

GENETIC PARAMETERS OF WEANING-TO-OESTRUS INTERVAL IN PIGS USING BAYESIAN ANALYSIS

Špela MALOVRH^{a)}, Milena KOVAC^{b)} and Rainer RÖHE^{c)}

^{a)} Univ. of Ljubljana, Biotechnical Fac., Zootechnical Dept., Groblje 3, SI-1230 Domžale, Slovenia, Assist., Ph.D., e-mail: spela@mrcina.bfro.uni-lj.si.

^{b)} Same address, Assoc. Prof., Ph.D.

^{c)} Christian-Albrechts-University of Kiel, Institute of Animal Breeding and Husbandry, Olshausenstrasse 40, D-24098 Kiel, Germany, PD., Ph.D.

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ABSTRACT

Genetic parameters for weaning-to-oestrus interval (WOI) were estimated on 11,026 sows from pig selection farm Ptuj (Slovenia). Univariate analyses of observations of WOI across parities and two-trait analyses of records of primiparous (PP) and multiparous (MP) sows were performed applying Bayesian approach. WOI was analysed on original scale, transformed using a natural log transformation (lnWOI) and considered as a mixture of normal and exponential distributions (trWOI). Statistical model included genotype, season of service as year-month interaction, and parity as fixed effects, and previous lactation length and number of piglets weaned as covariates. Direct additive genetic effect and permanent environment were considered as random effects. (Co)variance components were estimated by Bayesian analyses. Gibbs chains of length between 130,000 and 180,000 were run. Univariate analysis for sows across parities resulted in heritability estimates of 0.06, 0.07, and 0.07 for WOI, lnWOI and trWOI, respectively. Permanent environment (PE) accounted for 26 % of phenotypic variation for WOI and 19 % for both lnWOI and trWOI. In bivariate analysis, heritability was 0.19 in PP and 0.06 in MP. Genetic correlation for WOI between PP and MP was 0.80. The PE proportion was 0.10 in MP sows. Based on genetic parameters, selection on improved rebreeding performance in pigs is expected to be most efficient considering WOI in primiparous and multiparous sows as different traits. Transformation of WOI increased the genetic parameters only slightly.

Key words: pigs / sows / reproduction / weaning-to-oestrus interval / genetic parameters / Bayesian analysis / Gibbs sampling

GENETSKI PARAMETRI ZA INTERIM OBDOBJE PRI PRAŠIČIH S POMOČJO BAYESOVE ANALIZE

IZVLEČEK

Ocenjevali smo genetske parametre za interim obdobje (WOI) na 11026 svinjah s seleksijske farme prašičev Ptuj (Slovenija). Za enorazsežno analizo WOI za vse svinje skupaj ter dvorazsežno analizo opazovanj pri svinjah po prvi prasitvi (PP) in svinjah iz višjih rasitev (MP) smo uporabili Bayesov pristop. WOI smo analizirali na naravnih skali, transformiranega z naravnim logaritmom (lnWOI) ter kot mešanico normalne in eksponentne porazdelitve (trWOI). Statistični model je vključeval genotip, sezono pripusta kot interakcijo leto-mesec in zaporedno

prasitev kot sistematske vplive ter dolžino predhodne laktacije in število odstavljenih pujskov kot neodvisni spremenljivki. Direktni aditivni genetski vpliv in vpliv permanentnega okolja sta bila upoštevana kot naključna vpliva. Komponente kovariance smo ocenjevali s pomočjo Bayesove analize. Dolžina Gibbsovih verig je bila med 130 000 in 180 000 iteracij. Ocene heritabilitet iz enorazsežne analize za vse svinje skupaj so bile 0,06 za WOI ter 0,07 za lnWOI in trWOI. Permanentno okolje (PE) je pojasnilo 26 % fenotipske variabilnosti ter WOI in 19 % lnWOI in trWOI. V dvorazsežni analizi smo ocenili heritabiliteto 0,19 pri PP in 0,06 pri MP. Genetska korelacija za WOI med PP in MP je bila 0,80. Delež PE pri MP je znašal 0,10. Na podlagi ocenjenih genetskih parametrov bi bila selekcija na izboljšano sposobnost ponovne obrejitev pri prašičih najučinkovitejša, če bi bila WOI po prvi prasitvi in WOI v višjih prasitvah upoštevana kot različni lastnosti. Transformacija WOI je le nekoliko zvišala genetske parametre.

Ključne besede: prašiči / svinje / plodnost / interim obdobje / genetski parametri / Bayesova analiza

INTRODUCTION

Most effort in selection on reproductive traits in pigs is based on litter size. Sow reproduction is a rather complex area, since there are many different, but related traits. Some reproductive traits are difficult to measure (number of ovulated ova, milk production), they are not recorded (age at first oestrus, individual piglet birth weight) or distributions for traits do not follow a normal one like in conception rate, number of stillborn piglets, maternal ability, weaning-to-oestrus interval (WOI), farrowing interval, etc. Besides litter size, the 21-day litter weight and weaning litter weight are also often selected reproductive traits (ten Napel *et al.*, 1995b). Reproductive traits show usually low heritabilities.

The interval between weaning and oestrus (service) is a component of other rebreeding intervals, such as weaning-to-successful-service, weaning-to-farrowing and farrowing interval, and thus contributes to the variability of these traits. Farrowing interval together with litter size composes the number of piglets born or weaned per sow per year (Kovač *et al.*, 1992), which is a trait of interest in selection on reproductive traits. Lactation length, feeding, parity, housing, and management affect the WOI. After weaning their first litter, sows more often express prolonged WOI (Aumaitre *et al.*, 1976; Kovač *et al.*, 1982). Small differences are reported to exist between breeds and their crossbreds in WOI.

Heritabilities for WOI reported in the literature showed a wide range. Low values (0.04–0.07) were estimated for multiparous sows (Hanenberg *et al.*, 2001). In first-parity sows, heritabilities between 0.14 and 0.36 were found (Hanenberg *et al.*, 2001; Fahmy *et al.*, 1979; ten Napel *et al.*, 1995a). Genetic variances represented about 14 to 22 % of the phenotypic variances of WOI using observations across parities (Adamec and Johnson, 1997; Petrovičová *et al.*, 1990). Sternig *et al.* (1998) estimated heritability of 0.31 for ability to return to oestrus within 10 days. Other rebreeding intervals usually have lower heritabilities (Adamec and Johnson, 1997; ten Napel and Johnson, 1997).

All rebreeding intervals show skewed distributions with extended tail on right side. Ten Napel *et al.* (1995b) distinguished between normal and prolonged weaning-to-oestrus intervals. Prolonged intervals may be a consequence of many factors. Ten Napel *et al.* (1995b) assumed in their study the interval from weaning to first observed oestrus had a distribution which was a mixture of normal and exponential distributions.

The present paper is focused on estimation of (co)variance components for transformed and untransformed weaning-to-oestrus interval by Bayesian analysis.

MATERIAL AND METHODS

Records of reproductive performance for sows of four genotypes (Swedish Landrace, Large White, German Landrace, and crosses between Large White and Swedish Landrace) from pig breeding herd on farm Ptuj in Slovenia were analysed. The data set consisted of 11,026 sows with 33,083 records belonging to a period from April 1990 to December 1994 (Table 1). The pedigree contained 13,495 animals. The primiparous sows had on average for 8 days longer WOI compared to multiparous sows. In MP, 76 % of WOI lasted 5 days and 92 % of WOI were shorter than 8 days (Figure 1). These proportions were lower in PP: 43 % of WOI took 5 days and 61 % of WOI were found shorter than 8 days. The WOI does not follow a normal distribution. Thus, in addition to original data, the WOI was transformed using a natural log transformation ($\ln(WOI)$) and alternative natural log transformation ($\text{tr}WOI$) as suggested by ten Napel *et al.* (1995a), where distribution of WOI is considered as a mixture of normal and exponential distributions. Intervals longer than 6 days were transformed as

$$\frac{\ln(WOI)}{\ln(6) - \ln(5)} - \left(\frac{\ln(6)}{\ln(6) - \ln(5)} - 6 \right).$$

Table 1. Descriptive statistics for data analysed

Preglednica 1. Opisna statistika za analizirane podatke

	No. of records Število zapisov	WOI (days / dni)	PLL (days / dni)	NPW
Sows together Svinje skupaj	33,083	8.52 ± 10.25	23.88 ± 2.22	8.38 ± 1.68
Primiparous Prvesnice	8,362	14.65 ± 16.23	24.45 ± 2.23	7.90 ± 1.82
Multiparous Svinje z 2 ali več prasitv.	24,721	6.46 ± 5.86	23.68 ± 2.19	8.54 ± 1.60

WOI = weaning-to-oestrus interval / interim obdobje, PLL = previous-lactation length / dolžina predhodne laktacije, NPW = number of piglets weaned / število odstavljenih pujskov

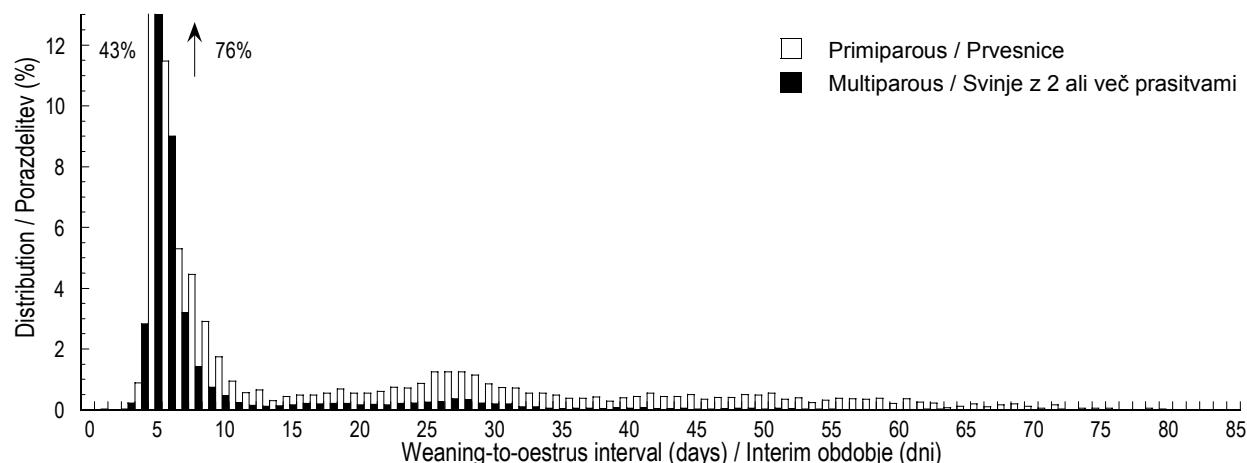


Figure 1. Distribution of weaning-to-oestrus interval in primiparous and multiparous sows.

Slika 1. Porazdelitev za interim obdobja pri svinjah po prvi prasitvi in svinjah iz višjih prasitev.

The following models written in matrix notation were used in the analyses:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a \mathbf{a} + \mathbf{Z}_p \mathbf{p} + \mathbf{e} \quad [1]$$

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a \mathbf{a} + \mathbf{e} \quad [2]$$

where \mathbf{y} is a vector of observations, $\boldsymbol{\beta}$ is a vector of fixed effects, \mathbf{a} is the vector of additive genetic effects, \mathbf{p} is the vector of permanent environment effects, and \mathbf{e} is the vector of residuals. Known incidence matrices \mathbf{X} , \mathbf{Z}_a , and \mathbf{Z}_p relate observations (\mathbf{y}) to fixed and random effects. The vector $\boldsymbol{\beta}$ contained genotype, season of service as year-month interaction, and parity as fixed effects, as well as lactation length and the number of piglets weaned as covariates. The statistical model [1] was used in the univariate analyses for original and transformed WOI of sows across all parities and for multiparous (MP) sows in the two-trait (bivariate) analysis, while the model [2] was used in the two-trait analysis for primiparous (PP) sows. Normal distribution of WOI, lnWOI and trWOI was assumed:

$$\mathbf{y} | \boldsymbol{\beta}, \mathbf{a}, \mathbf{p}, \sigma_e^2 \sim N[\mathbf{X}\boldsymbol{\beta} + \mathbf{Z}_a \mathbf{a} + \mathbf{Z}_p \mathbf{p}, \mathbf{R}\sigma_e^2] \quad [3]$$

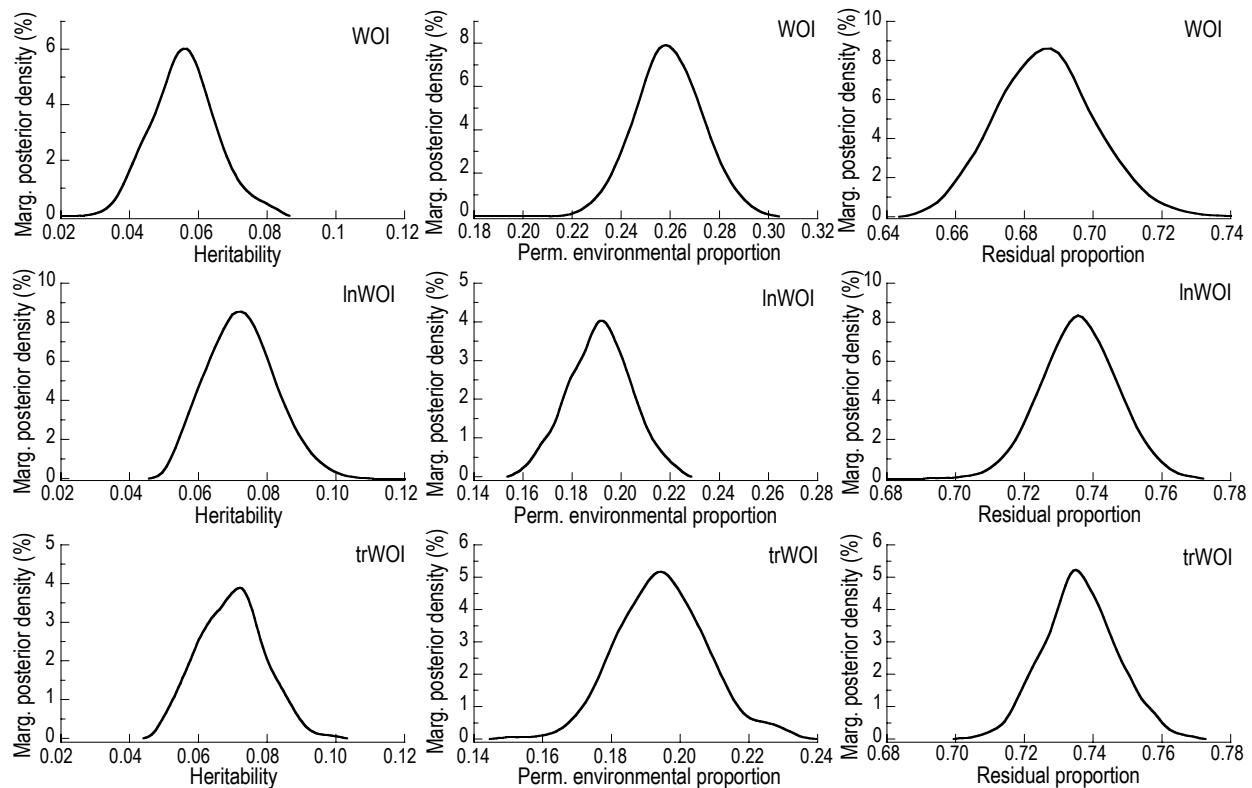


Figure 2. Marginal posterior density of genetic and environmental parameters for untransformed (WOI) and transformed weaning-to-oestrus interval (lnWOI, trWOI) for sows across all parities.

Slika 2. Robna posteriorna gostota genetskih in okoljskih parametrov za netransformirano (WOI) in transformirano interim obdobje (lnWOI, trWOI) pri svinjah iz vseh prasitev.

The following assumptions were used for the distributions of fixed and random effects:

$$\boldsymbol{\beta} \sim constant$$

$$\mathbf{a} | \mathbf{A}, \mathbf{G}_0 \sim N[\mathbf{0}, (\mathbf{A} \otimes \mathbf{G}_0)] \quad [4]$$

$$\mathbf{p} | \mathbf{P}_0 \sim N[\mathbf{0}, (\mathbf{I} \otimes \mathbf{P}_0)]$$

where, \mathbf{A} is the numerator relationship matrix, \mathbf{G}_0 is the matrix of additive genetic (co)variances with size 1×1 for univariate and 2×2 in bivariate analysis, \mathbf{P}_0 is the 1×1 matrix containing permanent environmental variance. (Co)variance components were estimated by Bayesian analyses. Gibbs sampling (Geman and Geman, 1984), a Markov Chain Monte Carlo method, as implemented in the program MTGSAM (Van Tassell and Van Vleck, 1996) was used. Uninformative flat priors were specified for fixed effects; small priors for (co)variance components were used in order to avoid improper posteriors. For thinning of Gibbs chain, serial correlation in GIBANAL (van Kaam, 1997) was estimated.

RESULTS AND DISCUSSION

For analyses of (co)variance components, Gibbs chains of length 130,000 for univariate and 180,000 for bivariate analyses were run in a long-chain scheme. First 30,000 iterations were discharged as burn-in period. The marginal posterior densities of genetic and environmental parameters are shown in Figures 2 and 3. Many of marginal posterior distributions deviated from normality, showing that standard errors based on assumption of normality can be misleading. Highest posterior density (HPD) intervals were more appropriate. The 95 % HPD for heritability of WOI ranged from 0.04 to 0.08 (Figure 2), while for both transformed WOI, the 95 % HPD interval started at 0.05 and extended to 0.09. In bivariate analysis, the HPD for heritability was 0.14 to 0.24 for primiparous and 0.04 to 0.08 for multiparous sows (Figure 3). The additive genetic correlations between WOI in primiparous and multiparous sows showed the 95 % HPD between 0.61 and 0.99 (Figure 3).

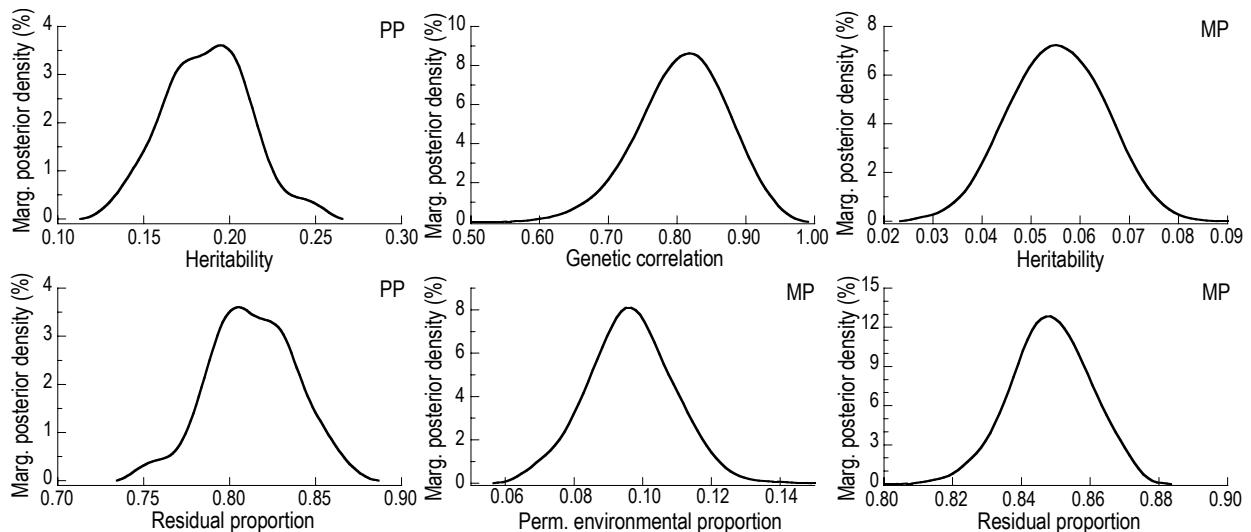


Figure 3. Marginal posterior density of genetic and environmental parameters for weaning-to-oestrus interval using bivariate analysis of primiparous (PP) and multiparous sows (MP).

Slika 3. Robna posteriorna gostota genetskih in okoljskih parametrov za interim obdobje iz dvorazsežne analize svinj po prvi prasitvi (PP) in svinj po drugi prasitvi (MP).

The posterior means of variance components from single trait analyses across parities differed among themselves and can not be compared due to transformations (Table 2). Additive genetic variance explained 6 % of phenotypical variability in WOI. Despite incorrect assumption of normal distribution for untransformed WOI, heritability was close to estimates of lnWOI and trWOI (0.07). Estimated heritabilities were lower than those in studies across parities by Adamec

and Johnson (1997) and Petrovičová *et al.* (1990). Possible reason for low estimates might be a bias arising from culling of sows which do not return to oestrus in a certain period after weaning. Culling was performed more strictly in multiparous than in primiparous sows. Permanent environmental proportion was 0.26 for WOI and 0.19 for its transformations. These values were significantly higher compared to 0.02–0.05 as reported by Petrovičová *et al.* (1990) and Adamec and Johnson (1997).

The heritability (0.19) for WOI in primiparous sows obtained by bivariate analysis (Table 3) was substantially higher compared to univariate analysis across parities. It is comparable to estimates reported by Hanenberg *et al.* (2001) and Fahmy *et al.* (1979), as well as to realised heritability (0.17) found by ten Napel *et al.* (1995a). The WOI of multiparous sows showed a heritability of 0.06 which was similar to 0.04–0.07 obtained by Hanenberg *et al.* (2001) in their multivariate analysis (for multiparous sows by multivariate analysis). Permanent environment accounted for 10 % of phenotypic variability in multiparous sows, which is close to 0.12 reported by Hanenberg *et al.* (2001).

Table 2. Posterior means of variance components due to additive genetic (σ_a^2), permanent environmental effect (σ_p^2), and residual (σ_e^2) and their phenotypic proportions for weaning-to-oestrus interval in sows across all parities
Preglednica 2. Posteriore srednje vrednosti komponent variance za aditivni genetski vpliv (σ_a^2), permanentno okolje (σ_p^2) in ostanek (σ_e^2) ter njihovi fenotipski deleži za interim obdobje za svinje iz vseh prasitev

	σ_a^2	σ_p^2	σ_e^2	h^2	p^2
WOI	68.71 ± 0.87	5.62 ± 0.81	25.93 ± 1.52	0.06 ± 0.008	0.26 ± 0.013
lnWOI	0.227 ± 0.003	0.022 ± 0.005	0.059 ± 0.004	0.07 ± 0.011	0.19 ± 0.012
trWOI	6.792 ± 0.074	0.643 ± 0.086	1.800 ± 0.125	0.07 ± 0.009	0.19 ± 0.013

WOI = weaning-to-oestrus interval / interim obdobje, h^2 = heritability / heritabiliteta, p^2 = permanent environmental variance as proportion of phenotypic variance / delež variance permanentnega okolja

Table 3. Posterior means of (co)variance components and their phenotypic proportions for weaning-to-oestrus interval using bivariate analysis in primiparous and multiparous sows
Preglednica 3. Posteriore srednje vrednosti komponent (ko)variance in fenotipski deleži za interim obdobje s pomočjo dvorazsežne analize pri svinjah po prvi prasitvi in svinjah iz višjih prasitev

	$\sigma_e^2 *$	$\sigma_a^2 *$	$\sigma_p^2 *$	σ_{a1a2}	$h^2 *$	r_a	$p^2 *$
PP	212.13 ± 9.81	48.70 ± 6.88		7.70 ± 1.03	0.19 ± 0.024	0.80 ± 0.098	
MP	29.25 ± 0.46	1.88 ± 0.32	3.32 ± 0.39		0.06 ± 0.010		0.10 ± 0.013

PP = primiparous / prvesnice, MP = multiparous / svinje z 2 ali več prasitvami, σ_{a1a2} = additive genetic covariance / aditivna genetska kovarianca, r_a = additive genetic correlation between weaning-to-oestrus interval in primiparous and multiparous sows / aditivna genetska korelacija med interim obdobjem pri prvesnicah in svinjah v višjih prasitvah; * = see Table 2 for description / za opis glej preglednico 2

The additive genetic correlation of 0.80 between WOI in primiparous and multiparous sows was high (Table 3). However, it is less than unity. In addition, genetic determination of WOI in primiparous sows was much higher than in multiparous sows. Thus, the WOI of primiparous sows is genetically different trait compared to WOI of multiparous sows. Besides lower

occurrence of prolonged intervals in multiparous sows, the culling procedure may be contributed to this difference.

CONCLUSIONS

Delayed oestrus after weaning is mainly a problem in primiparous sows and to smaller extent after second litter. The culling of sows which do not return to oestrus in a certain period after weaning is also more strictly carried out after second litter, which already presents selection against prolonged intervals.

The estimated heritabilities for weaning-to-oestrus interval showed that WOI can be improved by selection. Similar heritabilities were estimated for untransformed and transformed WOI across parities. Heritability of WOI in primiparous sows was higher than in multiparous sows. Therefore, larger response can be expected by selection on WOI in primiparous sows. Records of WOI from higher parities seem to be highly influenced by selection and may only be used to increase the accuracy of estimates of primiparous sows due to high genetic correlation.

POVZETEK

Sedanja selekcija pri lastnostih plodnosti prašičev temelji predvsem na velikosti gnezda. Plodnost svinj je dokaj kompleksno področje, ki ga sestavlja več različnih vendar povezanih lastnosti. Običajno imajo lastnosti plodnosti pri prašičih nizko heritabiliteto. Interim obdobje, tj. interval od odstavitev do estrusa (pripusta), je sestavni del drugih intervalov, povezanih s sposobnostjo ponovne obrejitev svinj, kot sta npr. poodstavitevni premor in doba med prasitvama in kot tako prispeva k njihovi variabilnosti. Doba med prasitvama skupaj z velikostjo gnezda sestavlja število rojenih/odstavljenih pujskov na svinjo letno, ki je dejansko cilj selekcije pri lastnostih plodnosti. Na dolžino interim obdobja vplivajo tako negenetski kot genetski dejavniki: dolžina predhodne laktacije, prehrana, zaporedna prasitev, vhlevitev, vodenje reje, pasma oziroma križanje itn. Različni avtorji v literaturi navajajo dokaj širok razpon heritabilitet: višje pri svinjah po prvi prasitvi (0,14–0,36) in nižje pri svinjah po kasnejših prasitvah (0,04–0,07).

Porazdelitev za interim obdobje kaže desno asimetričnost, kar otežuje statistično analizo te lastnosti. Namen tega prispevka je bila ocena komponent kovariance za transformirano in netransformiramo interim obdobje s pomočjo Bayesove analize.

Obdelali smo 33083 zapisov reprodukcijskih ciklusov 11026 svinj s seleksijske farme Ptuj. Podatki so obsegali štiri genotipe: švedska landrace, large white, nemška landrace ter križanke med švedsko landrace in large white. Zajeto je bilo obdobje od aprila 1990 do decembra 1994. Poreklo je vključevalo 13495 živali. Interim obdobje (WOI) smo analizirali na naravnih skali, transformiranega z naravnim logaritmom ($\ln\text{WOI}$) ter kot mešanico normalne in eksponentne porazdelitve (trWOI). Statistični model je vključeval genotip, sezono pripusta kot interakcijo leto-mesec in zaporedno prasitev kot sistematske vplive ter dolžino predhodne laktacije in število odstavljenih pujskov kot neodvisni spremenljivki. Direktne aditivne genetske vpliv in vpliv permanentnega okolja svinje sta bila obravnavana kot naključna vpliva. Za ocenjevanje genetskih in negenetskih parametrov disperzije smo uporabili metodo Markovskih verig Monte Carlo po imenu »Gibbs sampling« v programu MTGSAM. Tanjšanje Gibbs verig smo izvedli na podlagi serijske korelacije s programom GIBANAL.

Dolžina Gibbs verig je bila 130000 iteracij v enorazsežnih analizah in 180000 iteracij v dvorazsežni analizi. Prvih 30000 iteracij smo zavrgli kot dobo ogrevanja (burn-in). Nekatere robne posteriorne porazdelitve za (ne)genetske parametre disperzije so odstopale od normalne porazdelitve, zato so lahko standardne napake ocen zavajajoče. Primernejša statistika je interval

95 % največje posteriorne gostote (HPD). Posteriorne srednje vrednosti za heritabiliteto iz enorazsežne analize za vse svinje skupaj so bile 0,06 za WOI (95 % HPD med 0,04 in 0,08) ter 0,07 za lnWOI in trWOI (95 % HPD 0,05–0,09). Permanentno okolje je pojasnilo 26 % fenotipske variabilnosti pri WOI ter 19 % pri lnWOI in trWOI. V dvorazsežni analizi smo ocenili heritabiliteto 0,19 za WOI pri svinjah po prvi prasitvi (95 % HPD 0,14–0,24) in 0,06 pri svinjah iz višjih prasitev (95 % HPD 0,04–0,08). Delež permanentnega okolja v fenotipski varianci pri svinjah po drugi prasitvi je znašal 0,10. Genetska korelacija med WOI pri svinjah po prvi prasitvi in WOI v kasnejših prasitvah je bila 0,80 (95 % HPD med 0,61 in 0,99), kar pomeni, da je WOI po prvi prasitvi genetsko različna lastnost od WOI v višjih prasitvah. Poleg tega, da imajo svinje, ki so prasile večkrat, manj pogosto podaljšano interim obdobje, je prispevalo k temu tudi izločanje nebukajočih odstavljenih svinj, ki je strožje po kasnejših prasitvah.

Podaljšano interim obdobje predstavlja problem pri svinjah po prvi prasitvi in v manjši meri po drugi. Izločanje nebukajočih svinj že predstavlja selekcijo proti podaljšanemu interim obdobju. Na podlagi ocenjenih genetskih parametrov bi bila selekcija na izboljšano sposobnost ponovne obrejitev pri prašičih najučinkovitejša, če bosta WOI po prvi prasitvi in WOI v višjih prasitvah upoštevana kot različni lastnosti. Transformacija WOI je le nekoliko zvišala genetske parametre.

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