Original Article

Effect of Increased Number of Pigs Weaned Compared to Pigs Born Alive on Sows' Subsequent Reproductive Performance in Japanese Commercial Breeding Herds

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Summary

The use of a fostering technique is common in commercial breeding herds. Using a fostering technique makes it possible for the number of pigs weaned (PW) by a sow to be higher than the pigs born alive (PBA) to that sow at farrowing. The objective of the present study was to examine fertility measurements of the sows having more PW than PBA in Japanese breeding herds. The present study included 163,047 parity records of 60,790 sows and lifetime records of 22,711 sows that farrowed during 2007 and 2008 in 113 herds. Sows were categorized into two groups on the basis of the difference between PBA and PW : namely Increased-PW ($PBA < PW$) and Decreased-PW ($PBA \geq PW$) groups. Two-level mixed-effects models were applied using a herd at level 2 and an individual record at level 1. Increased-PW sows in parity 1 accounted for 32.3% of all weaned sows, and for parity 2 or higher sows the proportion was 23.3%. Increased-PW sows had heavier adjusted 21-day litter weights than Decreased-PW sows ($P < 0.05$). However, the Increased-PW sows had a longer weaning-to-first-mating interval, lower farrowing rates and fewer subsequent PBA than Decreased-PW sows in all parity groups ($P < 0.05$). As PW increased from 4 to 15 pigs, the WMI of Increased-PW sows in parity 1 increased by 1.14 days, whereas those in parity 2 or higher increased by 0.50 days. Furthermore, Increased-PW sows that were categorized at parity 1 farrowing had lower retention rates at farrowing by parity 3 than parity 1 categorized Decreased-PW sows ($P < 0.05$). However, there was no difference in the retention rates at farrowing in parity 3 between Increased-PW sows and Decreased-PW sows categorized at parity 2 farrowing ($P = 0.15$). Increased-PW sows categorized at parity 1 or parity 2 farrowing had lower parity at removal and fewer average lifetime PBA than Decreased-PW sows ($P < 0.05$). In conclusion, Increased-PW sows had better lactational performance, but had lower reproductive performance and lifetime performance than Decreased-PW sows. Therefore, it is not recommend that producers have parity 1 sows foster too many piglets.

Keywords : Cross-fostering technique, Farrowing, Lactation, Pigs weaned, Swine

Introduction

The fostering technique is a strategy widely used in swine breeding herds²⁾. The technique is used to equalize the number of piglets per litter, and so improve pre-weaning survival of piglets¹³⁾. Additionally, in Japan, producers often try to have parity 1 sows foster more piglets than the number of pigs born alive (PBA) that the sows farrowed. The aim is to improve the sows' mammary gland development for good lactational performance beyond parity 2⁴⁾. So, using the fostering technique makes it pos-

sible to increase in the number of pigs weaned (PW) by a sow to more than the PBA to that sow at farrowing. Therefore, weaned sows can be categorized into two sow groups, Increased-PW sows ($PBA < PW$) or Decreased-PW sows ($PBA \geq PW$).

There is some concern that the fertility function in Increased-PW sows could be compromised by fostering too many piglets. The sows selected as Increased-PW sows may also have innately lower PBA than the Decreased-PW sows. However, there is no fertility measurement data for about Increased-PW sows, such as reproductive performance, lactational performance and lifetime performance. Reproductive performance, including PBA and weaning-to-first-mating interval (WMI), in parity 1 sows is significantly lower than that in parity 2 or higher sows¹⁶⁾. A previous study¹⁵⁾ showed that parity 1 sows with WMI 7 days or longer had lower lifetime performance than those with WMI 1–6 days. Additionally, lactational performance, i.e. milk yields of sows, is

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typically measured by adjusted 21-day litter weight to enable comparisons of lactational performance between sows at different parities with different PW and different lactation length¹⁷⁾. Therefore, the objectives of the present study were to assess fertility measurements of Increased-PW sows and to compare them with those of Decreased-PW sows in Japanese breeding herds.

Materials and Methods

Data and Herds

In 2009, producers in approximately 120 herds in Japan that use the PigCHAMP recording system (PigCHAMP Inc., Ames, IA, U.S.A.), were requested to mail their data files to Meiji University each time they renewed their yearly maintenance contract. At this time the PigCHAMP database comprised 1.9% of the 6,250 breeding herds in Japan and 4.9% of the 910,100 female pigs in the 6,250 herds⁸⁾. By August 31, 2009, data files had been received from 115 breeding herds. Two of these herds were excluded from the present study because the herds were producing only purebred pigs. Mean herd measurements in the two-year period between 2007 and 2008 were collected from the remaining 113 herds. Mean ($\pm$ SEM) herd size was 421 ± 53.0 females with a range between 44 and 3,637 females. Sows in the studied herds were mainly crossbreds between Landrace and Large White, either produced within the herds or replacement gilts purchased from national or international breeding companies. Breeding stocks in the national breeding companies were originally imported from the U.S.A. or Europe. Approximately 90% of the herds in Japan using PigCHAMP use artificial insemination, and the recommendation by their veterinarians is to service sows during the first estrus post-weaning.

Exclusion criteria for reproductive data

The dataset contained 181,234 parity records of 64,360 sows that farrowed in 2007 and 2008. Sows with PW 3 or fewer were excluded (6,763 parity records) because their suckling intensity was not strong enough to suppress the resumption of estrus during lactation¹²⁾. Sows with lactation length 0–13 days were also excluded (904 parity records) because the sows were likely to have poor reproductive performance¹⁸⁾. Also, sows with lactation length 29 days or longer, or sows with PW 16 pigs or more were excluded (10,520 parity records) because they might have been used as nurse sows. Sows with WMI 120 days or longer were considered as extreme and were not used in the analyses⁷⁾. Lifetime performance of a sow was calculated when the sow was removed. Therefore, 163,047 parity records of 60,790 sows and 22,711 lifetime records were used in the present study. Additionally, one herd had no adjusted 21-day litter weight records. Therefore, the data integrity of weaning litter weight and weaning piglet weight records were evaluated in the remaining 112 herds by their normality using either the Shapiro-Wilk test ($W > 0.95$) or the Kolmogorov-Smirnov test ($D < 0.05$). These tests showed that weaning litter weight and weaning piglet weight records of

sows in 11 herds were not normally distributed, and these records were thought to be inaccurate. Therefore, the adjusted 21-day litter weight records in these herds were not used. In preliminary analysis, there was no difference in adjusted 21-day litter weights between the datasets of the original 112 herds and the 101 herds remaining after the normality tests. Additionally, we did not investigate pre-weaning mortality in the present study because foster-in and -out events and nurse sow events were not accurately recorded in some herds.

Categories and definitions

The difference between PBA and PW (PBA-minus-PW) was calculated using PBA at farrowing minus PW at weaning within the same parity of the sow. Sows were classified into two groups on the basis of PBA-minus-PW (sow groups): namely Increased-PW ($PBA < PW$) and Decreased-PW ($PBA \geq PW$) groups. Parity records of sows were classified into two groups: parity 1 and parity 2 or higher.

Adjusted 21-day litter weight was defined as the weaning litter weight for a sow, which was adjusted to 21 days of age, 3–6 parities and 10 piglets per litter⁹⁾. Farrowing rate was estimated as the number of sows that farrowed divided by the number of serviced sows multiplied by 100. Retention rate at farrowing in parity 3 was defined as the percentage of sows that successfully reached the third parity, after having been categorized in either parity 1 or parity 2. Retention rate at farrowing in parity 2 (%) was also calculated as number of sows that survived at second parity or higher divided by the number of sows farrowing at first parity, multiplied by 100. Average lifetime PBA was defined as the sum of PBA in lifetime divided by the number of parity at removal.

Statistical analysis

All statistical analyses were performed using SAS software (SAS Int. Inc., Cary, NC). A Chi-square test was used to examine the difference between the frequency distribution of Increased-PW and Decreased-PW groups by parity groups. Two-level analysis was applied, using a herd at level 2 and an individual record at level 1, to take account of the hierarchic structure of the individual female pigs within a herd¹¹⁾. A linear mixed-effects model using the MIXED procedure with a Tukey-Kramer multiple comparisons test was applied for adjusted 21-day litter weights, reproductive performance and lifetime performance of sows. A natural log-transformation was used on WMI data to obtain a normal distribution. After analyses, a back-transformation of the log-transformed WMI was performed to present the results in Table 2 and Figure 1. Additionally, a mixed-effects logistic regression model using the GLIMMIX procedure with contrasts was used for binary data, i.e. whether or not a sow farrowed (farrowing rate; 1 or 0), and whether or not a sow reached the second or third parity or higher (retention rates; 1 or 0). The ILINK option was used to back-transform least squares means into the original unit of binary measurements.

Model 1 compared reproductive performance of sows between

Fig. 1 Predicted weaning-to-first-mating interval (WMI) of Increased-PW sows under different numbers of pigs weaned by two parity groups. The prediction line equation ($\pm$ SE) is $\hat{Y} = 1.6116 (0.0270) + 0.0083 (0.0019) \text{ PW} + 0.1311 (0.0367) \text{ Parity} + 0.0072 (0.0036) \text{ PW} \times \text{Parity} - 0.0113 (0.0011) \text{ LL} - 0.0001 (0.0001) \text{ Herd size} + \text{Herd} + \text{Sow within the herd}$, where $\hat{Y}$ = Log-transformed WMI, PW = number of pigs weaned, Parity = parity 1 or parity 2 or higher (1 or 0) and LL = lactation length. The log-transformed WMI was back-transformed to obtain WMI.

sow groups and parity groups. Independent variables in Model 1 were sow groups, parity groups and a two-way interaction between the sow groups and parity groups. The two-way interaction between the two groups was removed from Model 1 when it was not significant ($P \geq 0.05$). Model 2 was constructed to compare adjusted 21-day litter weight, retention rates and lifetime performance of sows between the two sow groups. The independent variable in Model 2 was sow groups. For retention rates and lifetime performance, sows at parity 1 or parity 2 farrowing were categorized as either Increased-PW or Decreased-PW sows. The retention rates and lifetime performance of Increased-PW sows and Decreased-PW sows were compared at parity 1 and parity 2. Model 3 was constructed to quantify the associations between PW and WMI of Increased-PW sows by the two parity groups. The PW and parity groups were included as independent variables in Model 3. The quadratic expression of PW and a two-way interaction between PW and parity groups were also examined in the Model.

All the Models included farrowing year, four farrowing seasons (January to March, April to June, July to September and October to December) and two regions in Japan (East or West Japan) as blocks, and also herd size as a covariate. Additionally, lactation length was included as a covariate in Models 1 and 3, but was not included when PBA was analyzed. Herd size was subtracted at the herd mean, and lactation length was subtracted from the respective grand-mean. All the Models included the herd as a random intercept. Furthermore, the Models for reproductive performance included 3 four-monthly periods within the herd as a random intercept. The 3 four-monthly periods were used to ac-

count for part of the correlation of data within a sow in the Models.

Cross-classified frequency distribution and repeatability

Cross-classified frequency distribution and repeatability were obtained by using sows having three or more consecutive parity records. A Chi-square test was used to examine the difference between the frequency distribution of sow groups at consecutive parities from parity 1 to parity 4 or higher. The SURVEYSELECT procedure was used to randomly select 55 farms with approximately 50% of the parity records from the 113 herds, because there was a computational limitation due to the large number of records. Variance components analysis was conducted with the VARCOMP procedure. The repeatability for becoming an Increased-PW sow was determined as $S^2_{\text{sow nested within herd}} / (S^2_{\text{sow nested within herd}} + S^2_{\text{error}})$. The model for becoming an Increased-PW sow included parity, lactation length, farrowing year and the four farrowing seasons as fixed effects, and sows nested within a herd as a random effect.

Results

Of 163,047 parity records, 25.0% had more PW at weaning than PBA at farrowing. The proportion of Increased-PW sows in parity 1 was 32.3% of all weaned sows, and also for parity 2 or higher sows the proportion was 23.3%. Increased-PW sows in parity 1 and parity 2 or higher both has a mean of nearly three extra pigs weaned compared to PBA (PBA-minus-PW; Table 1). With regard to the main effects, Increased-PW sows had fewer PBA (7.3 vs. 11.9 pigs) and more PW (10.1 vs. 9.8 pigs) than Decreased-PW sows ($P < 0.05$). Also, parity 1 sows had fewer PBA and more PW than parity 2 or higher sows ($P < 0.05$). However, there was a two-way interaction between the two groups for PBA, and no difference was found between the PBA of Increased-PW sows in parity 1 and those in parity 2 or higher ($P = 0.99$). Additionally, there were no differences between sow groups and parity groups for PW ($P = 0.22$).

Table 2 shows comparisons of lactational performance and reproductive performance between the two sow groups and the two parity groups. Increased-PW sows had 2.7 kg heavier adjusted 21-day litter weight than Decreased-PW sows ($P < 0.05$). There were three two-way interactions between the two groups for WMI, farrowing rate and subsequent PBA, with Increased-PW sows having longer WMI, lower farrowing rate and fewer subsequent PBA than Decreased-PW sows ($P < 0.05$). The comparison between the two parity groups revealed that Increased-PW sows in parity 1 had longer WMI and lower farrowing rate than those in parity 2 or higher ($P < 0.05$). However, there was no difference in subsequent PBA between the two parity groups in Increased-PW sows ($P = 0.07$).

Table 3 presents comparisons of retention rates and lifetime performance between the two sow groups. Increased-PW sows categorized at parity 1 farrowing had 0.9–1.2% lower retention

Table 1 Comparisons of pigs born alive (PBA) and the difference between PBA and pigs weaned (PW ; PBA-minus-PW) between two sow groups¹ and two parity groups

Parity	Sow groups			
	Increased-PW		Decreased-PW	
	N	Mean $\pm$ SE ²	N	Mean $\pm$ SE
Pigs born alive, pigs				
1	10,111	7.3 $\pm$ 0.10 ^b	21,175	11.6 $\pm$ 0.10 ^{ay}
2 or higher	30,655	7.2 $\pm$ 0.10 ^b	101,106	12.2 $\pm$ 0.10 ^{ax}
PBA-minus-PW, pigs				
1	10,111	-2.9 $\pm$ 0.07 ^{by}	21,175	1.8 $\pm$ 0.06 ^{ay}
2 or higher	30,655	-2.8 $\pm$ 0.06 ^{bx}	101,106	2.5 $\pm$ 0.06 ^{ax}

^{a,b} Means within a row with different letters differ ($P < 0.05$).

^{x,y} Means within a column with different letters differ ($P < 0.05$).

¹ Sows were classified into two groups on the basis of the PBA-minus-PW in the same parity: Increased- (PBA < PW) and Decreased-PW groups (PBA $\geq$ PW).

² Means and SE were estimated by two-level mixed-effects models.

Table 2 Comparisons of lactational performance and reproductive performance between two sow groups¹ and two parity groups

Parity	Sow groups			
	Increased-PW		Decreased-PW	
	N	Mean $\pm$ SE ²	N	Mean $\pm$ SE
Adjusted 21-day litter weight, kg				
	21,774	66.5 $\pm$ 0.78 ^a	80,715	63.8 $\pm$ 0.78 ^b
Weaning-to-first-mating interval ³ , days				
1	9,607	6.7 $\pm$ 1.02 ^{ax}	20,284	5.5 $\pm$ 1.02 ^{bx}
2 or higher	26,651	6.6 $\pm$ 1.02 ^{ay}	89,594	5.4 $\pm$ 1.02 ^{by}
Farrowing rate, %				
1	9,607	85.9 $\pm$ 0.96 ^{by}	20,284	87.2 $\pm$ 0.86 ^{ay}
2 or higher	26,651	87.2 $\pm$ 0.89 ^{bx}	89,594	88.7 $\pm$ 0.74 ^{ax}
Subsequent pigs born alive, pigs				
1	8,176	10.1 $\pm$ 0.11 ^b	17,445	10.8 $\pm$ 0.11 ^{ay}
2 or higher	22,903	10.2 $\pm$ 0.11 ^b	78,818	11.3 $\pm$ 0.11 ^{ax}

^{a,b} Means within a row with different letters differ ($P < 0.05$).

^{x,y} Means within a column with different letters differ ($P < 0.05$).

¹ Sows were classified into two groups on the basis of the difference between pigs born alive (PBA) and pigs weaned (PW) in the same parity: Increased- (PBA < PW) and Decreased-PW groups (PBA $\geq$ PW).

² Means and SE were estimated by two-level mixed-effects models.

³ The log-transformed weaning-to-first-mating interval and SE were back-transformed to obtain the values of weaning-to-first-mating interval and SE.

rates at farrowing in parity 2–3 than similarly categorized Decreased-PW sows ($P < 0.05$). However, there was no difference in retention rate at farrowing in parity 3 between the two sow groups

categorized at parity 2 farrowing ($P = 0.15$). Parity at removal and average lifetime PBA were lower in Increased-PW sows than in Decreased-PW sows for sows categorized at both parity 1 and

Table 3 Comparisons of retention rates¹ and lifetime performance of sows between two sows groups²

Measurements	Sow groups			
	Increased-PW		Decreased-PW	
	N	Mean ± SE ³	N	Mean ± SE
For an Increased-PW or Decreased-PW sow categorized at the parity 1 farrowing				
Retention rate at farrowing in parity 2, %	10,111	95.2 ± 0.30 ^b	21,175	96.1 ± 0.33 ^a
Retention rate at farrowing in parity 3, %	10,111	87.6 ± 0.82 ^b	21,175	88.8 ± 0.72 ^a
Parity at removal	3,675	2.7 ± 0.07 ^b	7,296	2.8 ± 0.07 ^a
Average lifetime pigs born alive	3,675	8.4 ± 0.10 ^b	7,296	11.1 ± 0.10 ^a
For an Increased-PW or Decreased-PW sow categorized at the parity 2 farrowing				
Retention rate at farrowing in parity 3, %	8,351	95.4 ± 0.40	20,059	95.8 ± 0.33
Parity at removal	3,584	4.0 ± 0.07 ^b	8,156	4.1 ± 0.07 ^a
Average lifetime pigs born alive	3,584	9.1 ± 0.11 ^b	8,156	11.1 ± 0.11 ^a

^{a,b} Means within a row with different letters differ (P<0.05).
¹ The outcomes were back-transformed to obtain the values of retention rates and SE.
² Sows were classified into two groups on the basis of the difference between pigs born alive (PBA) and pigs weaned (PW) in the same parity: Increased- (PBA<PW) and Decreased-PW groups (PBA≥PW).
³ Means and SE were estimated by two-level mixed-effects models.

Table 4 Cross-classified frequency distribution¹ (%) of sows by two sow groups² between consecutive parities from parity 1 to parity 4 or higher

Sow groups	N	Sow groups at subsequent parity	
		Increased-PW (%)	Decreased-PW (%)
Parity 1			
Increased-PW	2,113	37.4	62.6
Decreased-PW	4,330	28.1	71.9
Parity 2			
Increased-PW	2,199	34.9	65.1
Decreased-PW	5,268	20.8	79.2
Parity 3			
Increased-PW	1,610	34.2	65.8
Decreased-PW	5,216	20.4	79.6
Parity 4 or higher			
Increased-PW	3,308	34.7	65.3
Decreased-PW	12,658	19.6	80.4

¹ Frequencies of within a row add up to 100%. The frequency distribution differed between the sow groups at subsequent parity groups (P<0.01).
² Sows were classified into two groups on the basis of the difference between pigs born alive (PBA) and pigs weaned (PW) in the same parity : Increased- (PBA<PW) and Decreased-PW groups (PBA≥PW).

parity 2 farrowing (P<0.05).
There was an association between PW and WMI of Increased-PW sows (P<0.05), but there was no significant quadratic expression of PW for the WMI (P=0.06). In addition, a two-way interaction between PW and parity groups was found for WMI

(P<0.05). Figure 1 shows predicted WMI of Increased-PW sows for different PW for the two parity groups. As PW increased from 4 to 15 pigs, the WMI of Increased-PW sows in parity 1 increased by 1.14 days, while those in parity 2 or higher increased by only 0.50 days.

Frequency distributions (%) of Increased-PW and Decreased-PW sows differed between consecutive parities ($P < 0.05$; Table 4). Just over one third of Increased-PW sows in any parity continued to be Increased-PW sows at subsequent parity. In the analysis of repeatability, the variance components in the sow nested within a herd and the error were 1.02 and 4.55, respectively. Therefore, using the repeatability equation described in the Materials and Methods, the repeatability of becoming an Increased-PW sow was 0.18.

Discussion

Our study showed that Increased-PW sows had longer WMI than Decreased-PW sows, and that the rate of increase in WMI as PW increased was greater for Increased-PW sows in parity 1 than for those in parity 2 or higher. These results indicate that it is hard for Increased-PW sows in parity 1 to suckle a large number of piglets, and agree with results from earlier studies that showed sows suckling a large number of piglets had prolonged WMI post weaning^{1,3)}. Additionally, the present study also implies that Increased-PW sows had higher milk yields than Decreased-PW sows. Various studies have shown that parity 1 sows consume insufficient amounts of feed to meet the required nutrient and energy intake levels for high milk yields and optimal reproductive functions^{5,6,10)}. This suggests that it is possible that the reproductive function of Increased-PW sows in parity 1 is impaired to a certain degree due to suckling many piglets and having a low feed intake. Therefore, it may not be good practice for producers in this study to have parity 1 sows foster too many piglets.

Increased-PW sows had lower reproductive performance, lower longevity and fewer lifetime PBA than Decreased-PW sows. These results indicate that Increased-PW sows are less efficient in reproductive performance than Decreased-PW sows, and are at risk of early culling. Our study is consistent with a previous study which reported that the low efficiency sows had characteristic low PBA, prolonged WMI and low farrowing rate across parity in their lifetime¹⁴⁾. Furthermore, in our study, Increased-PW sows categorized at parity 1 farrowing had lower retention rates than Decreased-PW sows. Thus, it appears that these low efficiency Increased-PW sows were treated differently from the Decreased-PW sows.

The present study showed that at least 30% of Increased-PW sows continued to be Increased-PW sows at subsequent parity, and suggests that a similar figure of about one third of Increased-PW sows are likely to remain as Increased-PW sow at subsequent parity in commercial herds. The study also showed a repeatability of 0.18 of becoming an Increased-PW sow.

In conclusion, the results of this study suggest that producers should not have parity 1 sows foster too many piglets. Additionally, the lower lifetime performance of Increased-PW sows, the lower retention rates in Increased-PW sows than Decreased-PW sows, and the repeatability in our study indicates that some In-

creased-PW sows were innately infertile.

Finally, it is noteworthy that this study was an observational study performed using commercial herds. Herd health, genetics and nutrition were not taken into account in the analyses. However, even with such limitations, this research provides valuable information about the characteristics of Increased-PW sows for swine producers and veterinarians.

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原 著

日本の養豚農場における分娩時生存産子数より増加した離乳時子豚数が 初産豚の次産次繁殖成績へ及ぼす影響

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要旨

養豚農場において、里子技術は一般的に行われているマネジメントである。里子技術により、母豚の離乳時子豚数(PW)は分娩時生存産子数(PBA)よりも多くなることがある。本研究は、日本の農場においてPWがPBAよりも多かった母豚の成績を調査することを目的とした。113農場における2007年から2008年に分娩した経産豚60,790頭の163,047回の産次記録と、22,711頭の生涯記録を分析に用いた。母豚は、PWがPBAよりも多いIncreased-PW母豚と、PWがPBA以下であったDecreased-PW母豚に分類された。分析には母豚をレベル1、農場をレベル2とした2階層混合効果モデルを用いた。Increased-PW母豚の分布割合は1産次で32.3%、2産次以上で23.3%であった。Increased-PW母豚の補正21日齢一腹子豚体重は、Decreased-PW母豚よりも重かった($P<0.05$)。しかし、Decreased-PW母豚に比べ、Increased-PW母豚の離乳後初回交配日数

は長く、分娩割合は低く、次産次PBAは少なかった($P<0.05$)。PWが4頭から15頭に増加するにつれ、1産次のIncreased-PW母豚では離乳後初回交配日数は1.14日増加したが、2産次以上のIncreased-PW母豚では0.50日しか増加しなかった。さらに、Increased-PW母豚の3産次までの生存割合は、Decreased-PW母豚よりも低かった($P<0.05$)。同様に、Decreased-PW母豚に比べ、Increased-PW母豚の淘汰産次は低く、生涯平均生存産子数も少なかった($P<0.05$)。結論として、Increased-PW母豚はDecreased-PW母豚よりも良い授乳成績であったが、繁殖成績、生涯成績は低かった。生産者は、1産次の母豚にあまりに多くの子豚を里子するべきではない。

キーワード：里子技術、分娩成績、授乳成績、離乳時子豚数、豚

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