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Gilt development to improve offspring performance and survivability

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Abstract

Methods for developing incoming replacement gilts can indirectly and directly influence survivability of their offspring. Indirectly, having proper gilt development reduces culling rates and mortality, which increases longevity and creates a more mature sow herd. Older sows are more likely to have greater immunity than gilts and therefore can pass this along to their pigs in both quantity and quality of colostrum and milk, thus improving piglet survivability. Directly, proper gilt development will maximize mammary gland development which increases colostrum and milk production leading to large, healthy pig. As for the developing gilt at birth, increasing colostrum intake, reducing nursing pressure, providing adequate space allowance, and good growth rate can increase the likelihood that gilts successfully enter and remain in the herd. Light birth weight gilts (<1 kg) or gilts from litters with low birth weight should be removed early in the selection process. Gilts should be weaned at 24 d of age or older and then can be grown in a variety of ways as long as lifetime growth rate is over 600 g/d. Current genetic lines with exceptional growth rate run the risk of being bred too heavy, reducing longevity. On the other hand, restricting feed intake at specific times could be detrimental to mammary development. In these situations, reducing diet amino acid concentration and allowing ad libitum feed is a possible strategy. Gilts should be bred between 135 and 160 kg and at second estrus or later while in a positive metabolic state to increase lifetime productivity and longevity in the herd. Once bred, gilts should be fed to maintain or build body reserves without becoming over-conditioned at farrowing. Proper body condition at farrowing impacts the percentage of pigs born alive as well as colostrum and milk production, and consequently, offspring performance and survivability. Combined with the benefit in pig immunity conferred by an older sow parity structure, gilt development has lasting impacts on offspring performance and survivability.

Lay Summary

Proper gilt development influences offspring performance and survivability by increasing gilt longevity and colostrum and milk production. Gilt development success starts in selecting gilts heavier than 1 kg at birth, prioritizing colostrum and milk intake, and weaning at 24 d of age or older. During the grower phase, attention must rely on nutrition and feeding management to avoid fat gilts at farrowing, promote adequate mammary development, and have structural soundness. Appropriate boar exposure and reaching target weight (135 to 160 kg) at breeding in the second or third estrous can dictate reproductive performance and longevity. During gestation, the whole focus is on body condition. Fat gestating gilts may struggle with leg and feet issues and compromise the litter due to lower colostrum and milk production. Properly developed gilts directly impact livability of their offspring through increased colostrum and milk production. Increased longevity indirectly improves livability because offspring of older sows have improved growth and survival rate compared to offspring of first litter sows.

Key words: birth weight, colostrum, lifetime performance, longevity, nutrition, pig

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; BW, body weight; BWP, birth weight phenotype; SID, standardized ileal digestibility

Introduction

Modern maternal-line genotypes have impressive farrowing performance, increasing litter size by approximately 0.33 pigs per litter per year since 2006 (Tokach et al., 2019). One of the keys to continually improve litter size is genetic improvement through gilt introductions. However, deficient management strategies in gilt development spanning from the gilt's first day of life until the first farrowing can lead to poor offspring performance and survivability.

There are two main paths to achieving high performance and survivability of gilts' offspring. First, improving gilt longevity in the sow herd aids in stabilizing herd health. An older sow parity structure will benefit newborn pigs by enhanced immunity which has a lasting impact on offspring performance and survivability. The second path to improving offspring survivability is by maximizing colostrum and milk production. Due to lower birth weight and inferior immune response, first-parity litters usually have poorer lifetime performance than litters born to multiparous sows (Piñeiro et al., 2019). Besides poorer growth performance, first-parity progenies have higher nursery and finishing drug costs and mortality (Moore, 2001). Thus, improving parity 1 sows' colostrum and milk production is essential to alleviate these disadvantages. One way to accomplish this goal through gilt development is to provide special attention to feeding and management strategies that improve mammary development in prepubertal stages (Farmer, 2018).

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Implementing development programs that focus on selecting gilts with the greatest reproductive potential, ensuring the number of gilts needed by the system, and adequate management and nutrition are vital in reaching a high-quality, productive herd. This paper will review current knowledge on gilt development-related key management and nutritional strategies that improve longevity and their production, as well as enhance offspring performance and survivability.

Birth weight and litter of origin

Gilts must be developed correctly to ensure their longevity in the herd and improve survivability of their offspring. Gilt management and selection start at birth (Table 1). Birth weight, litter of origin, and lactation and weaning management are points involved in early selection strategies that are indicators of future performance and efficiency (Patterson and Foxcroft, 2019). Birth weight is one of the essential traits that affects lifetime productive performance, both in finishing pigs (Wolter et al., 2002; Douglas et al., 2014) and replacement gilts (Almeida et al., 2015; Magnabosco et al., 2015). In a high-prolific multiplier system, Magnabosco et al. (2016) observed the impact of individual birth weight of gilts on their future reproductive performance up to parity 3. Age at puberty was not influenced by birth weight; however, gilts weighing less than 1.0 kg at birth produced fewer pigs born alive and more stillborn in the first farrowing. These gilts had 4.5 fewer piglets over three parities than the other birth weight classes. The retention rate was also affected by gilt birth weight, with gilts weighing greater than 1.28 kg at birth having greater days in the herd than gilts weighing between 1.0 and 1.28 kg at birth, with those weighing less than 1 kg having the fewest days in the herd. The fact that gilts with a birth weight under 1 kg show satisfactory results in terms of onset of estrus and farrowing rate hides the negative impact on retention from selecting light birth weight gilts as future replacements. Considering the long-lasting effect on reproductive performance, gilts less than 1 kg at birth should not be selected to enter a breeding herd.

Recently, studies have addressed the importance of the litter of origin of a replacement gilt. Considering that birth weight is a phenotypically repeatable trait (Foxcroft et al., 2009), it can be hypothesized that gilts born to sows with a low birth weight potential could pass that trait on to their offspring. Patterson et al. (2018) reported a lower retention rate within 4 d after birth, at 24 and 70 d of age, and at preselection when analyzing gilts born to sows classified as having a low birth weight phenotype (**BWP**; litter average birth weight < 1.15 kg) based on at least two successive parities compared to categories with over 1.16 kg birth

Table 1. Key aspects of managing and feeding gilts to improve lifetime performance and longevity, and produce high-survival pigs

Area	Action	Reason
Birth weight	Avoid selecting gilts weighing less than 1 kg at birth.	Gilts born < 1 kg of birth weight produce 4.5 fewer piglets over three parities than the other birth weight classes.
Litter of origin	At the multiplier, avoid selecting gilts born from sows farrowing litters with average birth weight < 1.15 kg in two or more farrows.	Gilts born to low birth weight phenotype sows can pass this feature to their progeny.
Colostrum intake/ cross-fostering	Sows with higher milk production (e.g., multi-parity sows) should nurse future replacement gilts.	Gilts consuming at least 250 g of colostrum will be heavier at 42 d of age and gilts heavier at weaning have higher survivability and odd to farrow a litter.
Weaning age	Replacement gilts should be at least 24 d old at weaning.	Gut health, postweaning survivability, and lifetime productivity are greater for pigs when weaned at 24 d of age or older.
Vitamins and minerals	Add more phosphorous than terminal lines, consider organic trace mineral sources, and add extra choline, pyridoxine, folic acid, and biotin.	Phosphorus recommendation levels for bone mineralization are 8% higher than for growth performance. Organic trace mineral supplementation can reduce osteochondrosis incidence. These vitamins are involved in reproductive functions and often not included in finishing pig premixes.
Mammary development	From 90 d of age to puberty, do not restrict energy intake too much; avoid overfeeding gilts in late gestation.	Appropriate mammary gland development can be reached without maximizing energy intake, but low intake also reduces mammary DNA. Overfeeding gilts in late gestation will deposit more fat in mammary glands, reducing colostrum and milk production.
Boar exposure	Provide adequate boar exposure with boars with at least 10-months of age. Promote as much physical interaction with gilts as possible.	Having more boars is better to avoid fatigue. Mature boars have more libido and are larger enough to stimulate estrous without being submissive to the gilts in pens.
Breeding targets	Breed on second estrus and 135 to 160 kg body weight (BW).	Inseminating in the first estrous reduces farrowing rate and litter size in the first farrowing. Breeding overweight gilts reduces their longevity in the herd.
Flush feed	Only flush feed gilts that might not reach BW target at breeding.	Flush feeding only improves reproductive outputs when gilts are below the target weight for breeding.
Gestation feeding	Early: do not feed gilts below maintenance and growth requirements and avoid feeding more than 7.5 Mcal of net energy (NE) per day. Late: unless body condition is low, avoid bump feeding.	Over-conditioned gilts can have lower litter size and have reduced feed intake and milk production in lactation. Bump feeding improves birth weight slightly but increases stillborn rate and lowers lactation feed intake and colostrum and milk production.
First lactation	Avoid having unsuckled mammary glands.	Mammary glands not suckled during first lactation produce less colostrum and milk in the subsequent farrowing.

weight. Natural selection and increased survival rate of the heavy weight gilts played an important role in that result. Conversely, it has also been observed that gilts from high BWP are more likely to grow exceptionally fast, such that they may be bred too heavy, impairing their reproductive performance over four parities (Patterson et al., 2020). Amaral Filha et al. (2010) observed that heavy gilts at first service had decreased farrowing rate in parity 2, and those gilts bred at >170 kg were at risk of low retention and greater locomotion problems over three parities. Thus, gilts that are heavy at birth and have exceptional growth rate may need to be slowed down to prevent them from becoming too heavy at breeding. Collectively, these data suggest that the selection of replacement gilts should start at birth, avoiding extremely low or high BWP litters of origin.

Colostrum and milk intake

Adequate colostrum intake plays a vital role in promoting newborn pig health, growth, and survivability, which can improve subsequent reproductive performance (Vallet et al., 2015; Declerck et al., 2016). Bartol et al. (2013) suggested a positive relationship between colostrum intake and uterine development. Colostrum intake also has an essential role in growth rate, with pigs consuming at least 250 g of colostrum being heavier at 42 d of age than those consuming less than 250 g (Ferrari et al., 2014). Knauer (2016) observed that increasing preweaning growth rate increased the proportion of gilts that ultimately farrow a litter. Due to the impact in preweaning survivability and weight gain, strategies to improve milk intake should be considered. In the study by Ferrari et al. (2014), regardless of the parity of the biological mother, pigs fostered on to multiparous sows were heavier at 42 d of age than pigs nursing primiparous sows. Bierhals et al. (2011) observed that pigs born to first-parity sows and fostered by parity 5 sows were heavier at weaning than those not cross-fostered. Nucleus and multiplier farms can take advantage of these results to maximize colostrum and milk intake of replacement gilts.

Priority should be placed on individual gilt birth weight, average pig weight in litter of origin, day 1 care, and cross-fostering. These early growth parameters initiate a cascade of positive outputs during the lifetime reproduction performance of the replacement gilt (Vallet et al., 2015).

Weaning age

Research regarding weaning age has been conducted with a primary focus on economics and growth performance from wean to finish. However, several findings from these studies may be applied to gilt development. From a physiologic standpoint, early-weaned pigs had increased intestinal permeability (McLamb et al., 2013) and a lower immunological response to stress than older weaned pigs (Davis et al., 2006). In these studies, the negative effects of early weaning persisted for months, similar to mast cell hyperplasia found in early-weaned pigs by Pohl et al. (2017), which lasted until adulthood. Together, these studies provide valuable information regarding young pig's gut health that might affect a gilt's health in the future.

Male and female enteric nervous systems react differently when challenged by weaning stressors like early weaning. Females exhibited higher neural-evoked secretory responses and more pronounced cholinergic activation (Medland et al., 2016) when compared to males. Thus, gilts response more negatively to being weaned at young ages than male pigs. Thus, farms raising replacement gilts should wean at older ages.

A major influence on survivability is related to weaning age. Studies have shown the significant effect of older weaning ages on the number of pigs that reach market weight (Main et al., 2004, Faccin et al., 2020). Faccin et al. (2020) reported an absolute reduction of 0.63% in nursery losses per day as weaning age increased from 19 to 28 d. Therefore, a 3-d increase in weaning age can decrease nursery mortality and removals by almost 2.0%. Besides gut health improvement, the swine industry can take advantage of older weaning ages to increase gilt survivability.

Knauer (2016) intended to associate pre- and at-weaning factors of 6,249 gilts that entered commercial sow farms with lifetime productivity. In this data set, weaning age ranged from 15 to 27 d. For each day of increase in weaning age, sow productivity was improved by 0.185 pigs per sow per year through four parities. Thus, increasing the weaning age by 3 d represented an increase of more than 0.5 pigs per sow per year. Also, in this study, weaning age positively affected the retention rate from sow farm entry to parity 2.

Economics of increasing weaning age in individual systems must be considered when producing replacement gilts. Because of the positive benefits on gilt health and reproductive performance, multiplication farms should wean gilts at a minimum of 24 d of age.

Target weight

An essential goal for replacement gilt nutrition is to develop prepubertal gilts to their physiological maturity in body weight (**BW**), tissue composition, structural soundness, and reproductive development. Thus, one main objective of gilt nutrition for longevity and excellent lifetime performance is to maintain growth rates to achieve 115 to 140 kg at puberty and 135 and 160 kg at breeding (Bortolozzo et al., 2009). Considering 1 kg/d of average daily gain (**ADG**), gilts need to be a maximum of 140 kg of BW when reaching puberty to be inseminated in the second estrus at less than 160 kg of BW. With ad libitum feeding systems, commercial gilts can exceed this weight threshold. Thus, production systems often need to limit growth to increase the proportion of gilts meeting BW targets at puberty and breeding. This is a key concept because inseminating overweight gilts can lead to locomotion and structural problems that result in early removal from the herd (Amaral Filha et al., 2010).

Nutrition strategies during growing phase

Ad libitum feed intake for current high feed intake and fast-growing genotypes is a concern because of potential lameness and leg problems (Farmer, 2018). Ad libitum feeding after 10 wk of age has been shown to increase the risk of osteochondrosis by 20% for each 100 g increase in ADG according to de Koning et al. (2013). However, limiting feed intake too much can be detrimental to the development of mammary secretory cells (Sorensen et al., 2002). A reduction in the Lys to energy ratio can be used to decrease growth rate and increase the number of gilts in an optimal BW range at first estrus (Lents et al., 2020) and reduce the occurrence of lameness and the severeness of joint lesions (Quinn et al., 2015). However, pubertal development can also be delayed by reducing the dietary Lys to energy ratio (Lents et al., 2020) or by a 25% restriction in energy intake (Johnson et al., 2022). These strategies did not have any other negative impacts on reproductive performance. Thus, reduced dietary energy and lysine can be used to alter BW at puberty with the understanding that puberty may also be delayed. Fiber can also be used to restrict the amount of daily metabolizable energy intake (Winkel et al., 2018); however, only high inclusion levels can indeed restrict feed intake (Helm et al., 2021). Extra feeder space and space allowance/gilt can generate a compensatory feed consumption resulting in the same feed intake of gilts fed ad libitum. As a tool to increase sow longevity, fiber intake can benefit gastrointestinal development and decrease the incidence of severe esophagogastric ulcers (Dirkzwager et al., 1998).

During the developer phase, efforts should also be made to prevent feed outages. Use of more coarsely ground grains (800 microns) should also be considered to minimize the incidence of gastric ulcers (Mößeler et al., 2012).

Lameness is usually one of the top three reasons for culling gilts and sows (Sasaki and Koketsu, 2008; Wang et al., 2019). From a nutrition standpoint, replacement gilt diets should be formulated differently than finishing gilts diets. Calcium and phosphorus are the most abundant minerals in the body and are related to multiple biological functions like growth performance and development, and maintenance of the skeletal system (Berndt and Kumar, 2009). Increasing levels of calcium and phosphorus can be beneficial because the levels to maximize bone mineralization are 8% greater than that to maximize growth rate (NRC, 2012; Vier et al., 2019).

Vitamins involved in reproduction like choline, pyridoxine, folic acid, and biotin should be added to the diet because finishing premixes usually do not include these vitamins (Flohr et al., 2016). However, data regarding the exact timing to start supplementation are not available. Thus, beginning at approximately 150 d of age is suggested due to proximity to the onset of the reproductive activity. Because of research indicating that supplementation of organic trace minerals (i.e., Zn, Mn, and Cu) reduces osteochondrosis in replacement gilts (Fabà et al., 2019), their addition to the diet should also be considered. Similarly, research demonstrates that dietary addition of 25-hydroxy-D3 can reduce the incidence or severity of osteochondrosis lesions (Sugiyama et al., 2013) and, thus, the use of 25-hydroxy-D3 should be considered for developing gilts.

Mammary development and feed management

Over the years, modern gilts have become leaner, more feed-efficient, and faster growing than gilts of previous decades. The mammary development of the young gilt is relatively slow, with mammary tissue and DNA accretion being low until approximately 90 d of age. Farmer (2018) summarized that first stage of mammary development was from 90 d of age until puberty with mammary DNA increasing 4 to 6 times during this period (Sorensen et al., 2002). Restricting feed intake by 20% to 25% during the growing-finishing period in gilts has been shown to negatively affect mammary development at puberty (Farmer et al., 2004; Sorensen et al., 2006). Ad libitum feeding from day 90 to puberty increases the parenchymal weight of gilt's mammary gland by 36% to 46% compared to restricted feed in the same period (Sorensen et al., 2002; Farmer et al., 2004). Since the time of these studies, feed intake potential has increased considerably, such that a 15% to 20% restriction of feed intake today results in similar intake to ad libitum consumption in Sorensen et al. (2002) and Farmer et al. (2004) studies. Recently, Gregory (2021) compared ad libitum to 20% feed restriction from day 90 to breeding, and no effect on milk yield was found. Together, these data suggest that mammary development may be impaired if a minimum nutrient intake is not maintained, but ad lib consumption may not be needed to reach that minimum level of required energy intake.

Space allowance and group size

It is well known that stocking density affects growth performance and welfare indicators of growing pigs (Brumm, 2004; Fu et al., 2016). Even with barrows growing faster than gilts, no gender and stocking density interactions appear to exist (Brumm, 2004). In gilt development, there are limited studies regarding space allowance. Young et al. (2008) compared 0.77 m^2 per gilt and 22 gilts per pen with 1.13 m^2 per gilt and 15 gilts per pen from 75 to 200 d of age. Growth performance was not affected by space allowance and group size. Still, lower space allowance and larger group size reduced the percentage of gilts in puberty by 200 d of age, which resulted in a greater average age at puberty. Age at puberty corresponds with the age at breeding and future reproductive performance. Gilts showing late puberty have an increased risk of being bred overweight. Young et al. (2008) observed no significant effects in reproductive performance through parity 3, and the percentage of removals and mortality was not affected by space allowance and group size. However, an increase of cracks on gilt's rear hooves was reported for gilts with greater space allowance and smaller group size, which may indicate some relationship between increased space and more physical activity. Young et al. (2008) did not observe a large impact of space allowance and group size during rearing; however, gilt developer facilities must pay attention to space allowance and the number of gilts per pen because they often impact access to feeders, drinkers, and the quality of boar exposure.

Boar exposure

Quality of boar exposure is one of the pillars in gilt development. Failing to detect the first estrus of a gilt automatically adds an extra 20 nonproductive days to the system, can impair the target of females inseminated per group, and results in overweight gilts at mating. It is common to find corpora lutea in gilts culled for anestrous. Diehl et al. (2003) found that 76% of gilts culled for anestrous had corpora lutea and/or albicans, the corpus luteum involuted form, at the slaughterhouse. Gilts with a greater growth rate generally reach puberty sooner. Early age at puberty has been linked to greater lifetime productivity, so boar stimulation should start between 150 and 170 d of age to achieve at least 80% of gilts reaching puberty after 30 d of boar exposure (Amaral Filha et al., 2009). Boars should be at least 11 mo of age, express good libido, and impose physical presence when in gilt pens. Young and small boars usually become submissive to gilts (Bortolozzo et al., 2006). Having a high number of boars is also important to prevent their exhaustion and locomotor problems. With good boar exposure, gilt development units should breed the majority of the gilts in the second estrus (prior to 220 to 225 d of age) and delay to the third estrus only gilts that have not met the target weight. Direct contact with boars in the pens reduces the time to find gilts in estrus by approximately 10 d compared to only providing fenceline contact (Patterson et al., 2002).

Flushing

Flush feeding gilts before breeding is a common practice recommended more than 30 yr ago to increase first-parity litter size (Cox et al., 1987; Beltranena et al., 1991). Flushing consists of full feed or increasing the amount of feed and consequently energy intake 1 to 2 wk before planned insemination. This results in an improved gonadotropin-releasing hormone pulse generator system followed by a higher stimulation of folliculogenesis and ovulation rate by luteinizing hormone (Ashworth and Antipatis, 1999; Prunier and Quesnel, 2000). In the 1990s, studies using Yorkshire × Landrace sows (Beltranena et al., 1991) and Chinese Meishan (Ashworth et al., 1999) confirmed the beneficial effect of increasing prebreeding feed intake. Improved nutrient uptake and utilization resulted in a greater number of follicles ovulated.

A recent trial addressed insights regarding flush feeding modern gilts. Mallmann et al. (2020b) inseminated gilts on their third estrus that were provided either 2.1 or 3.6 kg/d from puberty to second estrus or from second to third estrus. On day 30 postbreeding, gilts fed 3.6 kg/d during both cycles were determined to have had a greater ovulation rate. However, the increased feed allowance only increased viable embryos when provided from puberty to second estrus. Gilts that were provided extra feed between the second and third estrus had reduced embryo survival. This study demonstrated that flushing from puberty to the second estrus resulted in two extra viable embryos on day 30 of gestation; however, continuing flushing after the second estrus provided no further benefit. Thus, if gilts are not mated by the second estrus, feed intake should return to basal levels (2.1 kg in this study), representing 30 kg of feed savings per gilt. Another interpretation of these data is that most gilts met breeding weight targets in the second estrus (133 to 143 kg BW for the 2.1 and 3.6 kg treatments, respectively), which means that some gilts were overweight when inseminated in the third estrus, and this may have affected their reproductive performance. The lower percentage of embryo survivability for gilts fed 3.6 kg/d during the second cycle may have been due to lower plasma progesterone during early pregnancy. Progesterone metabolization by the liver in the first few days of pregnancy can significantly impact fertility because progesterone secreted by the ovaries is still low (Langendijk and Peltoniemi, 2013).

Bruun et al. (2021) compared no flush feeding to flushing for 7 d (follicular phase) prior to breeding, flushing for 18 d from (day 7 to 25) prior to breeding (luteal phase), or flushing for both periods (25 d). They observed that the weight of the gilt influenced total litter size. Gilts with low back fat tended to respond more positively to a longer flushing period than heavier gilts with more back fat. Flush feeding during the follicular phase (7 d) provided the greatest benefit in total born without increasing back fat.

In summary, the feed level provided during the first cycle after pubertal estrus is essential to establish the ovulation rate and the potential litter size. In contrast, the feed level in the estrous cycle before insemination affects embryo survival. Considering BW at breeding, flush feeding gilts only results in positive reproductive performance until achieving the target weight for breeding. Gilts inseminated above BW recommendations have no improvement in reproductive performance when flush fed.

Gestation feeding strategies

Feeding strategies in the first 3 to 4 wk of gestation have been discussed and researched for several years because of the capacity to impair embryo survival and, consequently, litter size (Leal et al., 2019). Progesterone metabolism by the liver can cause a reduction in embryo survival after insemination; however, published studies have conflicted on the response to feed intake in early gestation. When gilts had increased average daily feed intake (**ADFI**; 2.6 vs. 1.9 kg/d) from breeding to day 15 of gestation, a decrease of 20% embryo survival was found (Jindal et al., 1996). However, other reports have shown no differences when feeding 2.0 vs. 4.0 kg/d from day 0 to 7 after breeding (Quesnel et al., 2010). Another small-scale study found a two-pig increase in pigs per litter when increasing feed intake (3.25 vs. 2.5 kg/d) from day 3 to 32 of gestation (Hoving et al., 2011). In a recent large study on a commercial farm, Mallmann et al. (2020a) fed gilts and parity 1 sows with 1.8, 2.5, or 3.2 kg/d from day 6 to 30 of gestation and found a linear increase in BW and back fat thickness at 30 d of gestation and a linear negative impact in litter size. Collectively, these data suggest that besides reducing litter size, providing extra feed intake early in gestation can result in over-conditioned sows at farrowing, which may compromise lactation feed intake and increase lifetime maintenance requirements. Increasing feed intake has only been beneficial when the control was near maintenance feeding levels (e.g., 1.5 kg/d; Athorn et al., 2013).

Between day 22 to 42 of pregnancy, placenta vascularity increases and the transition from embryo to fetus starts (Wu et al., 2004). High energy intake during gestation can positively affect placental efficiency by reducing piglet weight variation (Che et al., 2017). However, increasing the amount of feed from day 22 to 42 of gestation has failed to improve farrowing performance. Mallmann et al. (2019b) compared 1.8 to 3.5 kg/d of feed in gilts fed from day 22 to 42 of gestation and observed a similar number of total and born alive piglets and no differences in birth weight.

High feeding levels (5 kg/d) in mid-gestation gestation have been found to increase secondary muscle fibers in the fetus as compared to feeding 2.5 kg/d (Dwyer et al., 1994). Two subsequent experiments with a larger sample size found no impact on birth weight when feeding 3.6 kg/d compared to sows fed 1.8 kg/d during mid-gestation (Musser et al., 2006). In the past decade, several studies have examined the effect of increasing feed intake (bump feeding) in the last 20 to 30 d of gestation of gilts and sows. A meta-analysis (Gonçalves, 2016) summarized trials that bump-fed gilts in commercial farms. On average, each 1 kg increase in a daily feed intake from day 90 to farrowing results in approximately 7 kg increase in sow BW. However, it only resulted in a modest increase in piglet birth weight of 13.5 g in gilts. More recently, Mallmann et al. (2019a) conducted a dose–response study (1.8, 2.3, 2.8, and 3.3 kg/d) in gilts from day 90 to farrowing. Similar to other studies, a linear increase in gilt BW and back fat thickness and no influence in litter size was found. However, gilts fed the lowest amount of feed had fewer stillborn pigs than gilts fed other levels. Greater back fat thickness also has been shown by others to be related to fewer piglets born alive (Lavery et al., 2018). Gilts fed 2.3 kg/d tended to farrow 20 to 30 g heavier piglets than gilts fed 1.8, 2.8, or 3.3 kg/d with no effect found for birth weight coefficient of variation (CV). Lactation feed intake may provide the most consistent response across bump feeding trials. Gilts and sows with greater feed intake in late gestation have lower lactation feed intake (Shelton et al., 2009; Mallmann et al., 2020a). These results highlight the concern with high feeding levels at any point in gestation which can result in reduced lactation feed intake increasing gilts' catabolic state and reducing milk production and litter weight gain.

Besides gilt growth rate, farrowing performance, and lactation feed intake, other questions frequently raised around bump feeding concern subsequent reproductive performance and colostrum yield. Mallmann et al. (2019a) observed no effect in subsequent wean-to-estrus interval, farrowing rate, and litter size due to feeding level during the previous gestation period. However, colostrum yield was linearly decreased with increasing feed intake in late gestation. The fact that gilts fed 1.8 kg/d was the only feeding level that lost back fat from day 90 to day 112 indicates that nutrients were prioritized for colostrum yield over fat deposition since colostrum is mainly synthesized in the week before farrowing (Devillers et al., 2007) and shortly after farrowing (Quesnel and Farmer, 2019).

In the last 13 yr, average total born has increased by 4.5 piglets (Tokach et al., 2019). Many efforts have been made to optimize colostrum and milk yield through better mammary gland development. Although mammary tissues undergo a high degree of hyperplasia post-farrowing (Kim et al., 1999b), the protein accretion rate after day 75 of gestation indicates a more significant protein requirement for mammary gland growth (Ji et al., 2006). This does not mean that it can be easily handled with nutrition because, as already mentioned, bump feeding gilts can reduce colostrum yield and decrease lactation feeding intake. A significant determinant of milk production is the number of secretory cells present in the gland (Head and Williams, 1991). Mammary glands of excessively fat gilts in late gestation have more fat deposition as the adipocyte competes for space with secretory cells, which reduces colostrum and milk production (Head and Williams, 1991; Howard, 1995). During late gestation, mammary glands undergo a major composition shift, going from a high-lipid to a high-protein content (Ji et al., 2006). Although no effect was observed when feeding high levels of crude protein, early research has shown that feeding high energy levels in the last third of gestation decreased secretory tissue, which can be detrimental to colostrum and milk production (Weldon et al., 1991). Interestingly, feeding 150% of the NRC (2012) requirement estimate for valine in gestating gilts improved fat synthesis in the milk, mammary DNA and protein content, and colostrum and milk production (Che et al., 2019, 2020, 2021). The authors revealed several pathways where Val is involved in the expression of proteins related to fatty acid synthesis. Due to the inconsistent results found in the literature, further work around amino acid supplementation in late gestation is needed

Questions about the lysine requirement of highly productive sows during gestation have also recently been addressed. Thomas et al. (2021a) found that increasing dietary standardized ileal digestibility (**SID**) Lys (11.0, 13.5, 16.0, and 18.5 g/d) during the course of gestation is associated with maternal body protein deposition, supported by increased BW gain with no change in back fat thickness. Increasing dietary SID Lys increased lean growth of the gilt but did not have an impact in litter size (15.3 pigs born alive across all treatments) or piglet birth weight (1.23 to 1.26 kg per pig across all treatments). Thomas et al. (2021b) modeled the Lys balance of gilts in their study and observed that those fed 13 g/d were above their Lys requirement for the entire gestation period. Those fed 11 g/d were in excesses for the first 100 d of gestation but fell below their estimated requirements for the last 14 d of gestation.

In summary, in the period immediately after breeding, gilts should not be fed below the base level (minimal energy to meet requirement for maintenance, growth, and reproduction) but avoid increasing ADFI to more than 10 Mcal of metabolizable energy (ME) per day. In late gestation, bump feeding modestly improves birth weight but results in a higher piglet stillborn rate, lower lactation feed intake, and lower colostrum and milk production. Keeping adequate body condition from breeding through lactation is essential to support sow longevity, minimize cost of maintenance, and increase lifetime productivity.

Importance of nursing all mammary glands

Mammary gland development continues during the first lactation (Ford et al., 2003) and maximizing lactation feed intake contributes to this development (Kim et al., 1999a). When not suckled, the gland suffers a process of regression and involution and after 10 d loses around 75% of DNA and wet weight mass (Kim et al., 2001). After weaning, a similar percentage of losses are seen in both suckled and unsuckled glands (Ford et al., 2003). Thus, unsuckled glands have less DNA available for subsequent parities as confirmed by Farmer et al. (2012), who found mammary glands not suckled in the first farrowing have 20% less parenchymal tissue per teat and 22% fewer DNA grams per teat in the second lactation. Glands that are suckled during the first lactation have greater milk production in the subsequent lactation than glands that are not suckled in the first lactation (Kim et al., 2001). Furthermore, piglets can recognize the more productive previously suckled teats than the ones not suckled in the first lactation (Devillers et al., 2016). Additionally, Guo et al. (2019) reported that increasing the suckling intensity through greater litter size and lactation length did not impair farrowing performance and reduced BW loss in the second lactation. Thus, avoiding having unsuckled mammary glands in the first farrowing has a vital role in reducing culling of young sows due to poor nursing capacity and is vital to improve colostrum and milk production (Kim et al., 2001).

Other Considerations

Heat stress

Heat stress is detrimental to the pig's life from both a growth and reproductive performance perspective. Heat stress also causes a long-term impact during gestation, damaging both the sow and its offspring (Lucy and Safranski, 2017). In their study, gestating females under heat stress increased body temperature and respiration rate, reduced activity, and increased back fat at the end of gestation compared to sows in a thermoneutral environment. Heat stress during gestation increased insulin resistance (Lucy and Safranski, 2017), which can lead to a cascade of adverse effects such as lower lactation feed intake (Mosnier et al., 2010), reduced birth weight (Lucy and Safranski, 2017), and higher preweaning mortality (Safranski et al., 2015). Heat stressing sows during gestation also resulted in offspring with elevated body temperature, increased fat deposition, and impaired gonad development

(Lucy and Safranski, 2017). Some older studies found in utero effects like reducing embryo viability, mainly when high environment temperatures occur in the first weeks of gestation (Omtvedt et al., 1971; Wildt et al., 1975). Collectively, these findings highlight the importance of promoting an appropriate environment (temperature and humidity) for gestating gilts and sows in multiplier farms.

Other environmental considerations

Although there is a relationship between reproductive activity and photoperiod, varying the intensity of lighting inside the barn, either in the follicular phase or early gestation, does not appear to affect a gilt's reproductive performance (Canaday et al., 2013). To our knowledge, there is limited information regarding air quality for gilts. However, both lighting and air quality must be thought of from a caretaker point of view. For example, if people involved in managing replacement gilts are exposed to a dark barn with high concentrations of gases, time spent with the gilts will most likely be reduced. Also, the flooring condition must also be considered. Slippery floors or floors needing repair may result in injuries and losses of gilts.

Animal–human interaction

The development of the relationship between humans and pigs involves many senses, including hearing, visual, tactile, and chemical (Tallet et al., 2018). However, the proportion of pigs attended per caretaker increased considerably over the years, reducing the time spent with each animal. Therefore, people involved with gilt management should make every interaction with replacement gilts a positive interaction. In other words, gilts should not be frightened by people when approached because fearful sows during gestation are more likely to savage their piglets in the subsequent lactation (Kraeling and Webel, 2015).

Conclusion

Proper replacement gilt development plays a role in offspring survival. Good gilt development promotes an ideal parity structure and having more older sows than gilts improves overall passive immunity creating more viable piglets. Furthermore, gilt development will influence mammary gland development which will play a role in colostrum and milk production over time, again influencing the viability of piglets. Even with gilts only representing 20% of active females in a herd, gilt management will dictate performance and health status of the whole farm through her productive lifetime. Collectively, these points highlight the vital importance of developing replacement gilts to enhance offspring viability.

Conflict of Interest Statement

The authors declare no real or perceived conflicts of interest.

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