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STOCHASTIC ANALYSIS OF PROFITABILITY OF THE PIG BREEDING PROCESS

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Abstract

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This study deals with the economy of agricultural production, specifically in animal farming.
The main goal is to find and apply an efficient simulation model of pig breeding process in order to investigate the impact of various changes in the production settings on the economy of a particular pig breeding. For this reason, it is necessary to take values given in the study as model ones.
Costs at particular parts of the breeding process were used as the main simulation inputs, together with number of parities, length of farrowing interval, number of weaned piglets depending on a parity number, lactation length, and the gestation length of sows. Additional inputs were price of produced piglets, price of insemination doses etc. Statistical distributions for the simulations of the inputs were obtained with theoretical curve fitting of sample data, which were provided from research projects focused on piglet production efficiency. The empirical distribution of sow profitability depending on the number of parities, which can help to decide about the culling of sows from the herd, was also determined in the research. A simulation was performed using the program @RISK. The obtained results and recommendations are discussed at the end of the paper.

Keywords: simulation, probability distribution, pig breeding, weaning of piglets, culling of sows

INTRODUCTION

Many authors have dealt with the economy of piglet production farms, e.g. Kleinhanss (2009), Pelletier *et al.* (2010), Boudný and Špička (2012). The key factors of economy of piglet production system can be divided into two groups – exogenous and endogenous. Exogenous factors, such as the price of feeding, the price of energy and the price of pork meat, can be influenced negatively. In contrast, the endogenous factors can be managed with success.

Reproductive performance of the sow herd is the key factor in controlling the efficiency of swine production. Improvements in sow productivity will be achieved by a combination of measures, which include reductions in non-productive days through better management of the insemination step, timely introduction of gilts and culling of barren sows. Very important is having trained and skilled stock people.

Some management practices, such as feeding strategy of breeding gilts, housing conditions of sows, method of oestrous stimulation and storage duration of semen, have an influence on the outcome of reproductive parameters such as weaning-to-oestrous interval and percentage of repeat breeders. These practices can be implemented rather easily by pig producers and may consequently lead to improvements of reproductive performance (de Jong *et al.*, 2013).

On average gilts attain puberty at about 6–7 months of age. Age at first mating in gilts is often about 6 weeks later than age at puberty. Age at first mating of the gilts was influenced by breed, birth month, birth litter size, birth parity, growth rate and backfat thickness (Tummaruk *et al.*, 2000). The results showed that the age at the first mating below 221 days and beyond 250 days negatively affected the performance records. The age at the first mating seems to be less important for the sow performance after the second parity (Babot *et al.*, 2003).

Litter size, the most important reproduction trait from an economic point of view, is included in many pig breeding programmes. In practice, however, considerable problems are associated with other reproduction traits, such as weak oestrous symptoms or high piglet mortality (Rydhmer, 2000).

Non-productive sow days measured as weaning-to-first service interval (WSI) is an economically important trait in commercial swine production. A reduction in WSI would increase efficiency and decrease production costs (Chansomboon, 2009).

The capacity to return to oestrus following weaning, the onset of puberty and the ability to conceive and maintain pregnancy are affected by some factors: season, lactation length, daily feed intake, parity number (Kaplon *et al.*, 1991). A total of 77.2% of females showed oestrus between 3 and 5 days post-weaning (Poleze *et al.*, 2006). Total litter size decreased for about 0.71 piglet when WSI duration was longer than 4 days (Karveliene *et al.*, 2008).

The farrowing interval was genetically favourably correlated with length of productive life, age at first farrowing and number of piglets weaned at first farrowing (Serenius and Stalder 2004). The mean farrowing interval was 140.9 + 5.7 days, with a 4.0% coefficient of variation. Variance analysis showed no effect of either year, season of farrowing or herd on the farrowing interval. The boar effect was not important for the farrowing interval, but the dam represented an important source of variation (Neto *et al.*, 2009).

Piglet production is intimately related to the reproduction process of sows and many different factors other than feeding may affect the final results. Hence, the increasing number of new variables and constraints affecting piglet production make difficult to explore all possible management alternatives to find the best one. Therefore, sow herd management models can play an important role to optimise management alternatives or to explore new ones (Rodriguez-Sanchez *et al.*, 2012).

Herd management is the process by which certain goals of the farm manager, expressed as amount of product, are achieved by consuming a corresponding amount of production factors. In order to be able to combine these factors in an optimal way it is necessary to know the main interrelations among them and their influence on the final productivity of the system. The challenge of the livestock modeller is to represent what is essential in the system in order to find relevant answers from a problematic situation that may initially seem chaotic (Plà, 2007).

The optimal replacement policy of sows is described by Rodriguez *et al.* (2011). Plà *et al.* (2003) have developed a production model using Markow chains and Semi-Markow chains (Plà *et al.*, 2009). A review of mathematical models for sow herd management is described by Plà (2007). Usage of stochastic process models in sow herd management is dealt with by Marín *et al.* (2005). Simulation model, which includes comparison of economic performance of two breeds of sows, was introduced by the authors in the article Friebel *et al.* (2013). The relation between culling rate and production efficiency in nucleus herd is assessed in Houška (2009).

In this study, we focused on the distribution of time spent by farrowing batches at different parts of the production process during farrowing interval. Because of the stochastic character of animal reproduction, we have developed a stochastic simulation model covering costs and incomes arising during the whole reproductive cycle.

MATERIAL AND METHODS

Stochastic analysis of the pig breeding process had to work under the circumstances of a model farm. However, the simulation model is designed to be applicable in any pig breeding company operating under condition of batch management.

The pig breeding process is depicted in Fig. 1. At the top of Fig. 1, we can see the time axis.

Total capacity of the model farm (581 sows) is divided into five particular sections – facilities. Capacity of particular facilities is given in Tab. I.

Because the duration of reproduction cycle is biologically set, we can only change the lactation length. However, the possible change of the above mentioned stage has to be ethologically admissible. For the purpose of simulation model we considered minimal weaning interval of 21 days, which is also minimal lactation interval.

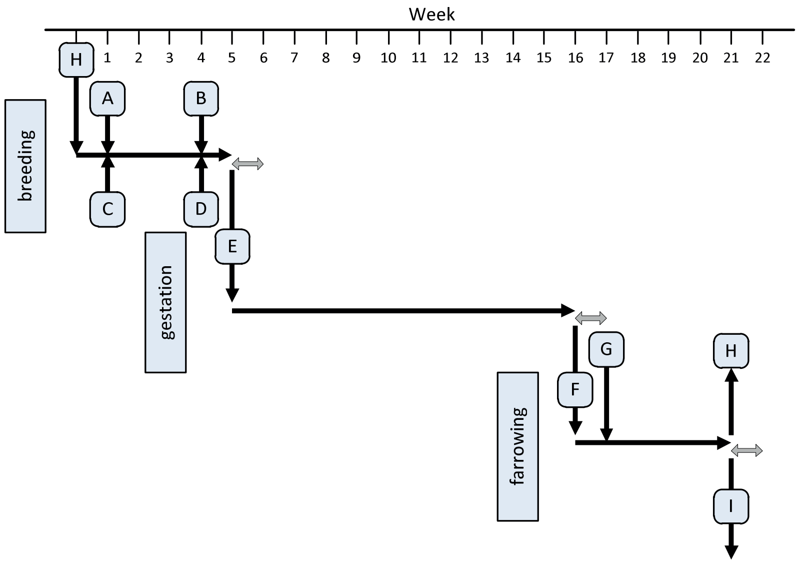
The second parameter of the pig breeding process which can be successfully changed and which has a great economic impact is the culling policy. At Czech farms is typical that the sows are culled for the health reasons (in our reference farm 68%) and the number of farrowing is not limited as in the other countries. Keeping the inefficient sows from the point of view fertility in reproduction process has an undesirable impact on the economy of the whole farm.

Inefficiency of the sows can be assessed from the point of view of pregnancy, fertility and veterinary costs.

Pregnancy is evaluated with a number of insemination and oestrus which are needed for becoming pregnant in the particular reproduction cycle. During the first and second reproduction

I: *Capacity of sections*

Facility	Capacity
Breeding	165
Gestation	286
Farrowing	130
Gilts acclimatization	40
Piglet rearing	1560



1: *Reproduction diagram**
*A – oestrus, insemination, B – detection of pregnancy, C – herd completion, D – detection of heat, E – movement do gestation facility, F – movement to farrowing facility, G –farrowing, H – weaning of piglets, I – movement to breeding facility, ⇔ disinfection of particular facility

cycle, it is possible to tolerate a higher number of inseminations; typical are three or four attempts. In the third and the next reproduction cycle, the number of possible insemination falls to two or three. It means unless the sow become pregnant after the second oestrus, it is culled from herd. In our study, we defined a critical value of oestrus for each reproduction cycle as an element of vector of pregnancy – **a**. This vector has got nine elements, because we consider nine reproduction cycles in maximum for the reasons stated below.

Fertility is the next important culling reason. It is represented with the number of weaned piglets. At the first farrowing, there should be at least seven weaned piglets, otherwise the sow is culled. For the next farrowing, the required number of the weaned piglets increases to nine. It is possible to concede a lower number of piglets after the fourth or fifth reproductive cycle. In our study, we defined a critical (minimal) value of weaned piglets for each reproduction cycle as a component of fertility vector – **b**.

Veterinary reasons have the great impact on the economy of whole production. There is not simple to include those costs into the simulation model. In this study, differences between particular stages of the reproductive cycles are provided with an inclusion of different veterinary costs at different production facilities. Veterinary costs change periodically not only during the reproduction cycle, but they also increase with the age of the sow. Therefore, it is not economically advantageous to keep sows in production too long. The next reason for culling the sows after reaching a particular age is the decreasing fertility (the number of weaned piglets) with increasing age. Hence a general critical age for culling sows is needed to be set. This age has to be adjusted in the whole reproduction cycles, accordingly as a maximal number of farrowing, in our study represented with a parameter l.

The change of both the weaning time and the culling rules has a great impact on distributions of sows at particular facilities. To change internal dispositions of a real farm may be difficult, thus possible changes, especially of the pregnancy rules, are limited.

Data

The reference data file included 1431 records of Czech Landrase (CL) sows. Each record included the birth date, date of culling, reason for culling, date of farrowing, date of weaning, number of weaned piglets in each litter, birth weight, litter weaned weight, number of insemination during farrowing interval, etc. The data had to be processed in order to gain necessary simulation inputs see below.

Structure of the Herd

The herd structure is a crucial parameter which influences the total efficiency of piglet production. This indicator is primarily given by the veterinary conditions at the farm. The secondary impact is the culling policy depending on efficiency of sows. The structure of the herd is depicted in Tab. II.

Costs Analysis

Total costs of sow farming have to include costs connected with purchasing of a sow, its integration into a herd, so called the acclimatisation phase. Moreover, the model includes costs connected with insemination and costs expended during the reproduction cycle. Regarding the intensity, these

II: *Structure of herd depending on frequency of litters*

Parity	CL-non culled
1	184
2	172
3	108
4	49
5	40
6	17
7	10
8	1
Total	581

costs are the highest in farrowing facilities primarily because of the high consumption of feed and energy. The model also includes costs expended on piglet rearing before their expedition.

The highest costs occur in the lactation facility. The level of costs here is about 200% higher than elsewhere. The costs do not increase in a linear way and therefore a cost function is used which is closely connected with feeding doses per sow in a farrowing facility per new-born piglets.

In order to achieve as an accurate model as possible, the costs in particular phases of the production cycle are described by cost functions, whose argument is the time spent on particular stands. The cost functions include veterinary costs (vaccination, deworming, and disinfection of facilities), energy costs (lighting, operation of automatic feeding systems, ventilation, heating etc.), water costs and wages. This part of the cost functions are for the given phase of the reproduction cycle constant, but they differ significantly from each other, see Tab. III. This is caused primarily by a different arrangement of particular farming parts given by different needs of sows during the reproduction cycle.

The cost functions include also feeding costs which differ not only from the point of view of particular phases of the reproduction cycle, but also during the stay of a sow and its piglets in a given stand as a feeding dose changes. The feeding dose changes more significantly in farrowing facilities, see below.

The first operation cost of the commercial herd is purchasing a sow. For the model use, we calculate the price to be CZK 6,000. These new sows need to be acclimatised before they are integrated into the herd. The construction of the cost function for the acclimatisation stay of the newly purchased sows is the easiest and it is possible to deduce it using data presented in Tab. III and from the costs per feeding day during the acclimatisation phase of the herd. We calculate CZK 26.20 per day in the acclimatisation phase; the costs per feeding day are CZK 12.50. The total time in this phase is considered to be 40 days.

After integrated into the herd, the sow is placed in the breeding facility. The cost function for this phase is constructed using the data from Tabs. III. and IV. Unlike in the acclimatisation phase, the costs in this phase increase because of the nursing costs – wages connected mainly with the insemination process and the observation of sows during the oestrus period (see Tab. II). The time spent in this phase changes for particular sows and it is connected with their ability to get pregnant, see Fig. 1. This ability is also connected with other costs covering sows' stay in breeding facilities, such as insemination. These costs were calculated to be CZK 139.

After getting pregnant, sows are removed to gestation facilities, where they are for a constant period of time. The costs calculated for this phase are based on the data presented in Tabs. III and V. For the simulation model use, in which the period is constant, it is possible to substitute these costs connected with the stay in gestation facilities with a lump sum.

IV: *Feeding costs at breeding facility*

Day	CZK/head
1	14.28
2	15.47
3	17.85
4–5	19.64
6–10	14.88
11–35	10.12

V: *Feeding costs at gestation facility*

Day	CZK/head
1–4	10.12
5–68	14.88
69–87	17.23

III: *Total daily non feeding costs*

Facility	Water	Wages	Veterinary	Electricity	Total
Breeding	0.52	5.09	3.50	5.65	15.57
Gestation	0.74	3.86	4.30	2.73	11.63
Farrowing	1.56	11.56	3.40	11.36	27.88
Gilts acclimatization	0.64	3.50	3.90	5.66	13.70
Piglets with sow	0.04	*	*	*	0.04
Piglets at piglet rearing	0.16	0.20	2.00	0.29	2.65

*included in per sow cost at the farrowing facility

VI: *Feeding costs at farrowing facility*

Day	CZK/head	Day	CZK/head
1–4	17.26	12	33.07
5	10.34	13	39.96
6	6.89	14–23	43.41
7	0.00	24	37.90
8	17.23	25	31.01
9	18.60	26	25.49
10	20.67	27	17.23
11	26.87	28	0.00

The farrowing facility is, considering the costs, the most important part of the reproduction farming. The highest costs of the commercial herd cover energy, as piglets require higher temperature, and also wages, due to the necessary assistance of keepers when the sows give birth. It is similar with the water consumption, see Tab. III. The most significant, considering the total costs in the farrowing facility, are feeding costs of lactating sows and of complementary feeding of their piglets.

Due to the variability, caused by the different weaning time of particular simulations and the different number of piglets in particular iterations, it is neither possible to generalise the costs in the farrowing facility or to use a cost function. In our model, we decided to separate feeding doses for sows and feeding doses for piglets.

To calculate the total costs of one sow in the farrowing facility, we used the data from Tab. VI. It is necessary to take into account different weaning times. We consider the weaning time to be 21–28 day. In this case, the phase of the intensive feeding gets longer. If we consider the total stay in the farrowing facility to be 28 day corresponding with the weaning time in 21 days, the intensive feeding takes place between day 14 and day 21, i.e. 7 to 16 days after the birth.

During the last five days in the farrowing facility, the feeding doses decrease, see Tab. VI, in order to stop lactation. It is necessary to add to the feeding costs also the daily costs presented in Tab. III. The feeding costs of piglets in the farrowing facility are the product of the average costs per feeding day of a piglet in the farrowing facility (CZK 1.14, which is complementary feeding) and their number generated during every iteration, see below. Costs of piglet rearing are calculated as the product of the number of weaners and the costs of a feeding day in the piglet rearing facility.

Incomes

The main income of a pig breeding farm was from sold piglets. The selling weight of piglets may differ. Piglets are shipped in a large scale and the total weight and the total number is taken into account. For this reason, the average weight is considered for the simulation purposes. The average weight of a sold piglet was 28 kg.

This price was computed as an average within the last year. The average price was CZK 56 per kg. The income per sold piglet for purpose of simulation model was computed as the multiple of average price and average weight and is set to CZK 1,568, in our model p_p.

The additional income consists of revenues for culled sows, which are sold for meat. But the price of meat from culled sows is lower than the price of pigs produced for meat. We calculate in the model with average weight of culled animals 250 kg and the average price of meat CZK 25 per kg. This income can partially balances costs for purchasing gilts. The difference between the purchasing price of gilts and the revenue, when they are sold after the culling, is represented by so called replacement cost – c_r.

Simulated Inputs

Number of Inseminations

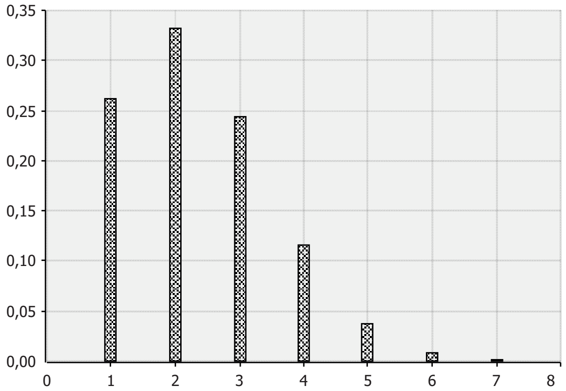
A successful insemination is conditioned by oestrus, which was not observed in the used data set. However, these two phenomena were put together which is the number of inseminations. The number of inseminations influences the time spent on breeding facility. As well the price of insemination dose is one of the important costs. The number of inseminations was monitored only up to the 9th parity for the same reasons as for the litter size, see below. In order to create this simulation input was used the Distribution Fitting function in the program @RISK (Hardaker and Winston, 2001). The most suitable were the Truncated Binomial distribution (1) (Johnson and Kotz, 1970).

$$P(k)=\frac{\binom{n}{k}p^k(1-p)^{n-k}}{1-(1-p)^n}. \quad (1)$$

Because the probability of conception differs from the increasing number of litters, we had to suggest a particular probability distribution function for each litter. In Fig. 2, we can see the probability mass function (PMF) of becoming gestation and for the first parity. It is the truncated binomial distribution (1) with parameters n = 9 a p = 0.24013, see Fig. 2. Such distribution is available for every considered litter, i.e. from litter 1 to 9, see Tab. VII. The number of inseminations necessary for farrowing is generated according to this distribution during every iteration.

Litter Size – Number of Piglets in a Particular Litter

The litter size depends on the relation to parity. For CL sows, this size went up to the fourth parity and thereafter went down. In order to create this simulation input we used the Distribution Fitting function in the program @RISK (Hardaker and Winston, 2001). The most suitable was the Binomial distribution. Because the probability of conception differs from parity to parity, we had to suggest



2: *Fitting of number of inseminations for the first litter*

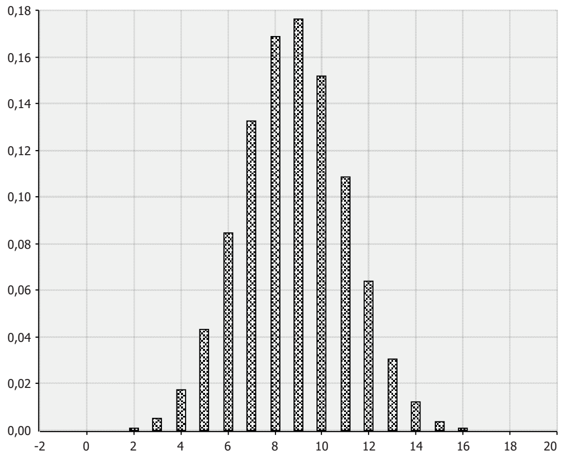
VII: *Fitting of number of inseminations*

Distribution	Truncated Binomial	
Number of litters	**n**	**p**
1	9	0.2401
2	14	0.0948
3	29	0.0410
4	19	0.0599
5	29	0.0590
6	17	0.0737
7	34	0.0371
8	15	0.0887
9	11	0.1168

VIII: *Fitting of number weaned piglets*

Distribution	Binomial	
Number of litters	**n**	**p**
1	20	0.4395
2	21	0.4599
3	23	0.4272
4	22	0.4410
5	22	0.4378
6	19	0.4896
7	18	0.5042
8	16	0.5659
9	16	0.5457

a particular PMF for each one. Parameters of these distributions used in the simulation model are given in Tab. VIII. The litter size was monitored only up to 9^{th} parity thereafter the efficiency of the sow slopes down mainly because of piglet mortality. In Fig. 3, we can see the PMF of litter size of CL sows and of the first parity. Because of completeness, we used the input data about culled sows for creating this simulation model.



3: *Fitting number of piglets for the first litter*

IX: *Culling rules**

Number of litters i	Maximal number of inseminations a_i	Minimal number of piglets b_i
1	4	7
2	3	9
3	2	9
4	2	9
5	2	8
6	2	8
7	2	8
8	2	8
9	2	8

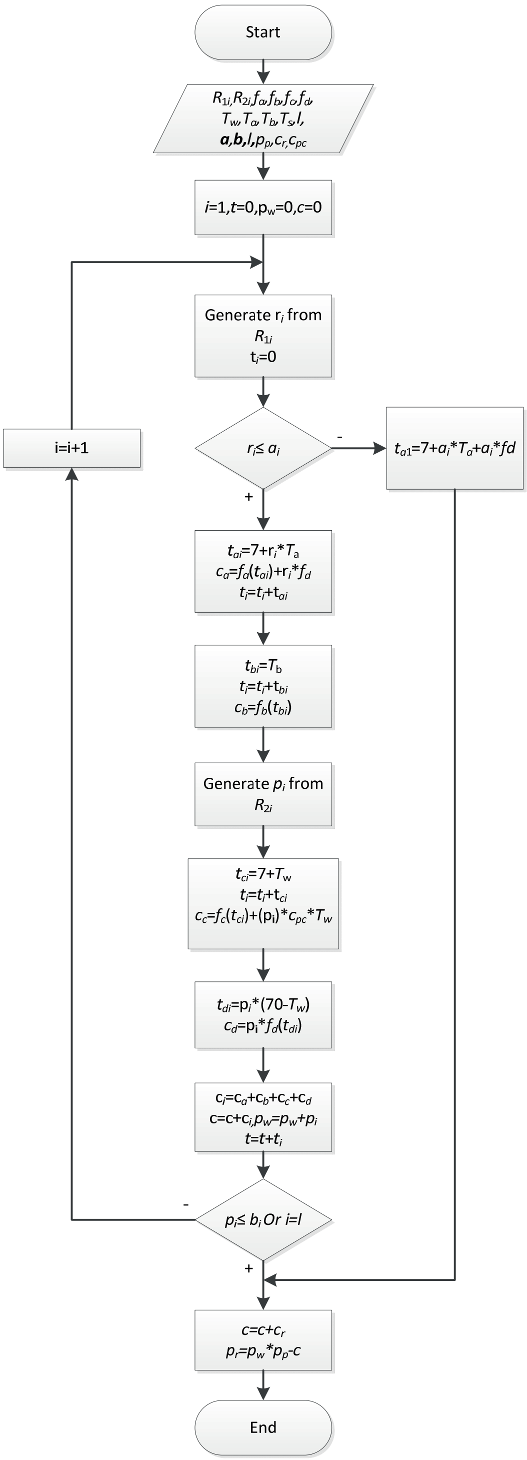
*A sow will be culled unless become pregnant in the maximal number of insemination or wean the minimal number of piglets.

Simulation Model

Simulation inputs

- Costs function in particular facility f_a (breeding), f_b (gestation), f_c (farrowing), f_d (rearing), the argument is always time spent in particular stands, see simulation outputs;
- Price of sold piglets p_p;
- Sow's replacement cost c_r;
- Price of insemination dose c_o;
- Costs per piglets and day spent on farrowing facility c_{pc};
- Number of inseminations before becoming pregnant for i-th litter $r_i \sim R_{1i}$;
- Number of weaned piglets for i-th litter $p_i \sim R_{2i}$;
- Culling rules see Tab. IX, vectors $\boldsymbol{a}$ and $\boldsymbol{b}$;
- Time spent in breeding facility T_b (87 days);
- Time securing gestation T_a;
- Maximal number of farrowings l;
- Time from farrowing to weaning T_w;
- Time from birth to shipping of piglets T_s (70 days).

For example, the number of inseminations during iteration No. 1 is generated as 5 (the sow gets farrowing in the fifth attempt). The sow



4: *Simulation model*

would, according to the rules presented in Tab. IX, spend 7 + 4 × 21 days in the breeding facility (the maximum number of inseminations for the first litter equals 4 – vector component a_1) and it would be culled after the farrowing check after the fourth insemination and a new one would replace it in the reproduction process. If the number of piglets during insemination No. 1 is generated as 6, the sow is culled from the process after its piglets are weaned, as the minimum number of weaners in the first litter is 7 – vector component b_1.

The simulation model is described in Fig. 4, where *i* denotes the order of the litter. The stands are denoted with *a*, *b*, *c*, *d* (*d* is the rearing facility).

Simulations outputs:

- Time spent by a sow in particular stands during the *i*-th litter t_{ai}, t_{bi}, t_{ci};
- Time spent by piglets of the *i*-th litter in stand *d* (rearing facility) $t_{di} = p_i(T_s - T_w)$;
- Costs of particular stands *a* to *d* and particular litter: c_{ai}, c_{bi}, c_{ci}, c_{di};
- Income per sow per cycle p_r.

RESULTS AND CONCLUSION

In our model, we were working with option, after which litter the sows should be culled and the weaning time. In fact, we were looking for the extreme of a multi-variable function, in this case of two variables. In calculus, this would be solved using partial derivatives. However, it is not possible in our case. Therefore, we had to test all allowable combinations of the weaning time and the maximum number of litters and determine the maximum average profit per sow.

At first, we performed 50.000 and 100.000 iterations for different weaning periods and different values of the maximal number of farrowing. We tested eight possible periods of weaning for 21–28 days and seven maximal number of farrowing for 3–9. The total profitability per year and sow for both numbers of iterations is shown in Tabs. X and XI.

For both models, with 50,000 and 100,000 iterations, it seems as the most efficient to cull sows after the eighth litter. The difference between the sixth, seventh and eighth litter is minimal, see Tab. XI. The reason is the minimum number of sows which get to a higher than the sixth reproduction cycle. For these reasons, it is common production farming to leave sows in the cycle only to the sixth litter. It is very likely that if we projected in veterinary costs the model, there would be no profitability after the sixth litter.

Considering the weaning process, the model proved that shorter weaning time brings higher profits. Unlike the number of litters (see the previous paragraph), the differences are most evident. To be more objective, it is necessary to note that the shorter weaning time may cause problems in the following inseminations. The reason is the unfinished uterine involution of some sows. Opinions on this topic differ, see Kiracofe (1980). In modern commercial herds, the weaning time of 21 days is commonly used.

Regarding the variability, the optimal weaning time of 21 days is the lowest of the all considered times, see Tab. XII. The highest variability is reached, in the model with 100,000 iterations and eight litters, for the weaning times in 22 days.

X: *Profitability in CZK (Profit per sow and year) 50,000 iterations*

Max no. of farrowing	Weaning interval [day]							
	21	22	23	24	25	26	27	28
3	7322.09	7284.29	7295.83	7289.46	7257.64	7200.38	7236.57	7169.84
4	7644.98	7586.08	7609.45	7594.70	7560.42	7505.19	7518.11	7472.24
5	7775.86	7698.93	7724.25	7712.34	7668.18	7623.45	7631.81	7591.31
6	7811.06	7729.11	7764.01	7750.09	7698.02	7658.94	7669.18	7627.43
7	7816.71	7735.21	7769.17	7752.59	7701.13	7666.49	7671.70	7630.92
8	**7821.01**	7734.63	7776.24	7752.34	7706.09	7668.36	7672.84	7628.74
9	7816.92	7729.19	7769.47	7748.18	7697.01	7664.76	7668.74	7624.70

XI: *Profitability in CZK (Profit per sow and year) 100,000 iterations*

Max no. of farrowing	Weaning interval [day]							
	21	22	23	24	25	26	27	28
3	7333.03	7286.12	7290.14	7277.07	7253.56	7217.21	7227.75	7175.09
4	7650.62	7587.55	7600.30	7582.11	7557.53	7519.36	7513.71	7480.66
5	7776.60	7702.22	7713.52	7701.55	7668.22	7635.74	7627.91	7601.10
6	7812.05	7736.98	7754.23	7738.35	7698.99	7670.99	7666.05	7635.45
7	7818.17	7743.36	7761.70	7741.94	7702.75	7678.89	7669.60	7639.04
8	**7822.24**	7744.10	7767.24	7742.40	7706.39	7679.67	7670.88	7637.45
9	7818.36	7739.09	7760.96	7737.08	7698.78	7676.58	7666.41	7633.01

XII: *Variability of profit per sow and year, max. eight litters*

Weaning interval	21	22	23	24	25	26	27	28
Min	4909.51	4117.48	5671.63	7441.85	1037.83	6422.89	5569.16	917.52
Max	9775.17	10396.03	10007.97	11207.08	8392.98	10754.03	10228.48	11943.07
Std dev	39.09	66.36	61.73	46.91	42.28	46.34	43.83	56.73

XIII: *Distribution of spent time between sections [day]*

Facility	Breeding	Gestation	Farrowing	Total	Piglet rearing
Time (mean value)	109.87	193.02	62.11	365	
Places new	175	307	99	581	1017
Places original	165	286	130		1560

The average length of the meantime in our model is 149 days and the turnover rate is 2.45. When considering the theoretical value of 141 days (21 day weaning time), it represents an increase by eight days due to repeated inseminations.

Another output of the simulation model is the capacity of particular sections during the year. The values presented in Tab. XIII, show how the capacity of these sections should be set up in the chosen operation mode. Considering the total capacity of 581 sows in the farm and the mode arising from the simulation, the original dispositions of the farm should be changed in accordance in respect to the following table.

The analysis also shows that the original capacity of the piglet rearing facility would be, considering the optimal profitability, too high, as the model comes with the mean required of 1,017 places. The average number of litter per sow till its culling is 3.112. The herd structure, regarding the number of litter, is characterised by Tab. XIV.

As was mentioned in the methodology part, one of the most important questions of the pig breeding

XIV: *Distribution sows in terms of parity (100000 iterations)*

Parities	Frequency	Share
1	18949	18.95%
2	27883	27.88%
3	21682	21.68%
4	12813	12.81%
5	5808	5.81%
6	4339	4.34%
7	3087	3.09%
8	5439	5.44%
Total	100000	100.00%

process with a great economic impact is the culling policy. This policy is closely connected with purchasing gilts and herd replenishing. Incomes for culled sows can balance the cost for purchasing gilts only partially. The most important culling reason in our model was farrowing – 67.16%. The second reason for culling was pregnancy – 29.36%. The age represented with number of parities was from that point of view culling negligible – only 3.48% of sows were culled after eighth parity.

The aim of this study was to design a simulation model and verify its usability in terms of one specific farm. The presented economic results of the proposed model are therefore tied to the farm in which the model was applied and the obtain outcomes serve to illustrate the use of the model. The implementation in other farms is conditioned not only by setting of specific economic variables which are associated with the production of piglets, but particularly with obtaining a sufficient number of observations for modelling key reproduction characteristics. The model is designed to allow us to find, in different farms, a configuration of variables, which are optimal from their economic performance point of view. Besides the assessed weaning period and the maximum number of parities, it is possible, in presented model, to study the influence of culling policy which, especially in breeds with better health conditions, may significantly influence the overall economic results. An additional output of the model is a loading of particular sections of the farm, which allows to adapt the technology to the changed production conditions.

REFERENCES

BABOT, D., CHAVEZ, E. R., NOGUERA, J. L. 2003. The effect of age at the first mating and herd size on the lifetime productivity of sows. *Anim. Res.*, 52(1): 49–64.

BOUDNÝ, J., ŠPIČKA, J. 2012. The effect of production efficiency on economic results in pig breeding. *Res. Pig Breed.*, 6(1): 1–8.

CHANSOMBOON, C., ELZO, M. A., SUWANASOPE, T. et al. 2009. Genetic and environmental factors affecting weaning-to-first service interval in a Landrace-Large White swine population in Northern Thailand. *Kasetsart J. (Nat. Sci)*, 43(4): 669–679.

DE JONG, E., LAANEN, M., DEWULF, J. et al. 2013. Management factors associated with sow reproductive performance after weaning. *Reprod. Domest. Anim.*, 48(3): 435–440.

FRIEBEL, L., FRIEBELOVÁ, J., MARINOV, L. 2013. Stochastic analysis of costs during the pig breeding process. In: *Proceedings of 31st International Conference on Mathematical Methods in Economics 2013*. Jihlava: College of Polytechnics Jihlava, 189–194.

HARDAKER, J. B., WINSTON, W. L. 2001. *Simulation Modeling Using @RISK*. Pacific Grove: Duxbury Press.

JOHNSON, N. L., KOTZ, S. 1970. *Distributions in Statistics – Vol. I–IV.* New York: John Wiley and Sons.

HOUŠKA, L. 2009. The relationship between culling rate, herd structure and production efficiency in a pig nucleus herd. *Czech J. Anim. Sci.*, 54(8): 365–375.

KAPLON, M. J., ROTHSCHILD, M. F., BERGER, P. J. et al. 1991. Genetic and phenotypic trends in Polish Large White nucleus swine herds. *J. Anim. Sci.*, 69(2): 551–558.

KARVELIENE, B., SERNIENE, L., RIGKEVICIENE, V. 2008. Effect of different factors on weaning-to-first-service interval in Lithuanian pig herds. *Vet. Med. Zoo.*, 41(63): 64–69.

KIRACOFE, G. H. 1980. Uterine involution: its role in regulating postpartum intervals. (Review). *J. Anim. Sci.*, 51(2): 16–28.

KLEINHANSS, W. 2009. Development of the incomes, liquidity and stability of pig holdings. *Berichte uber Landwirtschaft*, 87(3): 428–443.

MARÍN, J. M., PLÀ, L. M., RÍOS, D. 2005. Forecasting for some stochastic process models related to sow farm management. *J. Appl. Stat.*, 32(8): 797–812.

NETO, A. C., LUI, J. F., SARMENTO, J. L. R. et al. 2009. Genetic and environmental effects on the farrowing interval in sows in the southeastern region of Brasil. *Aro. Bras. Med- Vet. Zoo.*, 61(1): 280–285.

PELLETIER, N., LAMMERS, P., STENDER, D. et al. 2010. Life cycle assessment of high- and low-profitability commodity and deep-bedded niche swine production systems in the Upper Midwestern United States. *Agr. Sys.*, 103(9): 599–608.

PLÀ, L. M. 2007. Review of mathematical models for sow herd management. *Livest. Sci.*, 106(2–3): 107–119.

PLÀ, L. M., FAULIN, F. J, RODRÍGUEZ, S. V. 2009. A linear programming formulation of a semi-Markov model to design pig facilities. *J. Oper. Res. Soc.*, 60(5): 619–625.

PLÀ, L. M., POMAR, C., POMAR, J. 2003. A Markov decision sow model representing the productive lifespan of herd sows. *Agr. Sys.*, 76(1): 253–272.

POLEZE, E., BERNARDI, M. L., FILHA, W. S. A. et al. 2006. Consequences of variation in weaning-to-estrus interval on reproductive performance of swine females. *Liv. Sci.*, 103(1–2): 124–130.

RODRIGUEZ, S. V., JENSEN, T. B., PLÀ, L. M. et al. 2011. Optimal replacement policies and economic value of clinical observations in sow herds. *Liv. Sci.*, 138(1–3): 207–219.

RODRIGUEZ-SANCHEZ, S. V., PLA-ARAGONES, L. M., ALBORNOZ, V. M. 2012. Modelling tactical planning decisions through a linear optimization model in sow farms. *Liv. Sci.*, 143(2–3): 162–171.

RYDHMER, L. 2000. Genetics of sow reproduction, including puberty, oestrus, pregnancy, farrowing and lactation. *Livest. Prod. Sci.*, 66(1): 1–12.

SERENIUS, T., STALDER, K. J. 2004. Genetics of length of productive life and lifetime prolificacy in the Finnish Landrace and Large White pig populations. *J. Anim. Sci.*, 82(11): 3111–3117.

TUMMARUK, P., LUNDEHEIM, N., EINARSSON, S. et al. 2000. Factors influencing age at first mating in purebred Swedish Landrace and Swedish Yorkshire gilts. *Anim. Reprod. Sci.*, 63(3–4): 241–253.

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