SELECTION INDEX FOR REPRODUCTION OF CZECH LARGE WHITE AND CZECH LANDRACE BREEDS AND THE ENTIRE POPULATION OF MATERNAL PIG BREEDS

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Abstract

This study was aimed at constructing a partial selection index focused on the reproductive traits (RI) of maternal pig breeds in the Czech Republic and calculating the selection response to the index application. The RI was applied separately for Czech Large White and Landrace breeds and the entire population of maternal pig breeds, as well. The number of piglets born alive (NBA) and transformed farrowing interval (FI) were defined as breeding goals to improve the reproductive performance of sows. The genetic parameters and economic weights of these traits were calculated. Four traits were included for RI construction: total number of piglets born, NBA, number of piglets weaned and FI. The genetic correlations among all traits included for RI construction were positive (0.027–0.954). The economic weights calculated for the maternal pig breeds were: 620 CZK per piglet born alive and −105 CZK per day of FI (all expressed per sow and reproductive cycle). For the RI evaluated variants, a desirable response was observed for NBA (from 0.167 to 0.208 piglets per sow/year) and FI (from−0.010 to −0.031 days per sow/year). The inclusion of all reproductive traits for RI construction had a positive impact on the increase in selection response and index reliability for traits. The selection response in all RI variants calculated for individual breeds and the entire population was similar and therefore, a common RI could be applied. The evaluated RI gained the desired selection response and can be applied in routine genetic evaluations.

Keywords: Litter size, farrowing interval, selection response, index

Considering capital utilisation, farm animal breeding is considered one of the most effective activities aimed at increasing and improving the production of farm animals. Reproductive, growth and feed efficiency traits are usually dominant in selection schemes for pigs (Amer et al., 2014; Houška et al., 2010). Selection effects are evaluated to acquire information essential for the construction of future indices (Serenius and Muhonen, 2007; Wallenbeck et al., 2015) or evaluation of the efficiency of ongoing selection (Kasprzyk, 2007).

Considering the constantly evolving process of global swine breeding, it is necessary to occasionally review actual breeding programmes and adopt measures (with sufficient timeout) to avoid the loss of competitiveness. The selection of maternal pig breeds should focus on traits related to reproduction. In the Czech Republic, the breeding goal of maternal pig breeds (CPBA, 2017) is focused on growth rate (represented by average daily gain measured during field test analysis), reproduction (number of piglets born alive during the second and subsequent parities) and carcass quality (lean meat content). The genetic evaluation of pigs based on the BLUP Animal Model has been routinely performed since 1998 (Wolf et al., 1999) in the Czech Republic. Shortly thereafter, the total merit index, TMI (and/or overall breeding value, OBV) was defined in maternal pig breeds, which has included these traits since 2005: average daily gain (40%), lean meat percentage (5%) and number of piglets born alive (55%). Even though the percentage of reproductive traits in OBV is the highest, the positive phenotypic and genetic trends moderately reduced in the past generations (Krupa et al., 2016; Fig. 1) and in farms, number of piglets born alive NBA is 13.1 piglets per litter on average. Selection for increasing the number of piglets born alive can be related to an increase in the percentage of stillborn piglets and increase in pre-weaning piglet losses (Serenius et al., 2004). Although in the Czech Republic the phenotypic results have not confirmed the trend of increasing losses, the number of piglets weaned has increased more gradually than the number of piglets born alive (see Fig. 1) and moreover, from the genetic viewpoint, the positive genetic trend has reduced (Krupa et al., 2016).

The farrowing interval, which currently lasts for 155–156 days in maternal pig breeds, has a practical influence on the turnover rate of a herd, while it was additionally defined as an important reproductive trait by breeders involved in the CZEPIG programme (Krupová et al., 2017b). Additionally, the routine genetic evaluation of farrowing intervals, which began in 2012(Wolf, 2012) indicates a moderately positive (i.e. adverse) genetic correlation of this trait with litter size. To meet the normality of the FI trait, transformation is included within genetic evaluation. The inclusion of farrowing interval in selection is assumed to have a positive effect on the increase in herd turnover rate and overall sow reproduction. Therefore, selection for further reproductive traits is a requirement of pig farming. Methodical guidelines for estimating the breeding values of these traits were already developed and provided to breeders in 2002. An increase in the number of selection criteria for piglet number would be a problem that would complicate the practical decisions of breeders during selection. Therefore, the requirement for the construction of a partial reproduction index was established, which would include the above-mentioned reproductive traits. The objective of this study was to construct a partial selection index focused on the reproductive traits (reproindex - RI) of the maternal pig population in the Czech Republic and to compute a genetic and economic selection response during the use of the selection index.

Material and Methods

A partial selection index focused on reproductive traits was constructed for the pig breeds Czech Large White (CLW) and Czech Landrace (CL), which represent the entire populations of maternal pig breeds included in the CZEPIG National Breeding Programme (CPBA, 2017). For the index construction, the traits focused on by the breeding goal and selection index were defined, the genetic parameters of all traits were estimated, the economic values of the traits (economic weights, EW) were determined and the expected genetic and economic selection response in the breeding goal traits was computed. These breeding goals intended to improve the reproductive performance of the domestic population of maternal pig breeds were defined as follows: number of piglets born alive (NBA) and farrowing interval (FI) of sows.

Four traits were included in the index as candidate selection traits: total number of piglets born (TPB), number of piglets born alive (NBA), number of piglets weaned (NPW) and farrowing interval (FI). Table 1 show their basic characteristics for both breeds and the entire population, which were collected under CZEPIG during performance testing between 2012 and 2016.

The marginal economic values of the traits defined within the breeding goal (NBA and FI) were calculated using a complex bio-economic model with the EWPIG program (Wolf et al., 2016) considering gene flow (GFPIG 1.0.0., Wolfová et al., 2016). The economic weights indicated a change in the profit from the integrated production system at a high trait level and were defined as the partial derivative of the profit function as follows:

$$\mathrm{EW} = \frac{(\mathrm{Tprof_h} - \mathrm{Tprof_l})}{(\mathrm{TV_h} - \mathrm{TV_l})}$$

where TV_h is the value of trait i derived as $TV_h = 1.005 \times TV_{av}$, which implies that the average value of the trait (TV_{av}) increased by 0.5%. Similarly, TV_l was calculated by reducing the average trait value by the same amount: $TV_l = 0.9995 \times TV_{av}$. Furthermore, $Tprof_h$ and $Tprof_l$ denoted the total profit for TV_h and TV_l, respectively. The methodology used was described in detail by Wolfová et al. (2017). The numbers of sows in each link of the production system were 2500 CLW and 1000 CL sows. For constructing the selection index, the marginal economic weights of the selection traits were expressed per reproductive cycle considering 2.36 farrows per sow/year and simultaneously, the average weight of these traits was computed for the entire populations of maternal breeds included in the CZEPIG programme. The basic input parameters used for EW computation are shown in Table 2. Performance and economic data of the analysed production system of both breeds from 2015 to 2016 were made available by the Pig Breeders' Association of the Czech Republic or collected from cooperating breeders.

In addition to EW, the genetic parameters of the index selection traits were computed. The variance and covariance components of the variation of the evaluated traits were estimated by the REML approach using VCE 6.0 (Groeneveld et al., 2008).

A four-trait animal model comprised the following: quadratic regression (age at first farrow or farrowing interval), fixed effect of litter class, sire breed (only CLW and CL sires were assumed), type of insemination, random herd-year-season effect, permanent effect of sow and random effect of animal. PEST 4.2.3 (Groeneveld et al., 1990) was used for predicting breeding values. The reliability of the estimated breeding values was derived according to the method of Mrode (2014) using the prediction error variance of breeding values. The coefficients of correlation between the reproductive traits were computed using the CORR procedure supported by SAS (2008). Currently, breeding values are routinely computed for all four reproductive traits. Data from performance testing used for the genetic evaluation of the reproductive traits were provided by the Pig Breeders' Association.

For the construction of the reproduction index and computation of the expected economic and genetic selection response, the weight coefficients (b) of the traits were determined directly and the general principles of the theory of selection indices were applied. The selection index was determined using a matrix program developed in Interactive Matrix Language (IML), which is part of the SAS software (Přibyl et al., 2004). Totally, four variants of the index (A to D) were simulated when other reproductive traits (selection criteria) were added as information sources to the actually used reproductive selection traits (NBA) in the following way:

Index A = NBA and FI
Index B = NBA, NPW and FI
Indices C and D = TPB, NBA, NPW and FI

The weight coefficient 'b' in indices A to C was computed in order that a maximum selection response in the breeding goal traits would be reached. The coefficients of the traits in index D were proposed directly by breeders—they were based on an even proportion in litter size (30% per trait) and 10% for FI. Additionally, the weight coefficients of the traits in a given index were expressed in relative terms (%). At the selection intensity of one standard deviation, the selection response in the breeding goal traits was expressed in the units of the trait per year and in monetary units as well (considering the EW of the given trait). All computations were performed separately for the CLW and CL breeds and the entire combined population of maternal breeds.

To calculate the degree of similarity between all variants of the index, Spearman's rank correlation coefficient was used in the CORR procedure in the SAS programming package.

Table 1. *Basic characteristics of reproductive traits in the maternal pig populations* [a]

Trait (abbreviation)		Description (unit)		CLW	CL	Total
Total number of piglets born	TPB	Total number of fully developed piglets born	piglets / litter	14.73	14.44	14.67
Number of piglets born alive	NBA	Number of piglets born alive per sow/litter in the second parity and subsequently		13.42	13.39	13.42
Number of piglets weaned	NPW	Number of piglets weaned		11.71	11.56	11.68
Farrowing interval	FI	Average number of days between two consecutive farrows	days	156.52	156.03	156.42

[a] Average values of traits obtained in the purebred maternal populations of Czech Large White (CLW; 6 145 litters) and Czech Landrace breeds (CL; 1 646 litters) and on average, for the entire population of these breeds included in the CZEPIG program in 2016.

Table 2. *Basic input parameters for the computation of the economic weights of traits in maternal CLW (Czech Large White) and CL (Czech Landrace) breeds*

Parameter (unit)	**CLW**	**CL**
Maximum number of reproductive cycles (RC) in sows/boars	10 / 6	
Average productive lifetime (longevity) of sows (years)	4.86	4.84
Pre-weaning mortality of piglets per litter (average of all RCs)	2.9	3.2
Average fertilization rate of sows/gilts (%)	92 / 88	
Average age of gilts at first farrow (days)	354	357
ADG (g/day): of piglets before weaning	222	230
of young pigs in starter feeding phase	455	552
lifetime (from birth to finishing phase) of gilts	788	708
Costs per sow of the basic herd (CZK/RC) of:		
feed	4 232	4 302
veterinary care	395	592
mating (insemination)	472	527
other costs[a]	4 869	4 924
Cost of piglets weaned (average of all RCs; CZK)	897	915
Cost of reared gilts (from birth to farrow; CZK)	4 085	4 552
Cost of pig fattening (from birth to finishing; CZK)	3 821	3 856
costs per kg of slaughter weight (CZK)	34.29	33.75
Revenue from sale of fattened pigs (CZK/pig): gilts	3 828	3 873
barrows	3 842	3 869
Revenue from sale of breeding pigs (CZK/pig): gilts	6 960	7 487
young boars	22 470	24 075

[a] This includes the costs of sow housing borne during the reproductive cycles, including fixed costs and other material costs and services (bedding, illumination, air-conditioning, heating, preventive veterinary care and so on).

Results and discussion

Economic weights of traits

The bio-economic model of the EWPIG program (Wolf et al., 2016), which was used to determine the economic values of the selection objective traits, facilitates computations for a complex of more than 30 traits (growth and reproduction, health, feed efficiency and carcass quality). Considering the objective of this study, only the EWs of the breeding goal traits of the maternal breeds are presented herein, i.e. number of piglets born alive and farrowing interval (Table 3). Based on the currently available production and economic indicators of the pig sector in the CR, the profitability of the production system will be increased by 620 CZK if the number of piglets born alive increases by one piglet per sow and reproductive cycle. Naturally, the prolongation of farrowing interval by one day has a negative impact on the economics of pig farming and therefore, the EW of this trait is negative (−105 CZK per sow/day and reproductive cycle). The marginal EWs of pig traits were computed for the conditions in the Czech Republic more than ten years ago (Houška et al., 2004) when a model developed by de Vries (1989) was applied. Among the reproductive traits, only the number of piglets born alive was included for computation and its marginal EW in the evaluated maternal breeds was 2 040 CZK per piglet born alive. However, this trait was expressed in different units (per purchased gilt) and computed for commercial farms that adopt crossing. Similarly, in other studies, (e.g. Amer et al., 2014) the EW of NBA was determined for a specific production system of reproductive herds with piglets sold to specialized fattening facilities. In our actual computation, the basic and common aspect of the EWs of all traits was that they were expressed in units of the given trait per sow/year (and subsequently they could be converted per reproductive cycle) and the economic value of each trait was considered in a complex way within the integrated production system. This implied that generally, genetic progress (gain), which is realised in the breeding sphere, is ‘shifted’ to reproduction and production herds in relation to selection intensity and generation interval. Therefore, the results published in the literature cannot be directly compared with our results. The marginal economic weights for the three breeds involved in the three-way crossing system for a Czech pig breed population were calculated in our previous study (Krupa et al., 2017). The economic weights of 14 production and functional traits were calculated for CLW, CL and Pietrain breeds, considering the number of genes regulating these traits passed on by selected animals through one generation of their progeny in all links of the breeding system. Maternal traits were more important than growth and carcass traits in the maternal breeds than in the sire breeds. However, the relative economic importance of the maternal versus growth and carcass traits differed between the dam breeds. For example, the ratios of the economic weights of the number of piglets born alive and lifetime daily gain of finished animals were 103:1 for CLW and 92:1 for the CL breed. The ratio for the PN breed was 3.4:1. Moreover, the economic importance of functional traits relative to growth traits was higher in the dam breeds than in the sire breeds, (e.g., ratios of the economic weights of sow productive life and daily gain during finishing were 31:1, 27:1 and 1.3:1 for CLW, CL and PN, respectively).

Apart from the above-mentioned complex models, the EWs of traits can be defined directly by producers and breeders. The preferences for traits by pig farmers in the Czech Republic differ with respect to the traits they are defined for and the position of the breed in a hybridisation scheme (Krupová et al., 2017b). It implied that in defining traits and their importance for selection, the opinions of pig farmers should be considered along with the direct economic impact of traits on pig production efficiency. This is the reason for the consideration of the proposals of breeders in this study for the construction of the selection index of reproduction traits of maternal pig breeds (see index D).

Genetic parameters and breeding values of traits

Table 3 shows the genetic correlations between the traits of the partial index of reproduction along with the genetic standard deviations and reliability of the estimated breeding values of these traits. The genetic correlations between all traits of the index were positive. There was a difference in the intensity of mutual relationships when the correlations between litter size traits were moderate to high (in the range of 0.86–0.96); however, the correlations between litter size and farrowing interval were low (0.02–0.04). With selection performed hitherto, even such a low correlation resulted, in practice, in a moderately prolonged sow farrowing interval by 0.20 day/year (our own computations). All available data provided by breeders were used for computing the reliability of the estimated breeding values. Regarding the type of reproductive traits, the determined reliability of the estimated breeding values was in the range of 0.22–0.42. The Spearman’s rank correlation coefficient was used to examine the relationships between the breeding values of trait pairs. The coefficients of correlation between the BV of FI and other reproduction traits were moderate and negative (from −0.28 for NPW to −0.32 for NBA). The correlations between the other three reproductive traits were high and positive (0.95 and 0.79 for TPB-NBA and NPW, respectively and 0.85 between NBA and NPW). All correlations were highly statistically significant.

Selection index for reproductive traits and selection response

The construction of the evaluated variants of the selection index of reproductive traits along with their reliability and expected (genetic and economic) selection response is shown in Fig. 2 and Table 4. The selection response for the number of piglets born alive was positive in all the selection index variants and was in the range of 0.167–0.208 per sow/year. For the second breeding goal trait, the required selection response was computed: a decrease in the number of days comprising the farrowing interval of sows (from −0.010 to −0.031 days per sow/year). A similar phenotypic trend for the number of piglets born alive was observed in the domestic sow population in the preceding period (+0.155 piglets per sow/year; our own computations). In the Polish Landrace population, an analogous genetic increase in NBA by 0.170 piglets per sow/year was recorded over 25 years of breeding (Kasprzyk, 2007).

Additionally, in other countries, findings regarding the genetic trend for NBA as a correlated effect of selection for lean meat percentage were published (Chen et al., 2001; Cleveland et al., 1998, etc.). However, these results were substantially different (from a slightly positive to slightly negative trend for NBA), probably in relation to the evaluated population, selection intensity and other traits included in the selection criteria. In the Czech Republic, lean meat percentage is evaluated within OBV and due to minimum selection pressure on this trait (5% in the OBV of maternal pig breeds); no negative trend for NBA was observed (Krupová et al., 2017a).

Another important finding for the construction of the selection index for reproduction traits was that the increase in the number of selection criteria concerning the number of piglets (i.e. the inclusion of NBA, TPB and simultaneously, NPW in indices B and C) had a positive impact on the increase in the selection response for litter size and simultaneously, on index reliability (see Table 4 and Fig. 3). A decrease was observed only in the farrowing interval where the selection response decreased moderately from −0.03 to −0.01 days per sow/year. The highest (genetic and economic) selection response for litter size was determined in the indices C and D. In index C, the representation of traits was optimized in order to maximize the selection effect (representation of traits is shown in Fig. 3). However, the reliability of this index was lower than that of index D (ca. by 6 percentage points; see Table 4). This was because the resultant reliability of the index was influenced mainly by the representation of traits in the given index and reliability of the estimated breeding values in the population. In index C, the selection pressure on farrowing interval was higher, which was manifested in the selection response (genetic gain on average for the entire population for −0.02 days vs. −0.01 days in indices C and D).

Contrastingly, the reliability of the breeding values of farrowing interval was lower than that of litter size (0.22 vs. 0.32–0.42; Table 3). This was responsible for the lower reliability of index C than that of index D. We believed that both indices gave rise to the required selection effect and therefore, they are practical applicable. The choice of the acceptable reproduction index and intensity necessary for exclusive focus on farrowing interval requires the discretion of breeders and interested organisations. Furthermore, for constructing the selection index for reproductive traits, it is important that the reliability of the selection indices and selection response for breeding goal traits computed for Czech Large White and Czech Landrace breeds is similar in all variants and therefore, a common reproduction index can be applied to both maternal breeds. For pig farming, the resultant index will be published in animal evaluation systems (catalogues of gilts and young boars, lists of sows and boars, according to OBV and so on) and applied to practical animal selection. The Spearman's rank correlation coefficient was used to analyse the rate of similarity between the simulated selection indices. From all active animals, groups of the top 10%, 5% and 1% active animals were chosen. The same groups were used to analyse the obtained values of selection indices for breeding boar populations. Correlations between the indices of the top 10% active animals were moderate to high and positive (from 44% between the A and D variants to 92% between the C and D variants). Correlations for the groups of top 5% and 1% were higher than those for the groups of top 10% active animals. The coefficients of correlation between the optimized variants (A to C) were higher than that with the D variant (breeder preferences), whereas trends in the calculated accuracy of indices were reversed. All correlation coefficients were highly statistically significant ($P < 0.0001$).

***Table 3.** Economic weights (EW) and genetic parameters of reproductive traits in CLW and CL breeds and the entire maternal breed populations*

Breed	Trait	EW[1]	GSD	TPB	NBA	NPW	FI
CLW	TPB	-	-	0.1065	0.941	0.859	0.050
	NBA	608.82	0.792	-	0.099	0.954	0.027
	NPW	-	-	-	-	0.102	0.028
	FI	-112.10	1.299	-	-	-	0.090
CL	TPB	-	-	0.0963	0.923	0.857	0.050
	NBA	664.01	0.782	-	0.091	0.979	0.027
	NPW	-	-	-	-	0.076	0.028
	FI	-77.82	1.305	-	-	-	0.090
Total	TPB	-	0.900	0.104	0.937	0.859	0.050
	NBA	620.48	0.790	-	0.097	0.959	0.027
	NPW	-	0.674	-	-	0.097	0.028
	FI	-104.86	1.300	-	-	-	0.090

EW expressed as CZK/trait unit/sow and reproductive cycle; GSD, genetic standard deviation of trait (for trait description, see Table 1), genetic correlations of traits (above diagonal) and heritability coefficients of reproductive traits (on diagonal). Reliability of estimated breeding values of traits: 0.390 (TPB), 0.420 (NBA), 0.350 (NPW) and 0.220 (FI).

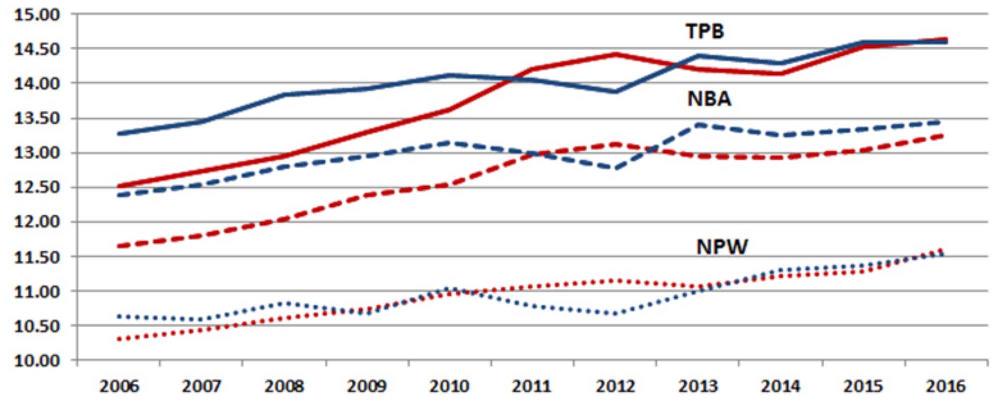
***Table 4.** Construction of index[a] variants and selection gain in breeding objective traits of maternal pig breeds in index variants*

Breed	Index variant	Weight of trait 'b' in the index				Index reliability (%)	Selection gain[b]	
		TPB	NBA	NPW	FI		NBA	FI
CLW	A	-	479.07	-	138.14	40.1	0.167	-0.034
	B	-	377.00	305.73	139.98	51.1	0.191	-0.028
	C	253.07	302.48	250.83	143.53	59.6	0.207	-0.023
	D	302.50	302.50	302.50	101.00	65.9	0.209	-0.010
CL	A	-	517.07	-	93.40	41.1	0.167	-0.019
	B	-	397.96	347.66	95.46	54.2	0.193	-0.015
	C	262.94	322.85	290.68	99.17	62.3	0.207	-0.011
	D	322.85	322.85	322.85	108.00	68.4	0.207	-0.010
Total	A	-	487.26	-	128.61	40.4	0.167	-0.031
	B	-	382.17	313.14	130.49	52.0	0.191	-0.025
	C	255.50	307.44	257.66	134.08	60.2	0.207	-0.020
	D	307.44	307.44	307.44	102.50	66.6	0.208	-0.010

[a] Weight coefficient 'b' of traits and reliability of reproduction index variants for breeds and the entire population. The traits and reproduction index variants are described in the Materials and Methods section and Table 1.

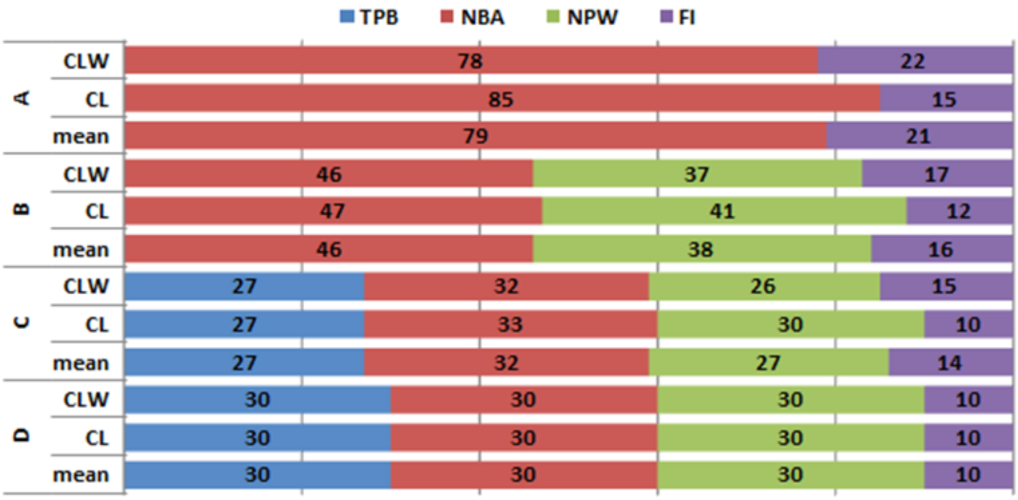
[b] Selection gain is expressed as the number of piglets born alive per sow/year and number of days constituting farrowing interval.

Figure 1. *Phenotypic trend for litter size in maternal pig breeds*



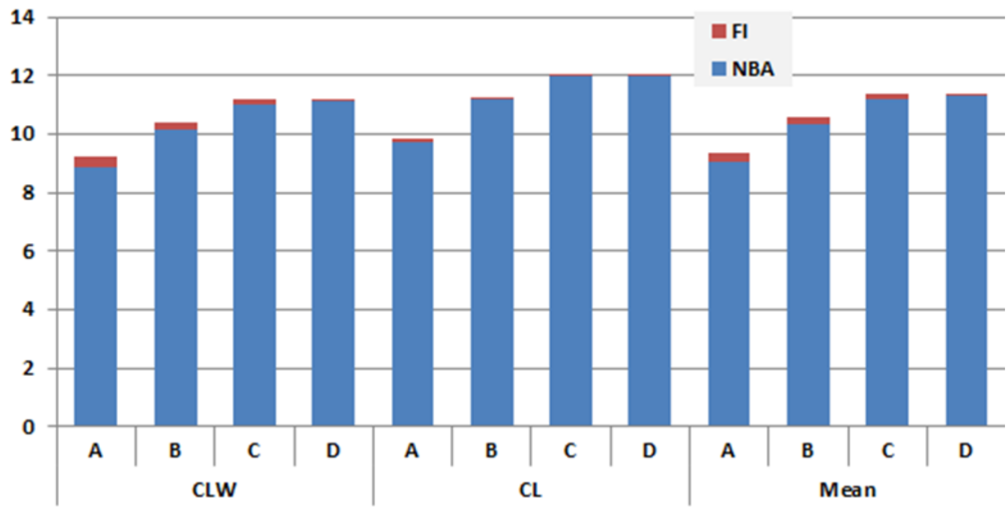
[a] Czech Large White (red curves) and Czech Landrace (blue curves). For trait description, see Table 1.

Figure 2. *Relative representation of traits (%) in reproduction index[a] variants*



[a] The traits and reproduction index (RI) variants are described in Table 1 and the Materials and Methods section.

Figure 3. *Economic selection effect[a] in breeding goal traits according to reproduction index variants and pig breeds*



[a] Selection effect is expressed as CZK per sow/year. For the description of traits and breeds, see Table 1.

Conclusions

Modern selection methods adopted in farm animal management are based on the selection of parents whose offspring will help generate considerable profit. The selection of domestic populations of maternal pig breeds included in the CZEPIG National Breeding Programme is currently based on overall breeding value (OBV), for which the number of piglets born alive is included as a selection criterion for reproduction. Owing to the low positive correlation of the above-mentioned trait with farrowing interval, there is an undesirable increase in the number of days constituting the farrowing interval. Simultaneously, selection for other components of the number of piglets per litter (total number of piglets born and piglets weaned) is a requirement for pig farming. Therefore, from a selection perspective, the definition of the number of piglets born alive and farrowing interval as breeding goals appears to be the basic prerequisite for the improvement of the reproductive performance of domestic populations of maternal pig breeds. The overall reproduction index, including several reproductive traits (total number of piglets born, piglets born alive and piglets weaned and farrowing interval) assures the high reliability of positive selection response for both NBA and farrowing interval. The reliability of selection indices and selection response for breeding goal traits computed for the CLW and CL breeds was similar in all variants and therefore, a common reproduction index could be applied to both maternal breeds. Moreover, the routine computation of breeding values of the above-mentioned reproductive traits is a positive fact, thus establishing the first prerequisite for the practical application of selection indices for reproductive traits.

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