The replacement gilt: Current strategies for improvement of the breeding herd

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Summary

The efficiency of swine production is affected by many factors. One of the most economically important factors is gilt reproductive performance. To achieve satisfactory results in breeding, both environmental and genetic factors must be monitored and constantly improved. For many years, intensive selection in the swine industry for increased carcass muscle to fat ratio has led to deterioration in some reproductive traits (eg, less favorable development of the reproductive system in gilts, problems with fertilization, large litters but tiny piglets). In recent years, many producers have focused on increasing litter size and weaning weights of piglets in addition to an emphasis on increasing sow productive life span. In replacement gilts, the systematic evaluation of both reproductive and structural soundness is of paramount importance. The main aim of this review is to summarize the current criteria for selecting replacement gilts.

Keywords: swine, gilt selection, reproductive efficiency, replacement gilts, breeding herd

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Resumen – La hembra de reemplazo: Estrategias actuales para la mejora del hato de cría

La eficiencia de la producción porcina es afectada por muchos factores. Uno de los factores económicamente más importantes es el desempeño reproductivo de la hembra de reemplazo. Para lograr resultados satisfactorios en las hembras de cría, se deben monitorear y mejorar constantemente, tanto los factores los medioambientales y genéticos. Por muchos años, la selección intensiva en la industria porcina para el aumento en la relación músculo grasa de la canal ha llevado al deterioro de algunas características reproductivas (vg, un desarrollo menos favorable del sistema reproductivo en hembras de reemplazo, problemas de fecundación, camadas grandes pero lechones pequeños). En años recientes, muchos productores se han enfocado en el aumento el tamaño de la camada y peso de destete de los lechones, además del énfasis en el aumento de la vida reproductiva de la hembra. En las hembras de reemplazo, la evaluación sistemática de la solidez reproductiva y estructural es de primordial importancia. El principal objetivo de esta revisión es resumir los criterios actuales para la selección de hembras de reemplazo.

Résumé – La cochette de remplacement: Stratégies actuelles pour l'amélioration du troupeau reproducteur

L'efficacité de la production porcine est affectée par plusieurs facteurs. Un des plus importants facteurs économiques est la performance reproductrice des cochettes. Afin d'obtenir des résultats satisfaisants en reproduction, les facteurs environnementaux et génétiques doivent être surveillés et constamment améliorés. Pendant plusieurs années la sélection intensive dans l'industrie porcine pour l'augmentation du ratio muscle de la carcasse/gras a mené à la détérioration de certaines caractéristiques liées à la reproduction (eg, développement moins favorable du système reproducteur des cochettes, problèmes de fertilisation, portées nombreuses mais petits porcelets). Au cours des dernières années plusieurs producteurs se sont concentrés à augmenter la taille des portées et sur le poids des porcelets au sevrage en plus de mettre une emphase sur l'augmentation de la vie reproductive des truies. Chez les cochettes de remplacement l'évaluation systématique des qualités reproductive et structurale sont d'importance primordiale. L'objectif principal de la présente revue est de résumer les critères courants pour sélectionner les cochettes de remplacement.

Reproduction is one of the most important factors influencing the efficiency of livestock production. In swine production systems, management and selection of replacement gilts is of great importance as these gilts represent the future production potential of the herd.[1] Unfortunately, heritability of most reproductive traits is low, and thus it may be difficult to improve reproductive traits through selection.[2,3] Those low heritable traits, such as fertility and piglet survival rate, are dependent on complex interactions between sow, boar, and embryo or piglet genotypes. Although, traits dependent on the female genotype (ie, ovulation rate and age at puberty) are possible to improve.[4] Proper selection of replacement gilts is based on many factors ranging from predicted reproductive ability to phenotypic production traits. The culmination of genetic factors, such as adequate growth and development, as well as

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environmental factors, such as management and selection, must be efficiently managed to maximize profit. This review article presents the current state of knowledge regarding selection of replacement gilts and the reproductive issues associated with gilts.

Herd management

The future production potential of a herd is closely related to replacement selection. Proper gilt selection is not a guarantee of profit, stability, or high business efficiency, but is a prerequisite for success. The number of sows culled annually by a farm depends on many factors such as health, climate, management, and breeding system. Annual sow culling rates have been reported to be 35% to 59%.[5-11] According to Früh,[12] in organic farms, more sows are culled in indoor (47.7%) than outdoor housing systems (45.8%). High replacement rates during the year may adversely affect the herd performance and production costs. The main reasons for culling sows are reproductive issues, such as return to service, failure to conceive, and anestrus, but production issues such as small litter size and lameness also contribute.[7,13] Reproductive issues comprise 27% to 34% of all culled sows,[5,7] while lameness disorders account for 22.5%.[14] The occurrence of reproductive failure increasing non-productive days in the herd can cause frequent replacement of females.[15] Early culling practices reduce profit from the investment while late culling practices for low performing individuals can affect herd profitability.[16]

Years of unilateral pig selection to achieve a high growth rate and faster rates of lean muscle gain has negatively impacted sow reproductive performance.[17,18] Szostak[19] showed that a high rate of growth negatively influences fertilization effectiveness and number of piglets born and reared in the first litter. According to Hermesch et al,[20] litter size was negatively correlated with growth rate, especially in the first parity (r_g = -0.30 for 3 to 18 weeks; r_g = -0.42 for 18 to 22 weeks). The results of other studies showed fast growing gilts were less likely to farrow (r = 0.52).[21] Additionally, rapid growth can lead to infantile development of the reproductive system[22] and has negative genetic associations with sow reproductive lifetime (r = -0.02 to -0.08).[23] Despite this, development of new methods for improving breeding herd and genomic knowledge provides an opportunity to improve rearing ability. Su et al[24] reported that selection for total number born between 1992 and 2004 led to an increase of 3.8 piglets per litter for Danish Landrace and 3.0 piglets for Danish Yorkshire, reaching 15.6 and 16.7 piglets per litter respectively in 2015.[25] Reproductive traits have a low to moderate heritability and are affected largely by external and internal environment.[26,27] Heritability estimates range from 0 to 0.73 for age at puberty, 0 to 0.76 for total number piglets born, 0 to 0.66 for number of piglets born alive, and 0 to 0.23 for prenatal survival rate.[4] Therefore, many factors can cause problems with reproduction including management, lack of or unsystematic production results, semen quality, poor estrus detection, length of lactation, health, feed quality, feeding management (especially during lactation), ineffective insemination, and other reproductive disorders.[15,26] Those factors lead to return to service, thereby decreasing reproductive efficiency and increasing non-productive days. It also negatively impacts farm economics because producers are not able to maintain production levels.[28] Research conducted by Iida and Koketsu[29] on Japanese herds showed 11.6% of gilts and 9% of sows returned to service. In the United States, the percentage of animals returning to service were 14% for gilts and 7% to 9% for sows.[15,30] Gilts were more likely to return to service than sows but occurrence of anestrus is higher in groups of multiparous sows when lactation duration is 15 to 19 days.[31] Moreover, incorrect detection of estrus reduces farrowing rate and causes a decreased number of litters per sow per year.[32]

Age at puberty

Onset of puberty in gilts is associated with the occurrence of first estrus. Age of first estrus and mating or insemination of gilts has an impact on subsequent reproductive performance and longevity.[33-36] Age at puberty is moderately heritable (r = 0.38), so potential opportunities for selection exist.[37] To decide when to start breeding gilts and how long they can be retained in the breeding herd, producers should consider the housing system to be used, herd management practices, longevity, and reproductive performance.[38] The onset of puberty is influenced by many factors including genotype, technique and effectiveness of estrus detection, season, environment, boar exposure, nutrition, and health.[11,39-41]

Both longevity and future reproductive efficiency are dependent on age at first mating.[35,42] Ovulation rate at first estrus is lower than in subsequent cycles,[43] indicating that artificial insemination (AI) or natural breeding should be carried out in the second or third estrus.[44] Le Cozler et al[34] and Young et al[11] demonstrated that the age of first farrowing affects herd management and showed that younger gilts (< 185 days of age) had more piglets over parities 1 to 3 than older gilts. Whereas, Tummaruk et al[45] showed that females whose dams were gilts grew slower, had less backfat at 100 days of age, and were mated later than their counterparts reared from multiparous sows. Moreover, it was observed that females from smaller litters reached sexual maturity earlier than gilts from larger litters. Lammers et al[46] reported that gilts reach sexual maturity between 160 and 190 days of age. Similarly, Tummaruk et al[36] reported that sexual maturity occurred at 180 to 210 days of age (6 to 7 months), while the results of previous studies indicate 200 to 220 days.[38] In tropical climates, the first estrus of gilts was observed from 188 to 251 days of age.[36,47] In Scandinavian countries, the reported average age for onset of sexual maturity was: 229 days in March and 245 in November (Sweden),[48] 210 to 270 days with 120 kg body weight (Sweden),[45] and 235 days (Finland).[49]

Delayed age of first mating in gilts increases the number of non-productive days and can negatively influence subsequent reproductive performance. According to Kapelańska et al,[50] it is possible to decrease the age of first mating to less than 6.5 months of age without negative consequences to their future productivity. Moreover, it would be beneficial for a farm's economic efficiency in pig production. On the other hand, the rapid development of a gilt's reproductive system starts from 6 months of age and is usually concurrent with the first estrus cycle. Therefore, mating gilts at this time may have negative effects on growth of the gilt and number of piglets born.

Weight and backfat thickness

Body weight and backfat thickness have an impact on gilt reproduction.[51] The proper body weight at breeding is necessary to protect females against excessive weight loss during their first lactation.[52] In a study conducted by Williams et al,[53] gilts with lower body weight (< 135 kg) had smaller litters their first three parities (31.1 total piglets born) than heavier females (32.3 to 33.1 total piglets born). Small litter size occurred among gilts whose backfat thickness was more than 20 mm.[51] The studies conducted by Tummaruk et al[36] showed on average that Landrace × Yorkshire females had their first estrus at 195 days of age with 106 kg body weight and 13 mm backfat thickness. Recent research from the same laboratory showed that replacement gilts should be bred at 240 days of age, with 130 kg body weight and 17 mm backfat thickness.[47] It was confirmed by Amaral Filha et al[54] that the largest litters were from sows with backfat thickness 16 to 17 mm. Appropriate backfat thickness results in a positive effect on litter weight and consequently limits piglet losses in the rearing period. Kummer et al[55] suggested that AI in gilts between 185 and 209 days of age is possible without adverse effects if the growth rate of individuals exceeds 700 g/day.

Season and climate

Reproductive efficiency is significantly correlated with season due to seasonal infertility. Seasonal infertility is defined as the difference between the number of successful inseminations in the summer (weeks 25 to 42) and winter seasons (weeks 1 to 18) in the same year.[56] It has been shown that the farrowing rate is lower in spring and summer than in winter.[48] Additionally, gilts born in the spring reach puberty later than those born in autumn.[57] Jarczyk and Nogaj[58] found that birth in the spring and summer seasons, positively affected reproductive efficiency and lifetime performance. Moreover, sows born from September to February had smaller litters with a higher number of males than those sows born from March to August.[59] Kawęcka et al[60] found no effect of season on the effectiveness of AI. Additionally, they noted the beneficial effect of AI, especially in summer, on the fertilization rate and the number of piglets born alive per litter. These findings were confirmed by Rekiel et al[26] which showed that stabilization of the environment inside modern pig facilities eliminated the seasonal influence on reproduction efficiency.

Studies conducted in Thailand showed that reproductive efficiency is lower in tropical than in temperate zones. The factors negatively affecting reproduction, especially the delay of first estrus and decreased litter size, include high temperature and humidity.[61-65] Pigs are very sensitive to ambient temperatures, especially in the absence of proper ventilation and can quickly become overheated. Heat stress results in decreased ovulation rate, conception rate, decreased embryo survival, and abnormal development and mortality of embryos. Gilts are the most vulnerable to adverse environmental conditions.[65]

Selection criteria

Gilt selection criteria often vary based on production goals.[66] Routine selection of gilts provides the opportunity to choose the best female for breeding. First, pre-selection should be made on the day of weaning, choosing two or three more piglets than needed as replacements, and focused on the health of individuals and pre-weaning average daily gain.[67,68] Pre-weaning growth rate positively affected post weaning growth performance and subsequent reproductive performance of sows in later life.[68-70] Moreover, Vallet et al[70] reported that selection of gilts with high birth weight characterized by slow growth rate (0.05 kg/day) during the pre-weaning period reached puberty later than gilts with lower birth weight but with higher pre-weaning growth rate. Previous results showed a relationship between weaning age and a gilt's subsequent reproduction where an increased weaning age by one day resulted in an increase of 0.185 piglets per sow per year.[68] The author[68] suggested increasing weaning age to 25 days. Additionally, gilts selected for breeding should weigh at least 7.5 kg at weaning. Final selection should be carried out around 140 days of age and should include a visual evaluation of structure with respect to feet and legs, underline, and external genitalia.[67]

Another form of selection is a one-step selection, carried out at 5 to 6 months of age. During this time, traits such as body weight, body condition, structure, backfat thickness, number of estrus cycles, and growth rate[44,71,72] are used in selection. Some researchers expanded those criteria to include structural soundness, body condition, vulva size, number of nipples, body weight, and litter size at birth.[41,46]

Criterion 1: Structural soundness and condition

Hooves and legs indicate strength and durability. Desirable legs are strong, straight, set to pasterns, and wide apart. Legs with very soft pasterns, buck kneed, too steep hock joints, or with any other abnormalities are undesirable. Properly developed limbs will support the added weight of the boar during mating, maintain proper condition during pregnancy, and prevent piglet crushing during farrowing. The problems with poor feet and leg soundness and osteochondrosis are one of the main reasons to replace sows.[32,73] Those weaknesses are visible during locomotion and changes in leg position.[74] Osteochondrosis is caused by a few factors including rapid growth, inheritance, or nutrition.[75] According to Yazdi et al,[76] correlation between osteochondrosis and longevity was low ($r = 0.07$) but significant ($P < .01$). Consequently, higher risk of culling occurs, impacting sow longevity. Heritability estimates for leg structure traits, leg score, and locomotion are low to moderate depending on the population and favorably associated with sow longevity.[23,77,78] Direct selection for improved leg soundness provides an opportunity to increase sow lifetime productivity. The two types of scoring systems for leg confirmation traits are binary and linear.[79] Both types depend on observers' training and experience, which may cause wide variations.[80]

Criterion 2: Reproductive organs

The udder is a very important criterion for replacement gilts, especially when modern females can farrow more piglets than the number of functional nipples. The evaluation is based on the number, size, shape, and location of the nipples. The udder should be wide and properly developed. Gilts should have at least 12 to 16 nipples.[41,44,46,81] Regardless of the number, the nipples should be in a straight line and evenly spaced to provide free access to all piglets. The last 3 or 4 pairs of nipples tend to tilt, making it difficult for piglets to access them. It is important to avoid clogged nipples as this is a serious problem during farrowing.[81] The number of nipples is affected by the presence of males in the litter from which the gilt was born (more males in the litter results in gilts with fewer nipples).[27,82] The gilt should have a well-developed and well-shaped vulva, proportional in size, with the tip pointing downward.[41,81]

Criterion 3: Body weight and litter size at birth

Gilts are impacted by the dam's fertility, milk production, and reproductive history, which is based on performance in the same housing conditions of the dam, gilt offspring of the dam, and siblings to the gilt undergoing selection from previous litters.[32] Additionally, a dam's reproductive history is based on good maternal ability. This trait is very individual, so elimination of sows with poor maternal responsiveness should be based on behavioral observations.[83,84] There are two main trends of choosing gilts based on litter size. First, replacement gilts should be chosen from the largest and heaviest litter and their dams should have a high fertility rate, at least 12 to 13 piglets per litter.[26] Moreover, gilts should be chosen from sows in their third parity, when it is possible to assess the fertility of the dam.[85] On the other hand, Jarczyk et al[86] showed that replacement gilts should be selected from smaller litters because they have more uterine space, and consequently had better conditions for development and growth during gestation. Additionally, research conducted by Flowers[87] showed positive effects of being raised in a small litter which consequently increased gilt longevity (to parity 6) and lifetime reproductive performance. Replacement gilts from litters with a larger number of females had more piglets than gilts from litters with more male siblings.[88] Litters with more than 12 piglets and a large number of males (67%) can cause problems with reproduction for gilts from this litter.[77,89] This is due to the occurrence of one-way blood flow in the uterus and because fetuses are exposed to hormones produced by the embryos that preceded them, which may be the other sex.[27,82]

Criterion 4: Growth rates

Gilts, which consume more feed, grow faster but tend to accumulate fat. Overweight gilts at breeding are a possible risk factor for reduced longevity and herd reproductive efficiency.[90] It is important to choose gilts with a good appetite but to prevent their excessive fattening.[46]

Construction of reproductive organs and uterine capacity

The length of the vagina and cervix and uterine capacity are increasingly used as indicators of reproductive efficiency. Uterine capacity is defined as the ability of the uterus to provide the appropriate development of some number of embryos from implantation until birth.[91,92] Each incremental increase in uterine size increases the number of offspring obtained because the uterine horn length is correlated with ovulation rate.[91,93,94] Thus, uterine size is an important limiting factor affecting litter size at birth. Prenatal mortality is mostly caused by intrauterine crowding .[95] Fetuses that die in a crowded uterus are more likely to be male.[82] In addition to limited space in the uterus, another important conceptus survival factor is the appropriate transport of necessary nutrients.[96] It is observed that localization of an embryo within the uterine horn is correlated with its survival and growth.[26,27] Thus, longer uterine horns can interfere with the ability of the uterus to provide the necessary nutrients for all fetuses.[93] There are several scientific theories which try to explain this relationship. According to the theory from Mossman,[97] embryos implanted closest to the ovary demonstrate the greatest degree of development. In turn, Hammond[98] proposed that the rate of metabolic processes in different tissues influences the distribution of nutrients carried by the blood. Therefore, with limited nutrients, just the most important tissue may continue to grow at the expense of lower tissue metabolism.[27] Consequently, in numerous litters, the fetal development was delayed and reduced birth body weight occurred. It is caused by the rate of blood flow through the placenta, not by uterine mass.[26] A unidirectional flow of blood passes through the pig uterus washing all fetuses inside the uterine horns.[27] Another theory seeking to explain the relationship between the embryo growth and survival was formulated by Eckstein et al,[99] whereby the number of embryos in the uterine horns affects the weight of the fetus and mass of the placenta. Embryos are exposed to two impact factors: a larger number of embryos in the uterine horn results in lower blood pressure and reduced blood pressure indirectly impacts the size of the fetus.[27] Even in the early stage of pregnancy, the competition for nutrients and space is observed among fetuses.[100] The optimum space for each embryo in the uterine horn should be 20 to 35 cm.[27] Previous research suggested 36 cm as the minimal space for normal development for every fetus.[101] The uterine horn length can only be measured posthumously, so it leads to the search for correlations with other reproductive organs. Rillo et al[102] reported that for each centimeter the vagina increased in length, the uterine horns increased 8 to 9 cm. Furthermore, other research showed a relationship between vaginal and cervix length (VCL) and litter size.[9,103,104] It is confirmed by Dybała et al,[105] who also reported that sows with a longer VCL were from litters that had 0.98 more piglets when compared to gilts with a shorter VCL. On the other hand, Tarocco and Kirkwood[106] obtained opposite results. They suggested the measurement of VCL in the second estrus was not an indicator of litter size. Uterine size and VCL showed great diversity between females and increased with gilt age and subsequent litters.[93,107,108] Although, according to Dominguez et al,[109] the reproductive tract of gilts stabilized after the first litter, so gilts have a shorter VCL than sows after first parity. Therefore, the length of reproductive organs is not a significant factor for gilt selection and determination for their future potential. However, other researchers have reported correlations between: ovulation rate and length of uterine horn ($r = 0.38$), prenatal survival of fetuses and uterine capacity ($r = 0.95$), uterine length and capacity ($r = 0.51$), and VCL and litter size ($r = 0.36$).[9,93,108]

Boar exposure

Replacement gilts with body weights between 90 and 100 kg should be introduced into the breeding herd, as it is the optimal time to use boar exposure. The stimulation should be started around 140 days of age because age at puberty has been shown to be associated with age at onset of boar exposure.[110] On the other hand, van Wettere et al[42] suggested that first boar exposure should be delayed until 182 days of age because greater synchrony occurred within gilt groups. After stimulation, gilts achieved first estrus sooner and consequently their lifetime productivity was greater. Kaneko and Koketsu[111] noticed gilts in herds using boar exposure were around 13 days younger at first mating than those in herds using only indirect boar contact. It is assumed that gilts that experience estrus within 30 days of boar stimulation will have more piglets in their first litter and reach greater lifetime productivity.[33]

Longevity

High breeding herd productivity is associated with sow longevity. Many factors impact sow longevity, including genetics, nutrition, housing, disease, age at first mating, length of lactation, body condition, and growth rate.[32,112,113] The goal is for the first litter produced by a replacement gilt to recuperate the cost of her introduction into the herd. Subsequent litters will bring economic profit to producers.[46] To maximize profitability of sows, females are replaced after 4 to 5 parities[16] or longer on small farms and at 3 to 4 parities or earlier on large farms.[7,114] The decision to replace sows depends mostly on average herd productivity. The most productive parities are 2, 3 and 4[33,63,115] with a reduction of 0.3 to 1 piglets beginning with parity 5. A high sow culling rate decreases farm productivity, especially in terms of the average number of piglets weaned per sow per year and increases the risk of introducing diseases into the herd by replacement gilts.

Summary

Over the last 20 to 30 years, the swine industry has undergone numerous changes. Despite those substantial technological and scientific changes, methodology involved in replacement gilt selection has remained largely the same as 20 years ago. The traditional selection of replacement gilts does not completely guarantee suitable reproductive efficiency. The greatest hopes are focused on genetic improvement, increased selection intensity, and the opportunity for producers to select animals with improved reproductive efficiency. Methods such as maternal responsiveness and VCL hold promise for such improvements, but more research and development is needed to perfect and disseminate these methodologies as selection tools.

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Conflict of interest

None reported.

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