A Survey on Farrowing Space Utilization Efficiency on Commercial Swine Farms

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(Received : March 11, 2015, Accepted : November 25, 2015)

Abstract: The objectives of the present study were to characterize farrowing space (FS) utilization efficiency on commercial farms and to examine the relationships between FS utilization efficiency measurements and those possible factors. A questionnaire survey was undertaken to obtain information on FS utilization from 115 breeding farms. The FS data of the 94 farms (81.7%) that returned the questionnaires were coordinated with the respective reproductive performance data. The 94 farms were categorized into two groups on the basis of the upper 25th percentile of number of pigs weaned per FS per year: high-performing farms and ordinary farms based on the FS utilization efficiency. In addition to herd reproductive performance data, a set of time-series data in 13 four-week periods during a year was created for each farm to obtain mean and its coefficient of variation (CV, %) as a measurement of within-farm variability for number of females served per 4-week. Correlation analysis and regression analysis were applied to the data. Means (±SEM) of pigs weaned per FS per year, litters farrowed per FS per year and the CV of the total number of females served per 4-week in a year were 97.33±2.70 pigs, 9.86±1.28 litters and 12.82±0.79%, respectively. High-performing farms had 42.91 more pigs weaned per FS per year, 3.89 more litters farrowed per FS per year and 4.83% lower CV for the number of females served than ordinary farms (P<0.05). In modelling, a higher number of pigs weaned per FS per year was associated with annual farrowing rate and a lower CV% for the number of females served 16 weeks previously (P<0.01). In conclusion, a higher FS utilization efficiency appeared to be related to mating management on female pigs.

Jpn. J. Swine Science, 52, 4 : 153–160

Key words: farm capacity, farrowing facility, farrowing rate, management

Introduction

Farrowing space (FS) including farrowing crates is the most expensive per sow space in breeding herds (MAIN et al., 2005), with one farrowing space typically costing four to five times more than one gestation space (DHUVESTER et al., 2012). Thus, maximizing the efficient utilization of FS should be considered to decrease costs for pigs weaned per sow in breeding herds.

The FS utilization efficiency is typically measured by the number of pigs weaned per FS per year (WILSON et al., 1986). The number of pigs weaned per FS per year is the product of the number of pigs weaned per sow, and the number of litters farrowed per FS per year which depends on the number of litters farrowed per female per year and the female inventory per FS (WILSON et al., 1986). The number...
of female inventory per FS is also a function of female inventory (herd size) and the number of FS.

In sow reproductive performance, lower farrowing rates than expected would decrease the FS utilization efficiency. Additionally, large within-farm variability of the female pig flow would affect the FS utilization efficiency because a limited number of FS is a bottleneck for pig production on most breeding farms (Wilson et al., 1986; Koketsu, 2005). Additionally, large within-farm variability in the number of females served per week decreased herd reproductive efficiency measured as the number of pigs weaned per female per year (Koketsu et al., 1999). It is hypothesized that the number of females served would be the most critical to use when monitoring the number of weaned pigs per FS for breeding farms. The within-farm variability of female pig flow, such as the total number of females served, can be measured as the coefficient of variation (CV, %) of the measurements using statistical process control (Montgomery, 2005). Additionally, pigs weaning weight per FS per year is another measurement for the FS utilization efficiency. However, no studies have examined associations between FS utilization efficiency measurements and those possible factors including CV (within-farm variability) for the total number of females served on commercial swine farms.

Reproductive performance measurements on high-performing farms have been used to set feasible targets for producers and veterinarians in best practice benchmarking (Stein et al., 1990; Koketsu, 2000). In turn, FS utilization efficiency measurements on high-performing farms could be used as benchmarks for commercial farms striving for survival in the competitive industry. Therefore, the objectives of the present study were to characterize FS utilization efficiency by comparing FS utilization measurements between two farm groups categorized by the number of pigs weaned per FS per year, and to examine the relationship between the FS utilization measurements and possible factors.

**Materials and methods**

**Surveyed farm-level information and sow records**

In March 2009, questionnaires requesting information about FS were sent to producers on 115 commercial swine farms that use the PigCHAMP (PigCHAMP Inc., Ames, IA, U.S.A.) recording system. The producers were requested to give the data about the numbers of FS they had on January 1 and December 31, 2008, the number of workers for farrowing barns and batch farrowing system practice.

Of the 115 surveyed farms, 98 (85.2%) returned their completed questionnaires and mailed their PigCHAMP sow records for reproductive performance to Meiji University by November 2009. Two of the 98 farms were producing only purebred pigs, and another 2 did not inform about the number of FS, and so these four farms were excluded from the present study. Therefore, the present study comprised data and numbers of FS for 94 farms. The number of FS in 2008 was calculated by the numbers of FS on January 1 and December 31 in 2008 divided by 2. Of the 94 farms, two increased the number of FS during 2008, and three farms did not practice a weekly batch system. In addition, a part of the questionnaire data was used in companion studies about management procedures for breeding female pigs and their piglets (Ichikawa and Koketsu, 2012; Ichikawa et al., 2014).

Annual reproductive performance in 2008 and 13 four-weekly data for the number of females served and farrowing rate throughout the year were separately abstracted from PigCHAMP. The reproductive data were coordinated with the surveyed FS information. The reason for using the four-weekly data was that some farms studied were small or mid-sized (≤200 female pigs; 40% of the 94 farms) with <10 females mated per week, and those farms had extremely large variability when we measured 52 weekly data in preliminary analysis. The range of farm size was from 50 to 3,600 breeding female pigs. Also, for litter weights at weaning (kg), at least 70% of all the litters weaned were weighed and re-
Definitions and farm categories

Females included mated gilts and sows. A gilt was defined as a female pig that was entered a farm, and was mated at least once, but had not farrowed; a sow was a female pig that had farrowed at least once. Definitions and calculations regarding FS utilization measurements in the present study are shown in Table 1. The 94 farms studied were categorized into two groups on the basis of the upper 25th percentile of number of pigs weaned per FS per year: high-performing farms for FS utilization and ordinary farms.

Within-farm variability and time-series data

In addition to herd reproductive performance data, a set of two time-series data for total number of females served and farrowing rate per 4-week in a year (13 periods) during the year was created for each farm to obtain mean and its standard deviation (SD) of successive observations (Statistix 9, Analytical Software, Tallahassee, FL). The CV was used as a within-farm variability measurement.

A time lag existed between the two datasets: the time-series data and herd reproductive performance data. It was assumed that the interval between the time a female was served and the time that the female farrowed was approximately 16 weeks. The first time-series data for the number of farrowing sows was obtained from Dec. 30, 2007 to Dec. 27, 2008. The second set of time-series data for the total number of females served was obtained from Sep. 9, 2007 to Sep. 6, 2008, which was the period running 16 weeks previous to the farrowing sow time-series data.

Statistical analysis

The observational unit was the farm. Comparisons between the high-performing farms and ordinary farms for herd reproductive performance and FS utilization measurements were analyzed by analysis of variance. Person correlation analysis was also performed to obtain coefficients between two variables. In the statistical model, the number of pigs weaned per FS per year was used as an outcome variable, and the 5 explanatory factors (lactation length, annual farrowing rate, female inventory, CV for total number of females served and CV for farrowing rate) were used. The explanatory variables were fit using backward elimination in the REG procedure (SAS institute, Cary, USA). The quadratic expressions of all the explanatory variables remaining in the model were examined. Next, interactions of all the explanatory variables remaining in the model were examined. In addition, normality of the residuals from the model was confirmed by using the rankit plots.

Results

Means (±SEM) of pigs weaned per FS per year, litters farrowed per FS per year and the CV of the
total number of females served per 4-week in a year were 97.33±2.70 pigs, 9.86±1.28 litters and 12.82±0.79%, respectively. High-performing farms based on FS utilization efficiency had 42.91 more pigs weaned per FS per year, 3.89 more litters farrowed per FS per year and 231 kg heavier pig weaning weights per FS per year than ordinary farms (P < 0.05; Table 2). High-performing farms also had 1.48 more female inventories per FS than ordinary farms (P < 0.05). With respect to the within-farm variability measurements, high-performing farms had 4.83% lower CV for females served per 4-week in a year than ordinary farms (P < 0.05).

In terms of herd management measurements, high-performing farms had 2.17 days shorter lactation length than ordinary farms (P < 0.05), but there was no difference between the two farm groups for the number of FS per farm worker.

Correlation analysis showed that the higher number of pig weaned per FS per year was correlated with more litters farrowed per FS per year, heavier pig weaning weights per FS per year and more female inventories per FS (P < 0.01; Table 3). The higher number of pigs weaned per FS per year was also correlated with shorter lactation length, higher annual farrowing rate and lower CV% of farrowing rate per 4-week in a year (P < 0.01).

In modelling, a higher number of pigs weaned per FS per year was associated with higher annual farrowing rate, shorter lactation length and a lower CV% for total number of females per 4-week in a year that had been served 16 weeks previously (P < 0.01; Table 4). There were no two-way interaction or quadratic expressions. Additional correlation

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**Table 2.** A comparison between two farm groups\(^1\) for farrowing space (FS) utilization and reproductive productivity measurements on 94 farms

| Measurements                                   | Mean (SEM)          | Mean (SEM)          |
|-----------------------------------------------|---------------------|---------------------|
|                                               | High-performing     | Ordinary farms      |
|                                               | farms               |                     |
| Farm number                                   | 23                  | 71                  |
| FS utilization efficiency measurement         |                     |                     |
| Number of pigs weaned per FS per year, pigs   | 129.74 (3.52)\(^a\) | 86.83 (2.29)\(^b\) |
| Litters farrowed per FS per year              | 13.07 (0.38)\(^a\)  | 9.18 (0.23)\(^b\)  |
| Pig weaning weight per FS per year, kg        | 836 (20.6)\(^a\)    | 605 (17.3)\(^b\)   |
| Within-farm variability measurements per 4-week in a year |             |                     |
| CV\(^2\) for total number of females served per 4-week (16 weeks previously), % | 9.18 (0.96)\(^a\)  | 14.01 (0.96)\(^b\) |
| CV\(^2\) for farrowing rate per 4-week in a year, % | 5.17 (0.56)\(^a\)  | 8.67 (0.52)\(^b\)  |
| Herd management factors                       |                     |                     |
| Lactation length, days                        | 20.95 (0.47)\(^a\)  | 23.12 (0.24)\(^b\) |
| Number of FS per farm worker                  | 23.20 (2.52)        | 24.27 (1.56)        |
| Female inventory measurements                 |                     |                     |
| Female inventory, pigs                        | 715 (199)\(^a\)     | 313 (43.26)\(^b\)  |
| Female inventory per FS, pigs                 | 6.04 (0.17)\(^a\)   | 4.56 (0.12)\(^b\)  |
| Productivity measurements                     |                     |                     |
| Litters farrowed per mated female per year    | 2.39 (0.02)\(^a\)   | 2.27 (0.02)\(^b\)  |
| Annual farrowing rate, %                      | 86.83 (0.64)\(^a\)  | 80.15 (0.95)\(^b\) |
| Number of pigs weaned per sow, pigs           | 9.93 (0.10)\(^a\)   | 9.49 (0.07)\(^b\)  |

\(^a\)\(^b\) Values within a row without a common superscript are different (P < 0.05).

\(^1\) Farms were categorized into two groups on the basis of the upper 25\(^{th}\) percentile of the number of pigs weaned per FS per year: high-performing farms and ordinary farms.

\(^2\) CV : the coefficient of variation.
Table 3. Correlation coefficients between key measurements and farrowing space (FS) utilization or the coefficient of variation (CV, %) of the number of females served per 4-week in a year (16 weeks previously) on 94 farms.

| Key measurements                                                                 | Correlation coefficients with two measurements |
|----------------------------------------------------------------------------------|-----------------------------------------------|
| FS utilization measurements                                                      |                                               |
| Litters farrowed per FS per year                                                 | 0.97*                                         |
| Pig weaning weight per FS per year, kg                                            | 0.92*                                         |
| Female inventory per FS, pigs                                                    | 0.88*                                         |
| Possible factors                                                                 |                                               |
| Litters farrowed per mated female per year                                       | 0.44*                                         |
| Number of pigs weaned per sow, pigs                                              | 0.34*                                         |
| Annual farrowing rate, %                                                          | 0.41*                                         |
| Lactation length, days                                                           | −0.50*                                        |
| Number of FS per worker                                                           | 0.01                                          |
| CV for farrowing rate per 4-week in a year, %                                     | −0.45*                                        |
| FS utilization measurements                                                      |                                               |
| Litters farrowed per FS per year                                                 | −0.44*                                        |
| Pig weaning weight per FS per year, kg                                            | −0.59*                                        |
| Female inventory per FS, pigs                                                    | −0.32*                                        |
| Reproductive efficiency measurements                                             |                                               |
| Litters per mated female per year                                                 | −0.44*                                        |
| Number of pigs weaned per sow                                                    | −0.40*                                        |
| Annual farrowing rate, %                                                          | −0.31*                                        |
| Lactation length, days                                                           | 0.34*                                         |
| Within-farm variability measurement per 4-week in a year                          |                                               |
| CV of farrowing rate per 4-week in a year, %                                     | 0.62*                                         |

*indicates P<0.01.

Table 4. Factors associated with pigs weaned per farrowing space per year

| Explanatory factors                                                                 | R-squared | Regression coefficient (SE) |
|-----------------------------------------------------------------------------------|-----------|-----------------------------|
| Coefficient of variation of total number of females served per 4-week in a year   | 0.38      | −0.89 (0.31)*               |
| Annual farrowing rate, %                                                          |           | 0.79 (0.30)*                |
| Lactation length, days                                                            |           | −3.86 (1.00)*               |

*indicates P<0.05.

Analysis showed that a lower CV% for total number of females per 4-week in a year that had been served 16 weeks previously was correlated with a lower CV% of farrowing rate per 4-week in a year and more litters farrowed per FS per year and more female inventories per FS (P<0.01; Table 3).
Discussion

The mean values of 13.07 litters farrowed and 129.7 pigs weaned per FS per year on the high-performing farms would be target values for producers who aim to improve the FS utilization efficiency. In order to optimize FS utilization efficiency, measured as the number of pigs weaned per FS per year, it is critical to increase the number of litters farrowed per FS per year and the number of pigs weaned per sow (Wilson et al., 1986). The increased number of litter farrowed per FS per year and the increased number of pigs weaned per sow can increase the pig weaning weight per FS per year. In fact, high performing farms based on the number of pigs weaned per FS per year had more litter farrowed per FS per year and heavier pig weights per FS per year than ordinary farms in our study.

In the present study, such an increase in the FS utilization efficiency per 4-week can be achieved by minimizing CV% for total number of females that had been served 16 weeks previously, maximizing farrowing rate and reducing lactation length. However, lactation length is actually being increased in the swine industry in order to improve growth performance in nursery and grower pigs (Hoshino and Koketsu, 2009). Furthermore, decreasing lactation length increases the percentage of sows with suboptimal performance (Koketsu et al., 1997). Additionally, reducing pre-farrowing days, which is number of days from due date when pregnant pigs were moved to FS, can be a problem, because pregnant pigs with fewer pre-farrowing days are at high risk of the pregnant pigs farrowing in gestation barns. Approximately 2% sows had gestation length 112 days or less (Sasaki and Koketsu, 2007). Therefore, lactation length and pre-farrowing days are not factors that producers wish to reduce too far. This indicates that decreasing CV% for the number of females served and improving farrowing rate are two of the best ways to increase FS utilization efficiency.

Producers managing breeding farms are recommended to reduce variability in the number of sows served per week in order to decrease within-farm production variability in the U.S.A. (Dewey et al., 1997). Furthermore, our study suggests that decreased CV% for total number of females served enable producers to increase the FS utilization efficiency such as the number of pigs weaned per FS per year and the number of female inventories per FS. In fact, high-performing farms based on the pigs weaned per FS per year had lower CV% for total number of females served, and more female inventories per FS per year than ordinary farms. It appears that decreased within-farm variability increase the capacity of female inventory on the farms. Additionally, decreased within-farm variability in the total number of females served increased reproductive productivity on U.S.A. commercial farms (Koketsu et al., 1999).

Finally, in our study high-performing farms based on FS utilization had more female inventories than ordinary farms. Large farms have use better facilities and the capability to hire more specialized workers than small farms (King et al., 1998). Therefore, it appears that large herds take advantage of their size to increase facility utilization efficiency in their farrowing barns.

In conclusion, the FS utilization efficiency appears to be improved due to decreased CV% for total number of females served, which can be decreased by stabilizing the numbers of sows and gilts served per 4-week and the farrowing rate. Also, improved FS utilization efficiency enables farms to increase the number of female inventory per FS and the farm capacity.

The present study is not a controlled experiment but an observational study using commercial farm data. This study also did not take into account herd health, nutrition, or genetics. However, even with such limitations, the present study provides practicing veterinarians and producers with valuable information about FS utilization on commercial farms that can help ensure appropriate FS utilization.

Acknowledgements

The authors gratefully thank cooperative producers for providing their data to be used in the
present study, and the PigCHAMP staff at Global Pig Farms, Inc. (Shibukawa, Gunma, Japan) for their technical assistance. We also thank Dr. I. McTaggart for his critical review of this manuscript. This work was supported by Research Project Grant from Meiji University, Japan.

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養豚生産農場における分娩スペースの使用効率の調査

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(2015年5月11日受付, 2015年11月25日受理)

要約 本研究の目的は, 生産農場における分娩スペース（FS）の使用効率の特徴を明らかにし, FS の使用効率の指標とその因子との関係を調べることである。同一生産ソフトを使用している115農場に, FS の使用についての質問票を送付し, 回答のあった94農場のFSとその農場の繁殖データを統合し分析に用いた。年間FS当たり離乳子豚数の上位25パーセンテイル値を用いて, 94農場をFS使用効率による高生産農場と普通農場に分類した。農場繁殖データに加えて, 1年間を4週間ごと13期間としたデータを農場ごとに抽出した。さらに農場内バラツキの測定値として, 4週間の総種付け数の13期間の平均とその変動係数（CV, %）を求めた。統計分析には相関分析と回帰分析を使用した。平均（±SEM）の年間FS当たり離乳子豚数は97.33±2.70頭, 年間FS当たり分娩腹数9.86±1.28腹, そして総種付け頭数CVは12.82±0.79%であった。FS使用効率による高生産農場は, 普通農場よりFS当たり42.91頭離乳頭数が多く, FS当たり3.89分娩腹数が多く, 4.83%総種付け頭数CVが少なくかった。FS当たりの多い離乳頭数は, 低い総種付け頭数CV%と高い年間分娩率に関連していた（P≤0.01）。本研究により高いFSの使用効率は, ピッグフローの農場内バラツキにおける交配マネジメントと関係していることが示唆された。

キーワード: 農場収容能力, 分娩施設, 分娩率, 飼養管理