as a function of age of Live weight, Cumulative feed intake, Cumulative Feed conversion ratio, Average Daily Growth, Daily Feed intake and marginal Feed Conversion Ratio, for Barrows (Blue line), Boars (Grey line), GnRH-boars (Yellow line) and Gilts (Orange line).