国内農場における繁殖雌豚への2回交配と3回交配の経済的利益の比較

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Comparisons in Economic Returns between Double- and Triple Matings in Female Pigs in Commercial Herds

Yasutaka TAKAI**, Yosuke SASAKI and Yuzo KOKETSU*

School of Agriculture, Meiji University, Kawasaki, Kanagawa, Japan 214–8571
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Summary

The present study compared economic returns between double- and triple matings in first-serviced and reserviced female pigs. Our reproductive performance data included 102,553 service records in 117 commercial herds. The service included a single- or more mating events during estrus. The economic models for returns over mating costs per service were constructed by using the data on reproductive performance and economic assumptions. The value for a weaned pig was estimated by the market price per pig minus the costs for feed, vaccines, veterinary treatments, transportation, slaughter fees, labor and utility per pig. Sensitivity analysis was performed to determine a threshold point for the farrowing percentage in the double matings required to exceed the returns in the triple matings. In the first-service group, triple-mated gilts and sows had higher farrowing percentages and number of pigs born alive (PBA) than double-mated gilts and sows ($P<0.05$). In the reservice group, no differences in farrowing percentage and PBA were found between double- and triple matings. The value per pig weaned was \$101.1. For first-serviced gilts and sows, returns over mating costs for triple matings were higher than those for double matings. We recommend performing triple matings for females to be first-serviced, and double matings for females returning to estrus for maximizing profitability in Japan. Additionally, our sensitivity analysis indicates that the returns in double matings for sows would surpass those in triple matings when producers increase the farrowing percentage by 1.0%.

Keywords : cost, economic model, farm management, mating frequency

Introduction

Double- or triple matings during an estrus period are recommended over single mating for female pigs (females) to optimize the farrowing percentage and number of pigs born alive (PBA)[3,4,22]. The issue is which is more beneficial for producers, double- or triple matings. Triple-mated gilts have a higher farrowing percentage than double-mated gilts in commercial herds[26]. In a controlled study, the PBA for triple-mated sows was higher than double-mated sows[25]. However, maximized farrowing percentage and PBA might not necessarily offset the costs of mating[18]. The increased mating costs necessary for superior performance might reduce profitability in some commercial herds. Double matings have been used more often than triple matings in commercial herds in the U.S.A.[15].

In a simulation study using theoretical biological values and economic assumptions for pigs weaned in the U.S.A., triple matings were found to yield higher economic returns than double matings[11]. Biological values and economic assumptions vary significantly among countries. In fact, Japanese commercial herds incur higher costs but realize a higher market price for pigs than herds in U.S.A.[12,17].

Economic analysis is a tool for producers and veterinarians to make decisions relating to their farm operations[13]. The value per pig weaned is necessary to perform economic analysis for breeding herds, although there is no market for weaned pigs in Japan. Opportunity costs have been frequently used for economic analyses in conjunction with sensitivity analyses[5,13]. Opportunity cost or economic opportunity loss is the value of the alternative forgone as the result of making a decision[14], but is not treated as an actual cost. The concept of opportunity cost has been applied to veterinary economics for mortality costs due to a disease[5,24]. The value per pig weaned can be estimated by using the concept of opportunity cost.

No literature was available on the comparative study of

* Corresponding author :
Yuzo KOKETSU
School of Agriculture, Meiji University, Higashi-mita 1–1–1, Tama-ku, Kawasaki, Kanagawa, Japan 214–8571
Tel : 81–44–934–7826 ; fax : 81–44–934–7902;
E-mail : koket001@isc.meiji.ac.jp
** Present address :
Takai, Y., Research and Development, Kyodo Shiryo Co., LTD. Higashi-shirakawa, Fukushima, Japan 963–5115

economic returns between the double- and the triple matings using the estimated value per weaned pig combined with reproductive performance data in commercial herds. Additionally, sensitivity analysis is another tool available to investigate the effect on returns when one parameter is varied over a possible range of values while holding the rest of the variables in the analysis constant[5]. Therefore, the objective of the present study was to investigate economic returns for double- and triple matings practiced in first-serviced and reserviced females based on reproductive performance data, economic assumptions, and sensitivity analysis.

Materials and methods

Performance Data

Performance data such as farrowing percentage and PBA were collected from an existing database (Meiji University, Kawasaki, Japan). The data analyzed were a subset of a larger dataset from a previous study performed by Takai and Koketsu[22]. The original dataset included 116,018 service records and 94,200 farrowing records of 54,722 females in 117 herds. Additionally, records of the second- or further reservices (number of services ≥ 3) were not used because the numbers of these records were few (1,931 service records and 935 farrowing records). Also excluded from the study as they were considered extreme were the following : missing records of farrowing events, records of sows with weaning-to-mating interval longer than 120 days, sows with lactation length <14 or >28 days, and females with reservice intervals longer than 150 days in 2,753 service records and 1,952 farrowing records of 570 females. Hence, the dataset included 111,334 service records and 91,313 farrowing records of 54,146 females. Records of single mating and four more matings (8,781 records) were excluded. Of the remaining 102,553 service records, 55,937 and 46,616 records included double and triple matings, respectively.

Animals and Herd Management

Females in the herds studied were mainly crossbreds between Large White and Landrace, or crossbred pigs purchased from international breeding companies. Both natural mating and artificial insemination (AI) were generally practiced in these herds.

Definitions of Production Parameters and Categories

A gilt was defined as a female that had not farrowed, and a sow was a female that had farrowed at least once. A mating was defined as any single AI or natural mating of a female during estrus. A service included a single- or more mating (insemination) events in the 10-day estrus period[16]. The number of services was divided into two groups : first-service and reservice. The first-service group included the first service in the reserviced females.

Statistical Analysis

All statistical analyses were performed with SAS software (SAS Inst. Inc., Cary, NC). Mixed-effects logistic regression models were applied for binary data (i.e. farrowing percentage) in the GLIMMIX procedure. Linear mixed-effects models were applied for continuous data (i.e. PBA) in the MIXED procedure. Statistical models were constructed to compare reproductive performance between the double- and triple matings in both first-serviced and reserviced females. Gilts and sows were separately analyzed, because explanatory variables for gilts differed from those for sows. First service and reservice records were also separately analyzed. Gilt models included the number of matings and age at first mating, whereas sow models included the number of matings, parity, lactation length and weaning-to-first-mating interval. All statistical models included the herds, four periods of three-month intervals, and the herd-period interaction as a random effect. The interaction was used to account for a part of individual services within a female, because each female was serviced on one or more occasions during the study period.

Gilt model for farrowing percentage was :

$$\text{Logit}\,(P_{ijk}) = \alpha + NM_i + AFM_j + F_k,$$

where P_{ijk} was probability of a gilt farrowing ; α was the intercept ; NM_i was the fixed effect of the ith group of the number of mating ($i = 2, 3$) ; AFM_j was a covariate; and F_k was the random effect of kth farm ($k = 1$ to 117). Gilt model for pigs born alive was :

$$Y_{ijk} = \mu + NM_i + AFM_j + F_k + e_{ijk},$$

where Y_{ijk} was the performance ; μ is the overall mean ; NM_i, AFM_j, and F_k were given as above ; and e_{ijk} was the random error.

Sow model for farrowing percentage was :

$$\text{Logit}\,(P_{ijklmn}) = \alpha + NM_i + PY_j + LL_k + WMI_l + F_m + P_n + F_m \times P_n,$$

where P_{ijk} was probability of a sow farrowing ; α was the intercept ; NM_i was the fixed effect of the ith group of the number of mating ($i = 2, 3$) ; PY_j, LL_k, and WMI_l was a covariate; F_m was the random effect of mth farm ($m = 1$ to 117) ; P_n was the random effect of nth period of four-month interval ($n = 1, 2, 3$). $F_m \times P_n$ was the random interaction effect between the mth farm and the nth period. Sow model for pigs born alive was :

$$Y_{ijklmn} = \mu + NM_i + PY_j + LL_k + WMI_l + F_m + P_n + F_m \times P_n, + e_{ijklmn},$$

where Y_{ijklmn} was the performance ; μ is the overall mean ; NM_i, PY_j, LL_k, WMI_l, F_m, and P_n were given as above ; and e_{ijklmn} was the random error.

Financial Analysis

Simple models for economic returns were constructed by using the reproductive performance from the present study. One U.S. dollar was treated equivalent to 100 Japanese yen. In the economic models, the 1,000 services category was used for first-serviced female models. In addition, the 100 services category was used for reserviced female models, because the percentage of reservice occurrences was approximately 10%[22]. The pre-weaning mortality value of 11.3% was obtained from a previous report[10]. The values for 3.1 feed conversion rate in fattening pigs and \$0.4 for feed cost per kg were used to the present study based on a previous report[7]. The mean value of market prices per marketed pig used were related to the period 2004 to 2007 in

herds having fattening pig inventory of 2,000 pigs or more[12]. The values of $20 for a dose of semen with a disposable catheter and $30 wage per hour were obtained from personal communications. Mean times spent per animal to perform routine activities of AI were 21.9 min and 12.6 min for gilts and sows, respectively[6]. The values of the costs for vaccines and veterinary treatments, transportation and slaughter fee, labor and utility were obtained from a producers' group.

Applying a concept of the opportunity cost[2], the value per pig weaned was estimated. The value for a weaned pig was defined as the difference between the returns obtained and the costs incurred in raising a pig to maturity and selling it at market price[2]. The mean of market prices per pig marketed for a four-year period obtained in the government web site[12] was corrected for mortality of fattening pigs (5.0%) from weaning to market[23]. The value per weaned pig in the present study was estimated as the corrected market price per pig marketed minus the costs for its feed, vaccines, veterinary treatments, transportation, slaughter fees, labor and utilities from weaning to market.

In economic return comparisons, the mating cost included the price of one dose of semen, a disposable catheter and labor costs of mating. We used the mating cost for estimating the cost of AI with purchased semen for our economic models. The AI with purchased semen is a simpler process than natural matings or on-farm AI, and we assumed that the costs of using purchased semen for AI were even lower. Additionally, our simple models could not account for the differences between mating frequency groups in facility space and equipments needed for increased PBA.

Return over mating cost per first-serviced females was calculated by the following equation :

Return over mating cost per first-serviced female = (Total revenue from 1,000 services − Mating cost for 1,000 services) / 1000 services. Similarly, return over mating cost per reserviced females was calculated as :

Return over mating cost per reserviced female = (Total revenue from 100 services − Mating cost for 100 services) / 100 services.

Sensitivity analysis

Sensitivity analysis was performed to determine how far producers using double matings should improve the farrowing percentage to surpass the returns for triple matings. Gilts and sows were separately studied in both the analyses. Sensitivity analysis[5] was done to examine the effects on the return per service when farrowing percentage was varied while holding the rest of the variables constant. The range of farrowing percentages used for the analyses was between 81 and 87%. Sensitivity analysis was not performed for varying PBA because higher PBA was highly correlated with higher farrowing percentage[20]. The threshold point was determined by setting it to the returns for triple matings and soloving for the performance in turn using a regression equation[5].

Results

Of the 111,334 service records, first-service- and reservices records were 100,443 (90.2%) and 10,891 (9.8%), respectively. In the first-service group, triple-mated gilts had a 3.2% higher farrowing percentage than double-mated gilts ($P<0.05$; Table

Table 1 Farrowing percentage and number of pigs born alive by the number of matings in first-serviced and reserviced females (Mean ± SEM)

Groups	n	Farrowing percentage, %	n	Pigs born alive
First-serviced gilts				
Number of matings				
Double	11,064	81.8 ± 0.37[b]	9,047	9.7 ± 0.10
Triple	7,505	85.0 ± 0.41[a]	6,379	9.8 ± 0.11
First-serviced sows				
Number of matings				
Double	39,775	83.5 ± 0.19[b]	33,220	10.4 ± 0.12[b]
Triple	34,358	85.5 ± 0.19[a]	29,376	10.6 ± 0.12[a]
Reserviced gilts				
Number of matings				
Double	1,293	66.1 ± 0.37	855	9.6 ± 0.15
Triple	1,006	63.6 ± 0.41	640	9.7 ± 0.17
Reserviced sows				
Number of matings				
Double	3,805	68.2 ± 0.75	2,593	10.3 ± 0.15
Triple	3,747	64.8 ± 0.78	2,429	10.4 ± 0.16

[ab] Values in the same groups within the column without common superscript letters differ ($P<0.05$).

Table 2 Biological- and economical assumptions applied to the economic models[a]

Variable	Value
Lactational and growth performance	
Preweaning mortality, %[b]	11.6
Feed conversion rate for fattening pigs,[c]	3.1
Body weight gain from 5 to 111 kg, kg	106.0
Economical assumptions	
Total feed used per pig marketed, kg	328.6
Feed price per kg, $[c]	0.40
Feed costs for the gain per pig marketed, $	131.4
Vaccines and veterinary treatments per pig, $	12.5
Transportation and slaughter fees, $	26.8
Utility cost per pig marketed, $	10.9
Labor cost per pig marketed, $	10.0
Market price per pig marketed, $[d]	307.1
Market price per pig corrected for fattening pig mortality (5.0%), $	291.7
Value for a weaned pig, $[e]	100.1
Mating cost	
Prices of a dose of semen and a disposable catheter, $	20.0
Labor for insemination (12.6 min per insemination) for sows (hourly wage at $30), $[f]	6.3
Labor for insemination (21.9 min per insemination) for gilts (hourly wage at $30), $[f]	11.0

[a] One dollar ($US) was treated equivalent to 100 Japanese yen.
[b] This single value was obtained from a previous report [9].
[c] These values were obtained from a previous report [7].
[d] This averaged value was obtained from previous reports [11].
[e] This value per pig weaned was estimated as the market price per pig ($291.7) minus the costs for feed ($131.4) and vaccines and treatments ($12.5), transportation and slaughter fees ($26.8), labor ($10.0) and utilities ($10.9) per pig marketed.
[f] The hourly wage was estimated to be $30, and mean time spent per animal to perform routine activities for gilts and sows was 21.9 min and 12.6 min, respectively [6].

1). No difference between double- and triple matings was found in PBA for the first-serviced gilts. Triple-mated sows also had 2.0% higher farrowing percentage and 0.2 more PBA than double-mated sows ($P<0.05$). In the reservice group, there were no differences between the double- and triple matings for farrowing percentage and PBA in gilts and sows.

Table 2 lists biological- and economical assumptions made for the present study. We calculated the market price per pig marketed and the value per pig weaned to be $291.7 and $100.1, respectively. The mating costs per service for gilts and sows were $31.0 and $26.3, respectively.

Table 3 shows the values for income potentials ($US) for use of 1,000 services for first-serviced gilts and sows. In the first-serviced gilts, triple matings yielded a higher return of $5 over mating costs compared to double matings. Likewise, in the first-serviced sows, triple matings yielded a higher return of $10 over mating costs compared to double matings. Additionally, returns over mating costs for double matings were higher than those for triple matings in both reserviced gilts and sows (Table 4).

Fig. 1 presents the results of sensitivity analyses for the returns per service for double matings obtained on varying the farrowing percentage between 81 and 87%. The farrowing percentage threshold values needed for the returns of double matings to surpass the returns of triple matings for gilts and sows were 82.4% and 84.5%, respectively. The returns for double matings surpassed the returns for triple matings as the farrowing percentage in gilts and sows increased by 0.6 and 1.0%, respectively. Sensitivity analysis was not carried out for the reserviced female category because no difference was detected between the mating frequency groups for any performance in this category.

Table 3 Economic returns for double- and triple matings for use of 1,000 services for gilts and sows to be first-serviced[a]

	Gilts		Sows	
	Number of matings		Number of matings	
Measurements	Double	Triple	Double	Triple
Farrowing percentage, %	81.8	85.0	83.5	85.5
Number of farrowed females	818	850	835	855
Pigs born alive per female	9.7	9.8	10.4	10.6
Pigs weaned per female	8.6	8.7	9.2	9.4
Total number of pigs weaned in 1,000 services	7,035	7,395	7,682	8,037
Value for a weaned pig, $	100.1	100.1	100.1	100.1
Total revenue from 1,000 services, $	704,204	740,240	768,968	804,504
Mating cost for 1,000 services, $	62,000	93,000	52,600	78,900
Return over mating cost per 1,000 services, $	642,204	647,240	716,368	725,604
Return over mating cost per first-serviced female, $	642	647	716	726

[a] Values for farrowing percentage and pigs born alive for double and triple matings employed in the present study.

Table 4 Economic returns for double- and triple matings for use of 100 services for reserviced gilts and sows returning to estrus[a]

	Gilts		Sows	
	Number of mating		Number of mating	
Measurements	Double	Triple	Double	Triple
Farrowing percentage, %	66.1	63.6	68.2	64.8
Number of farrowed females	66	64	68	65
Pigs born alive per reserviced female	9.6	9.7	10.6	10.7
Pigs weaned per reserviced female	8.5	8.6	9.4	9.5
Total number of pigs weaned in 100 services	561	550	639	618
Value for a weaned pig, $	100.1	100.1	100.1	100.1
Total revenue from 100 services, $	56,156	55,055	63,964	61,862
Mating cost for 100 services, $	6,200	9,300	5,260	7,890
Return over mating cost per 100 services, $	49,956	45,755	58,704	53,972
Return over mating cost per reserviced female, $	500	458	587	540

[a] Values used for farrowing percentage and pigs born alive for double- and triple matings were from the present study.

Discussion

Our study shows that performing triple matings is a better procedure than double matings for maximizing farrowing percentage and PBA in the first-serviced gilts and sows, and is consistent with the previous studies conducted[8,25,26]. The triple matings may have more opportunities for mating within an optimal period of estrus than the double matings[22]. From the economical standpoint, the present study shows more profits are possible in triple matings than those in double matings—a finding in agreement with a previous report using U.S.A. data[11]. Meanwhile, in both reserviced gilts and sows, double matings are enough to optimize profitability, because no difference between double- and triple matings was found in the performance outcomes. Additionally, the third mating during a late estrus or metestrus period resulted in suboptimal performance[18]. Females returning to estrus might have an optimal timing for mating which is not the same as that for first-serviced females. Reserviced females have shorter estrus duration—a major factor in ovulation timing— than females to be first-serviced[19,21].

Our sensitivity analyses indicated that employing double matings and increasing the farrowing percentage by only 1.0% improved the returns to over that obtained employing tripe matings. Costs of double matings are lower than those of triple matings including the costs of semen per dose, catheters and labor. Farrowing percentages of 82.4% for gilts and 84.5% for sows when using double matings might be feasible targets for commercial herds. The published benchmark of farrowing per-

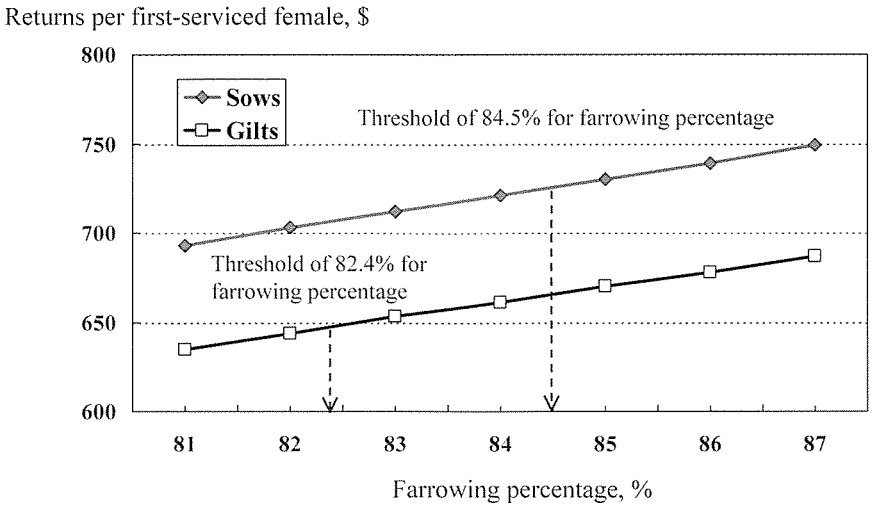

Fig. 1 Returns per service for sows and gilts using double matings in relation to farrowing percentage

centage for high-performing herds also was 85.7%[10]. An accurate detection of an initial stage of the estrus period in sows is critical for estimating the moment of ovulation and for pinpointing the insemination[9] that can result in improved farrowing percentage. Additionally, the higher farrowing percentage achieved by improving mating techniques results in higher PBA[20].

In conclusion, under the conditions in the current study, it is best to optimize profitability by employing triple matings for the females to be first-serviced and double matings for the females returning to estrus as is done in Japan. Additionally, increasing farrowing percentage and PBA by approximately 1.0% using double matings might improve the returns when triple matings are employed.

The limitations of the present study were that our cost calculation for mating frequency was based on AI costs using purchased semen, although the performance data included records performed by on-farm AI and natural matings. The higher costs of mating would reduce the thresholds. Additionally, as herd-to-herd variation in production costs would be very large in Japan, our results may not be applicable to all herds in that country. Even with these limitations, we believe that the present study provides valuable information on the economics on mating frequency for producers and veterinarians.

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原　著

国内農場における繁殖雌豚への2回交配と3回交配の経済的利益の比較

高井康孝・佐々木羊介・纐纈雄三*

〒214-8571　神奈川県川崎市多摩区東三田 1-1-1，明治大学農学部

要旨

本研究では雌豚への1回目種付け時と再種付け時での、2回と3回交配の経済的な利益の比較を行った。繁殖成績は117農場での102,553種付け記録を利用した。発情時期での1種付けには，1回以上の交配が行われている。1種付けあたりの費用と利益の経済モデルは，繁殖成績と経済的な仮定の値で作られた。離乳豚1頭あたりの価格は，市場価格から肥育コストである飼料費，ワクチン費，治療費，屠場までの運賃，屠場経費，労働費そして電気・水道・光熱費を差し引いて推定された。感受性分析は，2回交配における分娩率を上げる中で，3回交配による利益を追い抜く閾値を決定するようにしてなされた。初回種付けグループでは，3回交配された未経産豚と経産豚は2回交配された未経産豚と経産豚より，分娩率も分娩時生存産子数も上回っていた。再種付けグループでは，2回と3回交配の間で，分娩率も分娩時生存産子数にも差はなかった。離乳豚1頭あたりの価格は，101.1ドルと推定された。初回種付けの未経産豚と経産豚では，3回交配における純利益が，2回交配を上回った。それで，利益を最大にするために，日本では初回種付けされる雌豚には3回交配を，再発情した雌豚には2回交配を奨める。なお，感受性分析の結果は，生産者が2回交配で分娩率を1%上昇すれば，2回交配による利益が，3回交配による利益を超えることを示唆している。

キーワード：費用，経済モデル，農場マネジメント，交配回数

連絡先：纐纈雄三*
明治大学農学部
〒214-8571　神奈川県川崎市多摩区東三田 1-1-1
Tel : 044-934-7156 ; Fax : 044-934-7902
E-mail : koket001@isc.meiji.ac.jp