Low Retention Rate of Female Pigs Associated with Gilt Development, Lifetime Performance and Culling Pattern in Commercial Swine Herds

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Abstract : The objectives of this study were to characterize swine herds that had a low retention rate by parity 3 (LRR herds) in terms of gilt development and lifetime reproductive performance and to examine management factors associated with low retention of females. The retention rate by parity 3 was defined as the number of females first-mated and successfully reaching the third parity. Questionnaires were sent to 115 herds that use the same recording system requesting information about gilt development and herd management procedures in 2008: (1) whether or not there was restricted feeding for pre-pubertal gilts; (2) type of gilt development diet; and (3) percentage of home-grown gilts in the herd. Data of 81 completed questionnaires (70.4%) and herd productivity measurements were coordinated with the performance data of 15,678 gilts that entered into those herds in 2008. Herds were categorized into LRR herds and ordinary herds on the basis of the lower 25th percentile of retention rate by parity 3 (71.6%). Herd level analysis showed that the LRR herds had 3.4% lower farrowing rates and 7.7% higher culling rates than ordinary herds ($P < 0.05$). In addition, more LRR herds used restricted feeding and a gestation diet than ordinary herds ($P < 0.05$). Furthermore, LRR herds had 29.2% higher percentage of home-grown gilts in their herds than ordinary herds ($P < 0.05$). Individual female level analysis showed that first-mated females in LRR herds had 6.2-11.2% higher culling risk by parity 1-3 for reproductive failure than those in ordinary herds ($P < 0.05$). However, no difference was found between the herd groups for lifetime average pigs weaned ($P = 0.79$). In a multilevel proportional hazard model, the hazard of culling for a female was associated with the restricted feeding and higher percentage of home-grown gilts in their herds ($P < 0.05$), but not with the types of gilt development diet ($P = 0.21$). The survival probabilities at 60 weeks from first-mating were 80.1 and 84.1% for females that had restricted and unrestricted feeding as pre-pubertal gilts, respectively. In conclusion, too much restricted feeding during pre-pubertal periods is not recommended to improve female longevity. Additionally, strict selection procedures for reproductive soundness are recommended for home-grown gilts on entry to their herds.

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Key words : gilt development, questionnaire, reproductive performance, survival, swine

Introduction

Approximately 30% of culling of breeding female pigs in commercial herds occurs by parity 3 (ENGELM et al., 2007). However, economic analysis has indicated that positive lifetime net income is not obtained until parity 3 (SASAKI et al., 2011). Low retention rates and low sow longevity decrease herd reproductive productivity and profitability by decreasing subpopulations of mid-parity sows that
have high numbers of pigs born alive, and by increasing replacement costs (DIAL et al., 1992; KOKETSU, 2007). Thus, it is important to identify factors or herd management procedures associated with low retention of sows by parity 3. Such information should help to improve sow retention rates, herd productivity and profitability in those commercial herds that have low retention rates up to parity 3 (LRR herds).

Sow retention in commercial herds depends on both reproductive performance of sows and herd management (ANIL et al., 2008). Sows with low longevity have lower farrowing rates across parity than those with high longevity (SASAKI and KOKETSU, 2008). Gilt development is one of the most important management procedures that determine sow retention and longevity (FOXCROFT and AHERNE, 2001; PATTERSON et al., 2010). Important gilt development procedures include nutritional management during pre-pubertal periods and induction of puberty onset. Studies have shown that appropriate nutritional management during pre-pubertal periods is highly associated with earlier puberty age in gilts, improved sow retention rates and longevity (LE COZLER et al., 1999a; LE COZLER et al., 1999b; PATTERSON et al., 2010). Additionally, sows with low longevity are mainly culled for reproductive failure or locomotor problems (LUCIA Jr. et al., 2000; SASAKI and KOKETSU, 2011). However, no study has investigated the associations between characteristics of gilt development, culling patterns and reproductive performance in LRR herds. The objectives of this study were to characterize LRR herds in terms of gilt development and lifetime reproductive performance and to examine management factors associated with low retention of females.

Materials and methods

Questionnaire and herd selection

In March 2009, a questionnaire form was sent to 115 commercial breeding herds in Japan that use the PigCHAMP recording system (PigCHAMP Inc., Ames, IA, U.S.A.). The questionnaire requested information about gilt development and herd management procedures in 2008, and producers were asked to select the appropriate answers to the following questions: (1) feeding of pre-pubertal gilts: restricted or unrestricted feeding; (2) type of gilt development diet: gilt development diet, gestation diet, lactation diet or growing pig diet; (3) gilt age when the gilt development diet was started; (4) type of boar contact: direct boar contact or no direct boar contact; and (5) percentage of home-grown gilts in the herd. Situations with no direct boar contact include housing boars adjacent to females (KEMP et al., 2005) and fence-line boar contact between a boar and females housed in individual stalls (PATTERSON et al., 2002). The questionnaire was used in a companion study about gilt development and mating management for gilts (KANEKO and KOKETSU, 2012). In addition, by June 30, 2011, their completed questionnaires and female performance data were received from 86 of the breeding herds. Five herds of 86 herds were excluded from the study because two were producing only purebred pigs, one had no gilt records and two did not record birth dates of females. Hence, the data from 81 herds (70.4%) were used for the present study. Mean herd measurements e.g., herd size and number of pigs weaned per mated female per year which is used as a measure of herd productivity, were collected from the 81 herds for three 1-year periods from 2008 to 2010.

The females in the studied herds were mainly crossbreds between Landrace and Large White, either produced within the herds or they were replacement gilts that were purchased from national or international breeding companies. Breeding stocks in the national breeding companies were originally imported from the U.S.A. or Europe.

Reproductive data

Data of females entered in 2008, which included age of gilts at first-mating (AFM), were extracted from the PigCHAMP recording system, amounting to records of 15,707 female pigs in the 81 herds. The data included sow records until the end of June, 2011. Excluded data comprised records of females with AFM of less than 150 days or more than 365 days (28 records; TUMMARUK et al., 2001; BABOT et al., 2003) and records of removed females with no
removal type, i.e., culled, dead or euthanized (1 record). Of the remaining females, 4,091 (26.1%) were still alive when the data were collected. Sixty-four of the lived females did not reach third parity, and they were omitted. Hence, analyses in this study contained records of 15,614 females and lifetime records of 11,587 females. Of the removed females, 1,666 were dead or euthanized.

Definitions and categories

Retention rates by parity 1–3 were defined as the number of females successfully reaching first, second or third parity divided by the number of first-mated females, respectively (PATTERSON et al., 2010). Reproductive herd-life day was defined as the number of days from the date that the gilts were first-mated to the date of their removal. Lifetime average pigs weaned were defined as the sum of PBA in a female’s lifetime divided by the number of parity at removal. Annualized lifetime pigs born alive was calculated as lifetime PBA divided by the reproductive herd-life day multiplied by 365 days. In addition, culling risk by parity 1–3 were calculated as the number of female culled by parity 1–3 for reproductive failure or locomotor problems divided by the number of a first-mated female, respectively.

Herds were classified into two groups on the basis of the lower 25th percentile of retention rate by parity 3 for females entered in 2008: LRR herds (range = 48.7 to 71.6%) and ordinary herds (range = 71.7 to 100%). Culling reasons were divided into three categories based on previous studies (LUCIA JR. et al., 2000; ENGBLOM et al., 2007): “reproductive failure”, “locomotor problems” and “others”. “Reproductive failure” included no heat, did not conceive, failure to farrow, found not pregnant, negative pregnancy check and abortion. “Locomotor problems” consisted of lameness, downer, unsoundness, joint infection and injury.

Statistical analysis

Statistical analyses were conducted using either SAS (SAS Inst. Inc., Cary, NC) software or MLwiN software (University of Bristol, Bristol, UK). At the herd level, analysis of variance in SAS was performed to compare the two herd groups for retention rates, herd measurements, the gilt ages when the diet was started, the percentages of home-grown gilts in their herds. The analysis of proportion data was carried out using Chi-square or Fisher’s test as appropriate.

At the individual female level, two-level analysis was applied using a herd at level 2 and an individual female at level 1 in SAS (SINGER, 1998). A linear mixed-effects model using the MIXED procedure was applied for continuous outcome variables, e.g. reproductive herd-life days. Additionally, a mixed-effects logistic regression model with logit link function using the GLIMMIX procedure was used for binary outcome, e.g. whether or not a female was retained by parity 3 (1 or 0). Model 1 was constructed to compare the two herd groups for lifetime performance. The model included the herd groups as a fixed effect. Model 2 was constructed to examine the associations between the five management procedures and a probability of a female retained by parity 3. The model included the management factors as fixed effects. Additionally, the two-way interactions between the fixed effects were examined in Model 2, and non-significant interactions (P>0.10) were eliminated. The AFM was treated as a covariate in the Models. The herd was included as a random intercept in the Models. To assess the variations in the probability of a female retained by parity 3 that could be explained by the herd, the intraclass correlation coefficients were calculated by the following equations (DOHOO et al., 2009),

$$\rho = \frac{\sigma_{\text{Herd}}^2}{\sigma_{\text{Herd}}^2 + (\pi^2/3)},$$

where $\rho$ represents the intraclass correlation coefficient, $\sigma_{\text{Herd}}^2$ is the between-herd variation and $\pi^2/3$ is the variance at the individual female level.

A multilevel proportional hazard model in MLwiN was used to examine the associations between the hazard of culling for a female pig and the five management procedures (YANG and GOLDSTEIN, 2003). Culled females were treated as uncensored subjects, whereas surviving females and non-culled females were treated as censored subjects. Censored time for surviving females was determined as date of
data collection after first-mating. The logarithm of the number of culled females at any time was treated as an offset in the model. The baseline hazard was fitted by an order polynomial function. The order of the polynomial was performed until adding further terms did not alter the model parameters (YANG and GOLDSTEIN, 2003) or until the model did not converge. Additionally, the AFM was treated as a covariate, and the herd was included as a random intercept in the model.

Results

Mean (±SEM) retention rates by parity 1, 2 and 3 were 94.8±0.36, 84.5±0.83 and 77.1±1.05%, respectively. Herd level analysis showed that the LRR herds had 16.9% lower retention rates by parity 3, 3.4% lower farrowing rates and 7.7% higher culling rates than ordinary herds (P<0.05 ; Table 1). However, no difference was found between the herd groups for the number of pigs weaned per mated female per year (P=0.26). The LRR herds more used restricted feeding and a gestation diet, and less used a gilt develop diet than ordinary herds (P<0.05). Additionally, LRR herds had 29.2% higher percentage of home-grown gilts in their herds than ordinary herds (P<0.05). However, no difference was found between the herd groups for the gilt age when the diet was switched (P=0.79) and the percentages of herds performing direct boar contact (P=0.43) and herds using lactation diet (P=0.34) or growing pig diet (P=1.00).

Individual female level analysis showed that first-mated females in LRR herds had 105.0 shorter reproductive herd-life days and 6.2–11.2% higher culling risk by parity 1–3 for reproductive failure than those in ordinary herds (P<0.05 ; Table 2). However, no differences were found between the herd groups for annualized lifetime pigs born alive (P=0.09), and lifetime average pigs weaned (P=0.79) and culling risk by parity 1–3 for locomotor problems (P≥0.24).

Individual female level analysis showed that the restricted feeding and higher percentage of home-grown gilts in their herds were associated with lower probability of a female retained by parity 3 (P<0.05 ; Table 3). In addition, in a multilevel proportional hazard model, the hazard of culling for a female was associated with the restricted feeding and the higher percentage of home-grown gilts in their herds (P<0.05 ; Table 4). However, the types of gilt development diet, performing direct boar contact and gilt age when the diet was switched were not associated with a probability of a female retained by parity 3 (P≥0.27) or the hazard of culling (P≥0.14). The survival probabilities at 60 weeks from first-mating were 80.1 and 84.1% for females that had restricted and unrestricted feeding as pre-pubertal gilts, respectively (Fig. 1). In ICC, the herd effect explained 5.2% of the total variation for the probability of a female retained by parity 3.

Discussion

Our study showed that LRR herds had lower farrowing rates and higher culling rates than ordinary herds, although no difference was found for herd productivity between the herd groups. In addition, females in LRR herds had higher culling risk for reproductive failure than equivalent females in ordinary herds, but there were no differences between those groups in lifetime performance except for measurements related with longevity. The low retention rate represents low female longevity of females but that may not be necessarily associated with low reproductive productivity in females. This result is supported by previous studies showed a lack of association between reproductive productivity and culling risks or female longevity (KOKETSU, 2007 ; SASAKI and KOKETSU, 2011). In addition, our finding clearly showed that females in LRR herds, that had low farrowing rate, were likely to be culled for reproductive failure in low parity. A low retention of these low parity sows can be explained by poor gilt development, which decreases farrowing rate (KANEKO and KOKETSU, 2012), in LRR herds.

High percentages of using restricted diet quantity and home-grown gilts in herds were shown in the LRR herds. In addition, our study showed that restricted feeding during pre-pubertal periods and more use of home-grown gilts associated with lower survival probability and lower probability of a fe-
male retained by parity 3. Furthermore, our result suggests that the types of diet are not important for female longevity. In our study it is possible that pre-pubertal gilts in some herds were under excessively restricted feeding. The goal of nutritional management during the pre-pubertal period is to build up body reserves and to have higher longevity for females (KLINDT et al., 1999). If sufficient body reserves are not built up it can affect longevity, as shown by STALDER et al. (2005) who reported that gilts with very lean backfat were not retained long. However, it is also important to properly determine the feed quantity on gilt body condition because excess body weight have been associated with low female longevity (FOXCROFT and AHERNE, 2001). So, in order to improve sow retention, we recommended that herds used restricted feeding should reconsider a feeding program for pre-pubertal gilts. Meanwhile, the strict selection procedures based on reproductive soundness (STALDER et al., 2013) are necessary for producers rearing home-grown gilts. The efficient gilt pool management and selection

Table 1. Comparisons of retention rates, key herd measurements and gilt development procedures between low retention rate (LRR) herds and ordinary herds

| Measurements                      | LRR herds Mean±SEM | Ordinary herds Mean±SEM | P-value |
|-----------------------------------|--------------------|------------------------|---------|
| Number of herds                   | 21                 | 60                     |         |
| Retention rate by parity 1, %     | 92.3±0.7           | 95.7±0.4               | <0.01   |
| Retention rate by parity 2, %     | 75.5±1.3           | 87.7±0.6               | <0.01   |
| Retention rate by parity 3, %     | 64.6±1.2           | 81.5±0.8               | <0.01   |
| Annual measurements               |                    |                        |         |
| Average female inventories, female pigs | 397.2±84.8       | 473.2±90.0             | 0.64    |
| Pigs weaned per mated female per year | 22.2±0.4          | 22.8±0.3               | 0.26    |
| Parity at farrowing               | 3.5±0.1            | 3.7±0.1                | 0.06    |
| Farrowing rate, %                 | 79.8±1.4           | 83.2±0.8               | 0.03    |
| Lactation length, days            | 22.6±0.4           | 22.4±0.3               | 0.70    |
| Culling rate, %                   | 43.7±2.0           | 36.0±0.8               | <0.01   |
| Death rate, %                     | 5.4±0.5            | 5.8±1.2                | 0.84    |
| Gilt pool size, %                 | 10.5±1.0           | 11.1±0.4               | 0.48    |
| Gilt development and herd management procedures |                  |                        |         |
| Percentage of herds using each procedure |                   |                        |         |
| Restricted quantity diet, %       | 90.5±6.6           | 66.7±6.1               | 0.04    |
| Diet type during pre-pubertal periods |                   |                        |         |
| Gilt development diet, %          | 0                  | 20.0±5.2               | 0.03    |
| Gestation diet, %                 | 90.5±6.6           | 58.3±6.4               | <0.01   |
| Lactation diet, %                 | 9.5±6.6            | 20.0±5.2               | 0.34    |
| Growing pig diet, %               | 0                  | 1.7±1.7                | 1.00    |
| Direct boar contact, %            | 4.8±4.8            | 13.3±4.4               | 0.43    |
| Gilt age when the diet was switched, days | 160.2±5.4         | 128.8±2.6              | 0.79    |
| Percentage of home-grown gilts in their herds, % | 57.1±11.1         | 28.0±5.7               | 0.01    |

SEM=standard error of the mean.

*a* Herds were classified into two groups on the basis of the lower 25th percentile of retention rate by parity 3 (71.6%) : LRR herds and ordinary herds.

*b* Continuous data were analyzed by using analysis of variance.

*c* Proportional data were analyzed by using Chi-square or Fisher’s exact test as appropriate.

*d* One herd did not answer.
Table 2. Estimated lifetime performance and culling risk of female pigs by low retention rate (LRR) herds and ordinary herds<sup>a</sup>

| Measurements                                      | LRR herds | Ordinary herds | P-value |
|---------------------------------------------------|-----------|----------------|---------|
|                                                   | N         | Mean±SEM<sup>b</sup> | N         | Mean±SEM |
| Lifetime performance                              |           |                 |           |         |
| Gilt age at first-mating, days old                | 3,972     | 254.3±3.2       | 11,642    | 251.1±1.9 | 0.39  |
| Reproductive herd-life days, days                 | 3,254     | 529.7±16.7      | 8,333     | 634.7±10.2 | <0.01 |
| Parity at culling                                  | 2,888     | 3.3±0.2         | 7,033     | 4.1±0.1   | <0.01 |
| Parity at death                                   | 300       | 2.9±0.1         | 921       | 3.1±0.1   | 0.15  |
| Parity at euthanasia                              | 66        | 2.5±0.6         | 379       | 3.6±0.4   | 0.12  |
| Annualized lifetime pigs born alive, pigs         | 2,942     | 22.5±0.5        | 7,708     | 23.5±0.3  | 0.09  |
| Lifetime average pigs weaned, pigs                | 2,942     | 9.4±0.2         | 7,708     | 9.5±0.1   | 0.79  |
| Culling risk by parity 1                          |           |                 |           |         |
| Risk for reproductive failure, %                  | 3,972     | 11.9±1.3        | 11,642    | 5.6±0.5   | <0.01 |
| Risk for locomotor problems, %                    | 3,972     | 0.9±0.2         | 11,642    | 0.7±0.1   | 0.43  |
| Culling risk by parity 2                          |           |                 |           |         |
| Risk for reproductive failure, %                  | 3,972     | 16.8±1.7        | 11,642    | 7.6±0.6   | <0.01 |
| Risk for locomotor problems, %                    | 3,972     | 1.5±0.4         | 11,642    | 1.0±0.2   | 0.24  |
| Culling risk by parity 3                          |           |                 |           |         |
| Risk for reproductive failure, %                  | 3,972     | 21.3±2.1        | 11,642    | 10.1±0.7  | <0.01 |
| Risk for locomotor problems, %                    | 3,972     | 1.9±0.4         | 11,642    | 1.4±0.2   | 0.27  |

SEM=standard error of the mean.
<sup>a</sup>Herds were classified into two groups on the basis of the lower 25th percentile of retention rate by parity 3 (71.6%): LRR herds and ordinary herds.
<sup>b</sup>Mean and SEM were estimated by mixed-effects models, which included herd groups and age of gilts at first-mating as fixed effects.

Table 3. Estimates of fixed effects and random effect variance included in the final binary logistic regression model of the probability of a female retained by parity 3

| Fixed effects<sup>a</sup> and variance                                      | Estimate (±SE) | P-value |
|---------------------------------------------------------------------------|----------------|---------|
| Intercept                                                                 | 1.554 (0.112)  | <0.01  |
| Gilt development procedures                                               |                |         |
| Restricted quantity diet                                                  | −0.254 (0.122) | 0.04   |
| Percentage of home-grown gilts                                            | −0.002 (0.001) | 0.03   |
| Herd variance                                                              |                |         |
| Intraclass correlation coefficient (gilts within the same herd), %         | 0.182 (0.039)  |         |

SE=standard error.
<sup>a</sup>Age of gilts at first-mating is not shown in the Table because the variable was used as a covariate.
techniques improve longevity and reproductive efficiency for females (DIAL et al., 2001; WILLIAMS et al., 2005).

In conclusion, too much restricted feeding during pre-pubertal periods is not recommended to improve female longevity. Additionally, strict selection procedures for reproductive soundness are recommended for home-grown gilts before they were entered to the breeding herds.

Finally, one of the limitations of the present study is that it was an observational study using surveyed information and reproductive records from commercial herds. The present study did not take account of herd health, housing, genetics and daily feed amounts of individual gilts. Especially, the influence of genetic lines on the performance was not examined. Additionally, the LRR herds were objectively but arbitrarily categorized. However, even with such limitations, the present study provides practicing veterinarians and producers with valuable information on important characteristics of LRR herds.

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Table 4. Estimates of fixed effects and random effect variance included in the final proportional hazards model

| Fixed effects\(^a\) and variance | Estimate (±SE) | P-value |
|----------------------------------|---------------|---------|
| Intercept                        | -9.553 (0.088)| <0.01   |
| Gilt development procedures      |               |         |
| Restricted quantity diet         | 0.239 (0.094) | 0.01    |
| Percentage of home-grown gilts   | 0.003 (0.001) | <0.01   |
| Time function                    |               |         |
| Log-survival time                | 0.147 (0.050) | <0.01   |
| Log-survival time\(^2\)          | -0.964 (0.056)| <0.01   |
| Log-survival time\(^3\)          | -0.187 (0.065)| <0.01   |
| Log-survival time\(^4\)          | 0.871 (0.025) | <0.01   |
| Log-survival time\(^5\)          | 0.505 (0.024) | <0.01   |
| Log-survival time\(^6\)          | 0.074 (0.005) | <0.01   |
| Herd variance                    | 0.12 (0.02)   |         |
| Individual variance              | Poisson constrained |       |

\(^a\)Age of gilts at first-mating is not shown in the Table because the variable was used as a covariate.

SE=standard error.
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国内繁殖豚生産農場における種雌豚の低い生存割合に関連する
若雌種豚の育成法と生涯成績および淘汰パターン

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要約 本研究の目的は，種雌豚の3産次までの生存割合が低い繁殖農場（LRR農場）の若雌種豚の育成法と生涯繁殖成績を特徴づけることと，低い生存割合に関するマネジメント因子を調べることであった。3産次までの生存割合は，3産次まで生存した豚数を初交配豚の数で割り算出した。若雌種豚の育成法と農場マネジメントについての調査（性成熟前の制限給餌の有無，育成豚の飼料の種類，自家育成豚の使用割合）を行うために，2008年に同一の生産記録ソフトを用いる115農場に調査票を送付した。回答のあった81農場（70.4%）の記録を2008年に導入された15,678頭の豚の繁殖成績と合わせた。3産次までの雌豚の生存割合の下位25パーセンタイル（71.6%）を基に，農場をLRR農場と普通農場に分類した。農場レベルの分析では，LRR農場は普通農場に比べて，分娩割合が3.4%低く，淘汰割合が7.7%高かった（P<0.05）。また，LRR農場は普通農場に比べて，制限給餌を行う農場，育成豚に妊娠豚用の飼料を使用する農場の割合が高かった（P<0.05）。さらに，LRR農場の自家育成豚の使用割合は，普通農場に比べて29.2%高かった（P<0.05）。雌豚レベルの分析では，LRR農場の雌豚の繁殖障害による1-3産次までの淘汰割合が，普通農場に比べて6.2-11.2%高かった（P<0.05）。しかし，雌豚の生涯平均離乳子豚数における農場グループ間での差は見られなかった（P=0.79）。マルチレベルの比例ハザードモデルでは，雌豚の淘汰ハザードは，性成熟前の制限給餌と高い自家育成豚使用割合に関連したが（P<0.05），育成豚の飼料の種類とは関連しなかった（P=0.21）。初交配後60週齢における生存確率は，制限給餌された豚で80.1%となり，制限給餌されなかった豚で84.1%となった。結論として，雌豚の長期生存性の実現に，性成熟前の過度な飼料制限は勧められない。さらに，自家育成豚使用する際に，若雌種豚の繁殖形質の健全性に関する選抜をより厳しく行うことを勧める。

キーワード：若雌種豚の育成法，質問票，繁殖成績，生存，豚